TOWARDS A PHENOMENOLOGICAL CONSTITUTION OF QUANTUM MECHANICS: A QBIST APPROACH[1]

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Foreword

In this programmatic article, our aim is to sketch the outlines of a phenomenological constitution of quantum mechanics, thus drawing the ultimate consequence of previous phenomenological approaches to this theory (Heelan 2004, Bitbol 2011, Berghofer & Wiltsche 2020, Crease et al. 2021). In other terms, we wish to show a way to ascend from the situated lived experience of a knowing and acting subject, to the structure and use of the quantum formalism. QBism (Quantum Bayesianism), with its motivated focus on lived experience, and its decision to take the elementary epistemic attitudes of agents as primitives of its axiomatics (Fuchs 2015), will prove a decisive step to progress in this direction.

But what is phenomenological constitution, why is it suitable to apply it to quantum mechanics, and which obstacles are we likely to meet in this endeavor?

1-Constituting objects

To spell out phenomenological constitution, a useful preliminary step is to compare it with Kant's concept of constitution of objectivity. Kant introduced his central idea that objects are *constituted,* as a middle way between metaphysical realism and metaphysical idealism or pure empiricism. He wanted to suspend the prejudice that objects (especially the material bodies of classical mechanics) are entities inherently existing out there, without conceding that they are either figments of particular human minds or passively received appearances. To reach this aim, Kant started from the undisputed idealist/empiricist premise that what is given to us is nothing else than experiences or appearances. And he then noticed that our understanding provides a categorial framework that serves as a template to connect appearances into *seemingly* self-subsistent, subject-independent, dynamical

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aggregates (Bitbol, Kerszberg, Petitot 2009, 19). Each aggregate of appearances (phenomena, presentations) ordered according to such *a priori* unifying categorial framework, behaves *as if* it were an object detached from us, invariant with respect to changes of subject or situation. "(...) Insofar as (...) presentations are connected and determinable (in space and time) according to the laws of the unity of experience, they are called *objects*" (Kant [1787] 2013, B 522). Conversely, one may wonder which kind of categorial framework, which set of laws, must be imposed to appearances in order to make possible their unification *qua* experience of objects. This reverse procedure is called "transcendental deduction" (of categories, principles and laws). In one of his most daring breakthroughs, Kant used a transcendental deduction to provide an *a priori* justification of the law-like structure of Newtonian mechanics (Friedman 2013). Other authors then used modified versions of the transcendental deduction to propose a (relativized *a priori*) justification of the law-like structure of later physical theories such as special relativity (Reichenbach 1965) and quantum mechanics (Mittelstaedt 2011, Bitbol 1998, Pringe 2007, Kauark-Leite 2012).

Husserl's phenomenological constitution has something in common with Kant's transcendental constitution, although it deviates from it in several respects. What Husserl's constitution has in common with Kant's is that the (unformulated) project of organizing the manifold appearances under the unifying banner of a set of permanent objects, here again arises from knowing, acting and experiencing subjects. But there are also differences. Perhaps the most important difference is that, whereas Kant insists on the constitutive role of the understanding, Husserl tends to probe below this purely intellectual level. Husserl is mostly interested in how perception pre-reflectively cuts through the fleeting flux of sensory experiences to lock attention on a stable pole of identity taken as an object that can be referred to by a noun. The core procedure of such identification is a basic feature of consciousness called "intentionality", or "tensed interest" towards something. This tensed interest involves a lasting pre-focused direction of attention, and a pre-verbal kind of anticipation, that inclines one to recognize each sensory profile as a manifestation of some well-defined object. It then turns out that *"intentionality implies ... a construction of objective identity"* (Zahavi, 1993). Here, the word "construction" is not to be taken entirely at face value; it does not mean that consciousness "constructs" objects within it, thereby somehow containing them. As Husserl wrote, "the objects of which we become 'aware', are not simply present in consciousness as in a box, so that we only have to find them and grasp them" (*Husserliana* 19, 169, quoted by Zahavi 1993). But consciousness does not content itself with restituting the structure of an inherently existent object either: *"It is in various forms of objective intention that (objects) constitute themselves as what they are*" (Ibid.). Consciousness deploys in itself, in the most basic temporal structure of its tensed interest, the very motive for which we consider that objects have an inherent existence that transcends us. Perceiving an object indeed combines the

continuity in time of a succession of past (memorized) appearances, the givenness "in intuition" of a present appearance, and last but not least an endless "horizon" of expectations about possible future appearances. Since presently perceiving some object is inseparable from a perspective of unbound future development of the experience "of it", "it" exceeds by far our present consciousness. "Any intentional aiming of an object ... intends infinitely more than what is intuitively given. (The object) is a Kantian teleological idea" (Pradelle 2008). This "infinitely more" which the expectations of a present consciousness imply, is precisely what we mean when we claim that an object "transcends" consciousness. We should thus realize that even transcendence, even the excess of the object with respect of consciousness, manifests *qua* structure of consciousness. It is a "transcendance in immanence" (Patočka 1993, 127), an expression in which the non-dualist opposition immanence-transcendence replaces the standard duality of inner and outer (Husserl [1913] 1983, [68]). This being granted, it becomes clear that, unlike Kant's, Husserl's pre-intellectual concept of constitution does not lend itself to a justification of the theoretical structures of physical science. Yet, it digs below this level to a very fundamental pattern of cognition (recollecting, presenting and anticipating) that is found everywhere in life (Maturana & Varela 1991, Bitbol & Luisi 2004), and especially in the functioning of the brain (Friston et al. 2006). When carefully examined, every physical theory includes this pattern as an implicit presupposition of its theoretical structure. But, as we shall see later on, quantum mechanics exhibits such fundamental pattern of cognition in its purest form, so much so that any attempt to complement it with superstructures and overinterpretations looks contrived and clumsy.

2-On the material of the constitution: the Epoché and its tabula rasa

The most fundamental theories of physics since the early seventeenth century were born from: (i) a preliminary *Epoché,* (ii) various steps of phenomenological reduction (Husserl [1913] 1983, [59]), and (iii) a subsequent activity of constitution out of the resulting raw material. In less philosophically loaded terms, these theories arose from a suspension of judgment about higher-order concepts of entities endowed with monadic properties, a turnaround of attention towards lower-order experimental operations or observed phenomena, and a constructive ascent from this elementary ground to laws ruling the (relational) properties of objects. Let us give some examples. Galileo's kinematics was born from a suspension of Aristotelian absolutist concepts of "place" and "motion"; a turnaround of attention towards spatial coordination plus velocity measurement relative to various reference frames; and a subsequent formulation of kinematical laws bearing on the resulting variables. Newtonian mechanics arose from a suspension of former tentative mechanicist explanations of gravity; a turnaround of attention towards terrestrial and astronomical quantitative "phenomena" (namely spatial and kinematic

coordinates of earth-bound or celestial bodies); and a quest for their law-like dynamical connection. Special and General Relativity arose from a suspension of ordinary concepts of space and time; a refocusing of interest on the procedures of measurement of distance-durations with rulers-clocks, relative to inertial or non-inertial reference frames; and a formulation of the coordinating laws between these reference frames. Even more famously perhaps, the original version of quantum mechanics, namely Heisenberg's matrix mechanics, was based on the decision to establish "a theoretical quantum mechanics, analogous to classical mechanics, but in which only relations between observable quantities occur" (Heisenberg [1925] 1968, 262). Here, the classical higher-order concepts of spatio-temporal trajectories were discarded; the attention was turned towards spectral phenomena; and the quantum laws connected ordered sets of such discontinuous phenomena.

But despite this thorough isomorphism between the successive scientific revolutions, the case of quantum mechanics is unique, with a scent of radicality that emanates from it. As Kant lucidly acknowledged, from the moment in which the Galilean and Newtonian constitution of objects out of phenomena has been performed, one effortlessly forgets it, and thereby mistakes phenomena for presentations of inherently existent objects. Indeed, the Galilean and Newtonian constitution is so easy to push to its ultimate completion, which is the definition of entities and processes that behave *as if* they were truly *detached* from their constituting subject, that nothing prevents a confusion between their objective status and their existing "in themselves". This is why classical theories are so naturally interpreted as descriptions of natural processes and objects seen from a disengaged standpoint; and this is also why it is usually believed that classical theories provide physicists with an *ontology* in the strongest sense of the word. By contrast, quantum theories are stubbornly resistant to detachment, thus downgrading the status of objectivity to the rank of mere intersubjective agreement. One may also say that quantum theories have been constrained to relinquish "strong objectivity" in favor of "weak objectivity" (d'Espagnat 2019). Such resistance to detachment derives from the most fundamental quantum laws, which (as pointed out in Heisenberg's original paper) take the form of canonical commutation relations. Indeed, the lack of commutation of pairs of conjugate observables, and the correlative dependance of their values on the order of their measurements, is the mark of the inescapable contextuality of variables. Even those hidden variable theories that were designed to offer physicists the possibility of dealing with "beables" beyond observables, thereby recovering the old ideal (or illusion) of ontically interpretable theories, must accommodate a descriptive equivalent of contextuality. They are bound (self-defeatingly) to represent the reason why one cannot detach sufficiently from the quantum world to make it representable.

A momentous consequence of this lack of detachment is that quantum mechanics is permanently dependent on the deconstructive phase of its

foundation, namely on the initial *Epoché* that allowed to elaborate it on a sound (and prejudice-free) basis. Hence the disturbing need for pre-theoretic, epistemic, concepts such as "measurement", "observable", "outcome", "information" (etc.) in its daily use and even in its standard "postulates". Hence also the endlessly renewed quest for a proper reconstruction of the quantum formalism from the elementary building blocks left by the suspension of judgment about higher-order ontological concepts. To evoke just a few of these reconstructive attempts, let us mention the empiricist reconstructions of Destouches-Février (1951), Peres (1995) or Schwinger (2001), and the information-theoretic reconstructions of Rovelli (1996), Hardy (2000), Grinbaum (2003, 2007), Höhn & Wever (2017), D'Ariano et al. (2017), etc. Quantum mechanics looks like it can never get rid from the process of its own constitution, or from the building blocks and the scaffolding of its own reconstruction.

3-A deeper Epoché: from the life-world reduction to the transcendental reduction

But what are the building blocks? At what point should one stop the suspension of judgment about higher-order concepts? Which concept is of low enough level to be used as reliable material for the reconstruction of quantum mechanics? In the first years of quantum mechanics, the suspension of judgment was only partial. It was stopped at an intermediate level of description and analysis: the level of macroscopic events such as pointer readings, and classical concepts such as the space-time trajectories of pieces of apparatus. The three-steps procedure of suspension, reduction, and constitution was permanently remembered in the most specific quantum domain (micro-physics), whereas it was purposely forgotten in a domain for which classical physics remains approximately valid, allowing to adopt the usual *as-if* ontology of material bodies and properties. This half-way *Epochè* was promoted by Bohr, not as a defense of macroscopic realism, but as a practical basis for disambiguation and mutual understanding in communication between scientists. Its outcome closely corresponds to what Husserl (1989) called the "life-world reduction", namely the reduction of discourse about scientific entities to the practices and objects of everyday life (Bitbol 2021). Unfortunately, the Bohrian life-world reduction was not a stable option. It was soon criticized (i) for accepting as primitives of the physical theory a set of concepts (such as definite properties of pointers) that have *prima facie* no counterpart within this theory, and (ii) for a seemingly arbitrary decision as to which part of the measurement chain is to be described by ordinary language supplemented with classical concepts.

The first criticism was addressed by formulating decoherence theories, which proved to be a powerful heuristic tool for several applications of quantum mechanics (such as quantum computation), but a disputable success in their pretention to solve the measurement problem on their own (Joos 1999, Adler

2003, Wallace 2012, Zwirn 2016). As for the second criticism, Bohr initially addressed it by claiming that, although the methodological *function* of the classical-quantum boundary cannot be dispensed with, its *position* is arbitrary and can be moved according to purely practical criteria. But this criticism also revealed a sort of logical problem ingrained in the foundation of quantum mechanics: that its instrumental and epistemic meta-theory is, in principle, heterogeneous to it *qua* theory[2]. The meta-theoretical description of apparatuses and data, that serve to test it, involves "classical" concepts of properties and facts occurring by themselves, whereas its theoretical domain requires relativized concepts of properties and even facts (Brukner 2020). So much so that the Bohrian cut was sometimes given a logical rather than physical formulation, *qua* necessity to alternate between two conceptual realms, theoretical and meta-theoretical (Peres & Zurek 1982, Mittelstaedt 1998).

By far the most radical understanding of this logical acceptation of the Bohrian cut was developed by John Von Neumann ([1932] 1955). According to him, the boundary between quantum-theoretical superpositions and meta-theoretical definiteness can be pushed as far as to leave *nothing* but an "abstract ego" on the meta-theoretical side. What is located on this meta-theoretical side is then no "object" whatsoever, but the implicit and all-pervasive condition for anything to be taken (and *constituted)* as object: Husserl's "transcendental ego", *qua* bearer of constitutive consciousness. A few years later, London and Bauer (1939) proposed an approach of the measurement problem that unfolds the Husserlian implications of Von Neumann's short but daring remark. Contrary to its popular reading, London and Bauer's "solution" does *not* amount to assume a dualistic opposition of consciousness and world, and then to claim that consciousness imposes a reduction of the quantum state, from a superposition to some observable's eigenstate. Instead, as French (2020) convincingly pointed out, London and Bauer support an idealist-like monistic conception inspired from Husserl, according to which "to overcome (the paradoxes of quantum mechanics) the phenomenologist insists on *objectivity itself being constituted by consciousness*". Along with this monistic conception, a conscious observer does not modify something in the outer world (and has no power to do so); she rather "(...) *constitutes,* in virtue of her (self-)observation, *a new objectivity* by attributing a new state to the object: (an eigenstate of the observable)" (London and Bauer 1939). By saying this, London and Bauer suggested that the life-world reduction is not deep enough to serve as the starting point of a phenomenological constitution of quantum mechanics. Instead, as a preliminary for a sound activity of constitution, they advocated what we may call after Husserl a *transcendental phenomenological reduction*: "directing our gaze towards pure consciousness in its own absolute being" (Husserl [1913] 1983, [94]), and considering the being of its objects as relative and derivative.

[2] One of the explicit motivations of Bohm's theory is therefore to recover the homogeneity of the theory with its metatheory, within a conceptually classical framework (Bohm & Hiley 1995).

But is this dramatic philosophical move indispensable to make sense of quantum mechanics? Several arguments recently adduced by QBist thinkers seem to point in this direction.

4-On the transcendental reduction performed by QBism

QBism is an acronym for "Quantum Bayesianism" or "Quantum Bettabilitarianism" (Fuchs 2010, Fuchs and Stacey 2020). According to QBism, "state" vectors are just Bayesian-type probabilistic valuations. They are not descriptions of "physical systems", but prescriptions about what an agent is entitled to expect when she has interacted (experimentally) with her environment. The interest of QBists being thus no longer directed towards objects and their states, it is reflectively redirected towards the *epistemic function* and the *practical use* of the symbols of quantum mechanics. In QBism, the symbols of quantum mechanics are tools the agents use to assess the probabilistic weights of various outcomes of experiments, so as to make consistent bets about them (hence the word "bettabilitarianism").

Thus far, the primitives of QBism and the themes of its reflective interest (agents, experiments, interactions between apparatus and object, measurement outcomes) do not sound fundamentally different from Bohr's. In other terms, it looks like QBists stick to Bohr's standard life-world reduction. But QBism does not stop at this point. Firstly, in their most lucid texts, QBists replace the dualist *cliché* of an *inter-action* between agent and world, with the more advanced monistic concept of an *intra-action* within what there is (Fuchs 2015, 26; Fuchs 2017). Secondly, QBists point out that what a quantum probabilistic valuation is about, is *not* some macroscopic event such as a spot on a screen or a pointer position, located in the so-called external world; instead, it is an agent's *lived experience* of seeing such spot or pointer. Accordingly, the quantum formalism is understood by QBists as "a calculus for gambling *on each agent's own experience"* (Fuchs 2010). Read thus, the general structure of the quantum formalism strongly resembles Husserl's temporal analysis of lived perception, which involves an elaborate kind of experience made of (i) actual presentations and (ii) horizons of expectations to be fulfilled or disappointed by future presentations (De la Tremblaye 2020).

This emphasis of QBists on lived experience as a starting point and an ultimate reference of the activity of quantum physicists is tantamount to advocate a transcendental reduction, thus clearly going beyond Bohr's life-world reduction. In the course of its short history (say from 2000 to now), QBists declared more and more explicitly that the lived experience of agents should be taken as the most appropriate basis for the (re-)construction of quantum mechanics. This created some tensions between their semi-dualistic pragmatist picture of the intervention of an agent on/in the external world, and their inclination towards an experiential ontology that monistically absorbs the agent's interventions within the agent's experience of acting (Pienaar 2020). But

these tensions can readily be eased if a thoroughly phenomenological standpoint is adopted throughout (Bitbol and De la Tremblaye 2022).

Now, why do QBists depart so distinctly from Bohr's life-world reduction, and why do they insist so much that an experimental outcome is no outcome until it is an *experienced* outcome? Their move towards a thoroughly phenomenological approach of quantum mechanics is by no means a mere matter of taste. It is meant to dissolve at once a series of quantum "paradoxes" that involve the comparison between more than one agent's data. One example is afforded by EPR correlations that involve the comparison between the outcomes and predictions of two distant observers (say Alice and Bob). Another example is the comparison between the outcomes and predictions of Wigner and his friend in Wigner's friend paradox, as well as the comparison between the outcomes and predictions of four agents in recent refined varieties of Wigner's friend paradox (Frauchiger and Renner 2018). The QBist dissolution of this family of "paradoxes" is based on the remark that "Bob's answer is created for Alice *only when it enters her experience*" (Fuchs et al. 2014). As long as one compares the outcomes and predictions of agents from some "God's eye standpoint", discrepancies between them can (artificially) occur. And as long as experimental outcomes are dealt with as intrinsically occurring macroscopic events, or macroscopic traces of former events, comparing them from "God's eye standpoint" is a permanent temptation. But if outcomes and predictions are compared in the only place where they can be at the end of the day, namely *in the experience of a single agent at a single moment,* any contradiction fades away, and even the need for mysterious actions (or passions) at a distance disappears (Fuchs et al. 2014, Martin-Dussaud et al. 2019). We can conclude from these remarks that, far from being the whim of some maverick physicists, the strict transcendental reduction to pure experience, the uncompromising adhesion to the first-person standpoint, is indispensable to make full sense of quantum mechanics by making its "paradoxes and mysteries" vanish at one stroke.

5-Obstacles on the way of constitution

Once the ultimate transcendental reduction has been performed, once the descent towards pure present experience has been achieved, we are left with the task of (re)constructing an adequate physical theory and the familiar domain of mesoscopic objects from this raw material. The program of a (re)construction of the object-like environment of our everyday life from an experiential basis has been sketched repeatedly by some of the most brilliant minds of the twentieth century (such as Husserl, Carnap, Whitehead, Goodman etc.), and it has been found difficult, not to say insurmountable. Our task, here, is to describe shortly these attempts, together with the obstacles that discouraged their authors, in the hope of identifying the origin of these obstacles and overcoming them.

The first attempt was the phenomenological constitution of ordinary objects in experience, as expounded by Husserl ([1913] 1983). Petitot (1999) formalized Husserl's (re)construction, and he found that, although epistemologically sound and feasible in principle, it is so mathematically intricate that, for all practical purposes, one should rather dispense with it altogether. This intricacy is easy to understand. The standard (direct) problem, that we tend to privilege in the "natural attitude" of everyday life and science, consists in starting from an object whose spatial shape is (supposed to be) given "out there", and then projecting it so as to define its "apparent outlines", or profiles, as seen from various directions. Each projected profile can then be compared with what we actually see, thereby confirming (or denying) the postulated three-dimensional object's shape. By contrast, Husserl's phenomenological constitution consists in starting from a family of apparent outlines (or profiles), and then (re)constructing the shape of an object immersed in space. There are two difficulties in the latter (reverse) process. The first one is the complexity of the geometrical concepts to be used in the reconstruction. The second one, even more formidable, is the gap between the finiteness of the reconstruction basis (a few profiles), and the infinite number of presentations shown by an object's shape according to the angle of sight. The phenomenological reconstruction is then bound to remain indefinitely hypothetical, thus triggering the "realist" reflection that there must be *something out there* about which such hypothesis is made. Husserl acknowledged this difficulty by way of his concept of "transcendence in immanence", and by way of his frequently overlooked difference between "constitution" and "construction".

Rudolf Carnap in turn undertook a construction of the world *(Aufbau der Welt)* out of what he called an "auto-psychological basis" made of "elementary experiences", namely out of the "immediately given". This starting point was explicitly borrowed from Husserl and Whitehead (Carnap [1928] 1967, §3), and it was justified by the epistemic primacy of lived experience (Ibid. §54). Carnap did not ignore how challenging this option was. At first sight, the choice of an "auto-psychological basis" seems to imply a solipsistic thesis. But actually, only the sense of evidence and the method of solipsism are borrowed, not its disputable metaphysical claim. This means that Carnap's "solipsism" is only "methodological" (Carnap [1928] 1967, §64). Moreover, in it, any ascription of "reality", both to the so-called "external world" and to the "inner realm", is *suspended* (or bracketed) in the sense of Husserl's *Epoché* (Ibid.). As a consequence, Carnap's "auto-psychological" basis must be considered *subjektlos;* it must be taken as the experience of no *particular* subject; it must be construed as strictly *neutral* (in the sense of neutral monism), namely as prior to the subject-object divide. Such point was later insisted upon by Nelson Goodman, according to whom "the basic units of such a system are not taken as belonging to a subject and representing an object. They are taken as the elements in terms of which must be construed whatever objects, subjects, streams of

experience, or other entities the system talks about at all. These basic units are *neutral* material" (Goodman [1951] 1977, 103). And the same neutral premise, below the level of the dualistic "bifurcation of nature", was famously chosen by Whitehead (1929), under the name "actual occasions": a set of lived events that mirror other lived events through their relational "prehensions" (Dumoncel and Weber 2010).

The next stage of Carnap's "construction of the world" was to elaborate a field of intersubjective agreement (the "hetero-psychological" domain) about something that can be construed as common to all. Since this cannot be the case of the qualitative content of elementary experiences, the only possible common ground is the abstract network of relations between these experiences, namely their overall *structure*. "Even though the material of the individual streams of experience is completely different … certain structural properties are analogous for all streams of experience. Then, if science is to be objective, it must restrict itself to statements about such structural properties" (Carnap [1928] 1967, §66). This is why Carnap set out to find the most elementary relations that lift us from a strictly situated field of experience to a shareable body of knowledge. For that sake, he identified several levels of "similarity", a symmetric and reflexive type of relation that can hold between experiences. He then distinguished several levels of similarity: a similarity between elementary (past and present) lived experiences, a similarity between classes of experiences (or qualities), and a similarity between classes of qualities (Carnap [1928] 1967, §71-73, §78). But problems and difficulties then increased as soon as further steps of the construction were taken towards bodily objects (with their spatial extension and their temporal continuity), and towards the cultural level (Granger 1983). So much so that, in his preface of 1961 to the second edition of the *Aufbau,* Carnap declared that "nowadays" he found his former constructive procedure "too artificial". Even though the general project of reducing "… thing concepts to auto-psychological concepts remains (in principle) valid … the assertion that the former can be defined in terms of the latter must now be given up and hence also the assertion that all statements about things can be translated into statements about sense data". This explains why Carnap suspended the daring endeavor of the *Aufbau* and eventually adopted the opposite strategy: *Physicalism,* the doctrine that all statements, including those about psychological facts, can be translated into statements about physical objects and processes.

6-Dissolving obstacles

These obstacles met by Carnap and Husserl in their attempts to "reconstruct" an objective world out of lived experience, can hardly be overcome as they stand. But they can be readily dissolved, provided one gives priority to the *function* of the concept of object in our cognition, rather than to the structure of each particular object. Now, what is the primary function of the implicit or explicit concept of an object? We have seen that, according to Husserl,

identifying an object in perception always means going beyond what is immediately presented. Identifying such permanent item within the flux of appearances is intended to afford a proper basis for predicting what is likely to appear next. From the standpoint of a living and experiencing agent, an object is then nothing more than an operator of limitation of what she will live and experience while focusing her attention on "it". In particular, the structure she ascribes to such an object, has no other use than to be a generator of anticipated future presentations. We could say that, for her, an object is a mere bundle of expectations. As for the so-called "transcendence" of the object, it is just the expression of the agent's awareness that her expectations can sometimes be disappointed or overwhelmed, that her cognition is not immune to surprises.

So, we might well be more successful in our attempt of *phenomenological constitution* if we sidestepped the task of reconstructing entirely each object, together with its detailed structure, out of an experiential basis. We might reach an efficient strategy of constitution if we rather focused directly on the form of our expectations about future experience. This new approach would indeed account for the global *function* of the concept of an object, without having to enter into details about it. It would also enable us to retain the phenomenological meaning of the "transcendence" of objects (namely indefinite openness and liability to surprise), without retaining its metaphysical meaning (namely detachment from, and independence of, experience). And it would then show us a way to go beyond the realist thesis that there are entities which are literally "external" to us, without overlooking the most valuable nucleus of its intuition, namely that something eludes us in our experience, that we cannot control or produce every appearance.

The QBist approach to quantum physics precisely fits this agenda. In it, any consideration about object-like "systems" and their "(quantum) states" is suspended. And what is adduced instead is an interpretation of state vectors as weighted betting patterns. Moreover, as mentioned previously, the betting patterns of QBism do not bear on a set of events happening autonomously out there in our macroscopic environment, but on facts that are relative to agents' interventions, and identified to the latter's pure experiences. So, here, only the *role* that objects play in ordinary cognition is retained, not their elusive structure in space-time and even less the claim that they exist independently of cognition. Only their function *qua* lived bundles of expectations remains, while any attempt at positing them as some autonomous "substances" in the outer world is indefinitely suspended. As for the reason for our treating objects as "transcendent", namely the experienced sense of being overwhelmed by something that exceeds our limited personal position and will, it is acknowledged at two levels by QBism. It is acknowledged at the most elementary level by considering each (experienced) fact as a "unique creation" (Fuchs 2010) resulting from an "intra-action" that splits *what there is* into an agent and a reagent. And it is acknowledged at the higher level of the structure

of our expectations by showing that the fundamental law of quantum probabilities, namely the Born rule, cannot be derived from a clause of internal consistency (such as the Dutch book condition), taken in isolation, but that an additional clause "above and beyond the standard rules of probability theory" (DeBrota et al. 2020b) is needed.

This QBist way of accommodating a residue of "scientific realism" is likely to undermine our spontaneous (dualist and reifying) ontology. Indeed, it implies that a physical theory (here quantum mechanics) is not meant to provide us with a *description of* the outer world. Quantum mechanics affords nothing else than normative *prescriptions* about how to cope with the product of our intra-actions *within* what there is. It is nothing more than a "user's manual" for inhabitants of the world. If we take it seriously, it thereby inclines us to replace our ontology with what Maurice Merleau-Ponty (1964, 279) calls an "endo-(or intra-) ontology": a discipline of what it is like to partake of Being, rather than a doctrine of beings (Bitbol 2020).

Moreover, since *what it is like to partake of Being* takes the form of lived experience, an "endo-ontology" is bound to be a phenomenological ontology. Although with some hesitations, QBism is then clearly leaning towards this non-standard kind of ontology, and accordingly sketching a project of "constitution". Here are two illustrations of this tendency, drawn from two supporters of QBism:

"In QBism, an element of reality is an experience" (Pienaar 2020);

"Any user's own experience constitutes all of the raw material out of which she constructs her world" (Fuchs et al. 2014).

But can we content ourselves with the mere patching together of the standpoint of phenomenology and the motivation of scientific realism? We wish go beyond that, and reach the level of a purely phenomenological construal of the world and our being-in-it. In another paper, we expressed such project in the form of a twofold slogan partly borrowed from two recent developments of French phenomenology (Barbaras 2019, Bégout 2021): en-worlding experience and en-experiencing the world (Bitbol and De la Tremblaye 2022). An en-worlded experience is the broadened equivalent of an em-bodied experience. En-worlding experience then means recognizing that we experience our belonging to the world in the same way as we experience our belonging to a (human) body: by treating it as an extension of ourself. Conversely, en-experiencing the world means recognizing the continuity of nature between experience and what it is an experience of; namely acknowledging that the world is given as nothing else than our experience "of it" (including the permanent feeling that it may have surprises in store for us). This being granted, lived experience can be accepted as the *terminus a quo* and *terminus ad quem* of scientific research and its associated ontology, without jettisoning the conviction that this research somehow bears on the world.

Interestingly, this project of bringing any concern about the "real world" back into the phenomenological field of pure experience, was already a burning issue at the time of Husserl. One (half-forgotten) German philosopher and phenomenologist was especially active in this area: it was Max Frischeisen-Köhler, who was brought to our attention by a brief mention of Carnap (1967, §64). In one of his major pieces of work (Frischeisen-Köhler, 1912), this author insisted that (unlike in its most widespread version) the concept of "reality" should *not* be defined in terms of independence from consciousness. For, after all, "reality is given and determinable only as a content of consciousness" (Frischeisen-Köhler, 1912)[3]. But then, how can we account for the feeling that something exceeds our finite (human) existence? To start with, we must realize that there is a momentous difference between exceeding finite individual existence and exceeding consciousness as such. The medieval, and then Berkeleyan, doctrine, that what exceeds our individual existence is a universal spirit or consciousness (God), then paves the way towards an alternative concept of reality. It paves the way towards a concept of reality that indeed "transcends the fragmentary experiences of empirical human subjects, (but is not) impervious to consciousness in general" (Staiti 2016). Accordingly, to constitute a strong concept of reality, one that fits the requirements of the science of nature, we do not have to find a way to get out of consciousness. We just need to articulate two features of consciousness that make us rightly think that something exceeds our finite existence: resistance and universality. Resistance (or surprise) emerges in action: "it is in our capacity as agents, and not as contemplators, that we encounter reality" (Staiti 2016, Frischeisen-Köhler 1912, 275). As for universality, it is the outcome of a quest for intersubjective agreement. To sum up, Frischeisen-Köhler's concept of reality boils down to accepting that "the whole world with its suns and stars and peoples and heroes is only a world of appearances, it exists only to the extent that it is in consciousness; but *this consciousness is not mine, it is not yours"* (Frischeisen-Köhler 1912, 251). Making sense of surprise and intersubjectivity is then all we need in our project of phenomenological constitution of quantum mechanics.

7-On the primacy of Now

Let's recapitulate. The inaugural gesture of the QBist interpreter of quantum mechanics is to put the subject's experience at the forefront of any scientific discourse or theoretical elaboration. David Mermin thus declares that, before QBism, "what was missing was a recognition that the goal of science is to bring order and coherence to the experience of the person who uses it." (Mermin 2013). To recover this kind of coherence, we propose (as announced in the previous paragraph) to carry out a phenomenological analysis of what surprise and intersubjectivity represent in lived experience. This is how we wish to

[3] These quotes of Frischeisen-Köhler were translated and commented by Staiti (2016)

reconcile immanence and transcendence in physics: the immanence of experience, and the transcendence of the objects and laws it targets.

As a preliminary move, we must ask an almost naïve question: what does the experience of a person using physics consist of? Mermin points out that before we even speak of personal experience (with its continuity along a period of time), we must realize that the first experience we all find ourselves facing, is that of the Now. We are in the present, and all that we can say about the world is said in the present; any biographical narration of "my" life, any discourse about physical processes extended in time, is anchored in the present. Despite this, Mermin points out, the present is absent, and even intentionally banned, from the discourse of physics. This creates an insuperable gap at the heart of physics, according to Einstein himself, whose words are reported by Carnap: "He [Einstein] explained that the experience of the Now means something special for man, something essentially different from the past and the future, but that this important difference does not and cannot occur within physics. That this experience cannot be grasped by science seemed to him a matter of painful but inevitable resignation" (Carnap 1963, 37). Since such unique meaning of the present for humans has no place in physics, a choice must be made. Einstein, and most physicists with him, chose to minimize the scope of the agent's time, of the human time, by considering it as narrowly subjective, parochial, idiosyncrasic; and they tended to privilege the objective time of science instead. If we accept this choice, we are doomed to consider that lived time is nothing more than a sort of illusion generated by our egocentric standpoint in objective time; for it is impossible to give an objective status to the singular experience of the present of a subject, and it is then impossible to find a place for it in the stable and universal time of (classical or relativistic) physics. But a diametrically opposite choice is also possible, and it is precisely this one that was made by most QBist authors. We have seen that QBists put the experience of the agent back at the center of physics; but they also, simultaneously, put the Now back at the center of an agent's experience. Indeed, the two questions, about experience and about the now, are so closely related that they are likely to answered all at once. If science (here represented by QBism) is no longer exclusively fascinated by its image of an external world, but tends to wonder, reflexively, about the scientific agent and about her lived experience (Mermin 2013), then it must go to the end of this new quest: it must bring to light lived experience in its nascent state, namely in the immediacy of the Now. After all, as Mermin (2013) pointed out, "my experience of the now is a primitive fact". My experience of the Now is the most primitive fact of all, more than any enduring contents of experience, more than permanent objects, and more than the persistent identifiable "me". For, any such enduring content is envisaged from the standpoint of the experience of the Now (or, more plausibly, from the standpoint of pure present experience). To overcome certain obstacles that she created by banishing the Now from her speech, the physicist must then start all over again from scratch.

She must start from her present experience. She must then ask herself what led her to ignore the glaring present experience, and rather allow herself to be absorbed by the objectified spatio-temporal continuants she has constituted out of it. "The problem of the Now will not be solved by discovering new physics behind that missing glowing point. Nor is it solved by dismissing the Now as an 'illusion' or as 'chauvinism of the present moment'. It is solved by identifying the mistakes that lead us to conclude, *contrary to all our experience,* that there is no place for the Now in our physical description of the world" (Mermin 2013, 2018).

To mark out this path that the physicist should take according to Mermin, we can rely on the analyzes of Husserl's phenomenology concerning the concepts of the living present, and of the present deployment of both memories and future possibilities. We will thus retrace the thread that (according to phenomenology) starts with present experience, and then leads to the constitution of the agent, as well as the communities of agents, out of it.

It should be noted from the outset that, unlike physics, Husserl's phenomenology is not immediately concerned with objective time. "The time of the world, the time of things, the time of nature in the sense of the natural sciences" (Husserl 1964 [1905] §1) are not the object of phenomenology. For Husserl, as for QBists since Mermin, the most fundamental experience, the root of everything else, is the present experience in the first person singular. Present experience becomes the actuality *of an "I", of a subject,* only insofar as it is polarized and in flux, that is to say insofar as it takes the form of what Husserl calls our "living present". Indeed, the living present is a field of actuality endowed with (i) motivation and (ii) a twofold tension, out of which the subject constructs her own biography. The living present is the unique field in which experiences perceived as barely past, and experienced projections into the future, take place. Husserl names these two poles: retentions and protentions. The subject (but also the QBist agent) then constructs herself, as an enduring subject, by relying on this presently available resource to elaborate her autobiography. For that sake, the subject extends the pole of retention towards her past memories, and the pole of protention towards her projects in life.

In the experience of the Now there is thus contained the whole narrative which makes the subject a unique subject for herself. As Husserl (2001 [1930], 182 [126]) writes, "my immanent present being, founds my past-being and my future-being". And the living present also founds any reconstruction of an objective time, meant to be used as an inter-subjective replacement of the subjective sequence past-present-future. In such phenomenological context, it is thus clear that the time of the subject, or of the agent in the QBist sense, precedes the time of physics and makes it possible.

This latter (phenomenological) choice being made, we are able to address Einstein's concern. The reason why *Now* escapes the discourse of science, is that the discourse of science presupposes it. What science describes and predicts, can

be described and predicted only in the immanence of the present. The experience of the Now doesn't occur within science; science occurs within the experience of the Now. The option taken by Mermin and the QBists is then a very strong philosophical gesture: it tends to affirm the precedence of the immanent time of experience over the transcendent time of theoretical physics.

Those who consider that such option of QBism is risky and adventurous, that it goes against the most basic principles of theoretical physics, and that it must therefore be dispensed with altogether in quantum physics, should think twice before upholding this dismissal. Indeed, it is precisely the decision to grant ultimate reality to present experience, that allows QBists to perform their radical dissolution of the paradox of "spooky action at a distance" associated with the EPR thought-experiment. In their own terms, "Quantum correlations, by their very nature, refer only to time-like separated events: the acquisition of experiences by any single agent" (Fuchs et al. 2014). Let us develop this point, for the sake of clarity. A quantum (EPR) correlation can be established only within the experience of some agent who presently dwells at the intersection of the light cones of the two correlated events. Before that, the correlation is at most probabilistically anticipated. As a consequence, even the notion that such correlated events are space-like separated, is the byproduct of an *a posteriori* (re)construction within the present experience of the agent. And the urge for an explanation of the correlation in terms of some action-at-a-distance or holistic feature of the universe, then looks as an artifact of this *ex post facto* reconstruction. On the contrary, taking seriously the QBist slogan "no correlation is a correlation until it is a presently experienced correlation", makes any explanation of the correlation in terms of mutual effect of two space-like separated events unnecessary (e.g. Smerlak & Rovelli 2007).

8-Intersubjectivity without exteriority

If, as QBists believe, all scientific discourse finds its source in the present experience of an agent, how can we uphold the very project of science, which is to achieve an objective knowledge? Can we ensure the compatibility of the desire for objectivity with the first-person singular point of view, which QBism openly adopts? These are burning issues. So burning that the QBist decision to take the agent's pure experience as the point of departure and the point of arrival of physical theory triggered a strong aversion in many physicists, who had the feeling that the very basis of their discipline was shaken by this option. This is evidenced, for example, by long discussions on this topic between Christopher Fuchs, David Mermin and Rüdiger Schack (Fuchs 2015). Some physicists disqualify QBism because they take it for "mere" instrumentalism, and others because they take QBism for a form of solipsism (Norsen 2016). But these are superficial criticisms. Fuchs (2017) has shown that QBism goes far beyond the instrumentalism it looks like at first glance. As for the accusation of solipsism, it has already been brandished with little success against other interpretations of

quantum mechanics, including some which have the reputation for vindicating "realism", such as Everett's relative-state interpretation: "Everett's replacement of the past by memories is a radical solipsism, extending to the temporal dimension the replacement of everything outside my head by my impressions, of ordinary solipsism or positivism" (Bell 1987, 136).

Against this recurring accusation, a resource is available to QBism, as to Everett's interpretation. It consists in showing that, according to the internal logic of these interpretations, a form of inter-subjective agreement cannot fail to emerge from the coordination of subjective experiences; and in noting that the condition of intersubjective agreement is equivalent, from the point of view of knowledge, to a condition of objectivity. Indeed, as Poincaré (1905, 262) pointed out, "what is objective must be common to several minds". And, conversely, what is common to several minds behaves exactly as if it were objective.

The problem is, if one draws all the conclusions from the priority QBism places on singular lived experience, invoking intersubjectivity is by no means straightforward. In QBism, it is all about the agent who makes a measurement, her own expectations, and her own past experiences that condition those expectations. "What quantum theory does is provide a framework for structuring MY expectations for the consequences of MY interventions upon the external world" (Fuch 2015). Each agent has her own experiences, her own expectations, and organizes them by means of Born's rule. So much so that, from a QBist point of view, "There is no 'we', there is no 'our'. At this level of consideration, *quantum theory has nothing to do with intersubjective agreement*" (Fuchs 2015). QBists go so far as to assert that "There's no transformation that takes the one personal experience to the other personal experience. William James was just wrong when he tried to argue that two minds can know one thing" (Fuchs, 2015). Yet, notwithstanding these strong statements against the clause of intersubjective agreement, QBism cannot be equated with solipism. Indeed, according to the QBists authors, personal first-person singular pronouns, such as "I" and "me" are universally usable, by any agent whatsoever, not just one. They define Quantum mechanics as "a handbook that anyone can use" (Fuchs 2018, 21). Quantum mechanics is a tool for anyone, although it is not a theory for everyone.

Beyond this abstract idea that any agent can use quantum mechanics, however, the interactive concept of intersubjective agreement *about something* (be it the result of an experiment or a theoretical formalism) plays a discreet role in the QBist framework. But, if intersubjective, or inter-experiential, agreement still has a role to play, it is only to the extent that it acquires meaning within a single lived experience. If the first-person plural is permitted in QBism, it is only because it is based on the first-person singular of the present tense. Mermin (2014) thus suggested very clearly that intersubjectivity is constituted within subjectivity: "Although I cannot enter your mind to experience your own private

perceptions, you can affect my perceptions through language. When I converse with you or read your books and articles in Nature, I plausibly conclude that you are a perceiving being rather like myself, and infer features of your experience. This is how we can arrive at a common understanding of our external worlds, in spite of the privacy of our individual experiences". The almost unique means proposed here by Mermin to make sense of the experience of another agent is language, which is used to communicate with other agents. But Mermin also tacitly relies on a broader capacity for communication, for which language only provides an opportunity, and which is presupposed by language. This skill is *empathy:* the empathetic recognition by me of the ability of someone other than me to perceive like me. Once this empathetic move has been performed, my own expectations can be changed by other agents. By empathically recognizing that other agents have the same capacity as I do to feel, experience, and have expectations of their own, I can communicate with them, be affected by them, and recognize their knowledge as if it were mine.

This is exactly how Husserl understands the constitution of intersubjectivity, out of a situated lived experience. According to him, the constitution of intersubjectivity takes place in two stages. Firstly, I recognize in myself the quality of being both an objectified being, and an objectifying being; I recognize that I am endowed with both a perceived body, and a perceiving body. Secondly, I also recognize in the other an objectified being and a perceived body, similar to mine, and I infer, through empathy, the capacity of the other to be objectifying, perceiving, and feeling like me (Depraz 1995). In other words, I have to analyze and elaborate my own experience to grant this perceived body the capacity to have its own perceptual experiences similar to mine. This is how I constitute "it" as someone other than me.

There is therefore no need to imagine that the experience of the other, QBist agent or Husserlian subject, exists *in itself*. One would rather tend to say that the experience of the other is constituted in mine. But this (which derives from what Husserl calls a "cartesian" reduction) is still only a first approximation, which maintains an asymmetry between me and the other. To go beyond this first approximation, we must remember: (i) that the situated first-person experience from which all things are constituted, especially "my" other, is also the present experience from which is constituted this "me" in which I recognize myself; (ii) that, in present experience, "me" can only be constituted in opposition to some "other" which is also constituted. Therefore, if it is true that the other is constituted *in* me, it is just as true that she is constitutive *of* me. This restores a sort of symmetry between subjects.

These processes of constituting myself and the other are narrowly intertwined. This is why it is necessary, in order to think of the other, to consider her experience and mine as being concordant. To imagine that if I were in the other's shoes I would have a certain experience, it is necessary to assume that we are both looking at one and the same thing. So, to allow this

interchangeability between subjects, I need to think of the objects of the world as invariant under the effect of a change of subject.

It is at this point that a first decisive philosophical turnaround takes place: the objects of the world, common to several subjects, exist only because of the need for me (the pure, transcendental, pre-personal "me" of present experience) to make sense of the experience of other. In order for my experience to be consistent with that of another subject, one must admit the uniqueness of the object we are looking at. The existence and invariance of objects in the world are here a prerequisite for making sense of the existence of other subjects, for co-constituting me and others, and not the other way around. There is therefore no need to postulate the objects of the world outside of the first-person experience: their invariance here is based only on the necessity to think, in the first person, of the concordance of the experiences of several subjects. In other words, the invariance of the objects of the world is the condition of possibility of the relation of empathy established, in present experience, between the other subjects and myself. In order for there to be no ontological difference between the other subjects and myself, both must be constituted as having situated experiences of the same *objects*. The constitution of the objects of the world is thus imposed by the constitution of the other subjects, which takes place, like the constitution of "me", within a pre-personal experience in the first person of the present tense. Objectivity is conditioned by intersubjectivity.

Understood in this strictly phenomenological sense, the concept of intersubjectivity should no longer pose a problem for QBism. It is no longer a question of admitting that subjects agree about objects that actually exist out there. Conversely, it is a matter of setting invariants (treatable as objects), in order to be able to suppose that the experience of the other agrees with mine.

At this point, there is no need to postulate a reality external to the singular lived experience. It is simply required to recognize the use of the invariants which we pose in order to establish a system of concordant experiences. So, how do we use them? We have seen in section 6 that identifying an invariant, and treating it as an object, makes it possible to anticipate what will appear behind the visible, by imagining aspects "of it" that are still invisible. Then, seeing a new aspect makes it possible to readjust such expectations. This process is part of the dynamics of lived experience. And, in quantum theory as interpreted by QBism, the same process is formalized by a succession of probabilistic anticipations and experimental readjustments (de La Tremblaye 2020).

9-Surprise without an outer world

But one step is still missing to reconcile the quest for objectivity and the recognition of first-person experience as an unsurpassable reference for any investigation. This step consists in accounting for the resistance of phenomena to the anticipations of agents. It consists in accounting for the fact that a subject can allow herself to be surprised by an unforeseen phenomenon. Does not

surprise prove an outer world, since something resists the agent, and escapes her control? Isn't surprise the very manifestation of the world *in itself,* independent of the subject? This is what some QBists authors suggest, when they claim that "the consequences of measurement actions are beyond the agent's control; (thus) *the world* can surprise the agent" (DeBrota et al. 2020). Here, realists seem to score a point. We must admit that surprise escapes the usual dynamics of experience, made up of presence and motivated anticipations. What place could surprise find within experience, since it precisely supposes a *non*-anticipation, a situation in which all expectations have been shattered? To make room for surprise in the usual dynamic of experience, one would have to anticipate surprise, thus depriving surprise of its very essence, which is precisely the capacity to escape all anticipation. Is it then possible to think of surprise other than as a break in the fabric of experience, as an eruption into the experience of something that is entirely foreign to it? We believe so, and we are going to propose the second philosophical turnaround to which we are led by our phenomenological approach to QBism.

As we have seen previously, present experience is composed of presence and motivated expectations. A surprise, an unexpected event, then manifests itself as a disappointment of expectations. Motivated expectations are disappointed, none are fulfilled, and they are replaced by the new presence which is the surprising event. Surprise is, at first, a "shift from possible to impossible" (Serban 2016, 89). It is first of all a disappointment of all expectations, a frustration, a closure of the possibilities opened by anticipations. But, by tipping the previously possible into the impossible, surprise also transforms what was previously impossible (because unanticipated), into new possibilities that are more open and indeterminate. A pre-defined possibility is replaced by an open possibility, thanks, precisely, to surprise. Here, surprise no longer has the meaning of an external contingency. It doesn't go beyond the dynamic of first-person experience, but amplifies it. It is the condition of possibility for the unfolding of new open and infinite possibilities within the anticipatory first-person experience. In order for experience to unfold by alternating presences and anticipations, it is necessary to leave a place for open possibilities, and this place is provided by the plausibility of surprise. In other words, it would be pointless for us to anticipate something, if this anticipation did not fit into a larger framework that admits the plausibility of surprise. Pre-defined possibilities only make sense if they tacitly assume open and indeterminate possibilities. Surprise therefore belongs to experience; it is even the condition for the possibility of anticipation in it. It turns out that, rather than testifying to a world entirely outside experience, surprise is one of the fundamental assumptions of the dynamics of first-person experience. There is no need to assume a world radically external to the experience we have of it. Surprise is external only to the most limited dimension of the experience, made up of prejudices and rigidified expectations; or, if you will, it is external only to the most closely personal

aspect of experience. Here, we come back to Frischeisen-Köhler's intuition (§6), according to which what we call "the world" is entirely within experience, but an experience that expands beyond the peculiarity of mine and yours.

A few words for an epilogue

What can we conclude from these first orientations about the phenomenological constitution of quantum theory? We have seen that, if taken fully seriously, the agent's experience (in the sense of QBism) allows us, without too many difficulties, to reconstruct some crucial features of the objectivity promised by science. Thus, QBism reverses the ordinary relationship between science and experience. Instead of marginalizing lived experience, QBism makes it the radical starting point of the whole scientific enterprise. Instead of maintaining lived experience in the blind spot of the discourse of science (Bitbol 2002), it makes it a pivotal element of the scientific discourse. Once this reversal has been accomplished, nothing prevents one from reconstructing the dualistic self-representation of the task of science: the representation of a face-to-face between a subject (an agent), and an object given to her to elucidate. To achieve this reconstruction, it is simply necessary to give a new meaning to others, to the objects of the world, and to the world itself. But we have seen that this new meaning corresponds precisely to what the transcendental turn of Husserlian phenomenology made possible: founding any claim of transcendence in the radical immanence of present lived experience.

This remark is very promising for the future of our understanding of quantum mechanics. Grinbaum (2007) rightly pointed out that making sense of quantum mechanics may not require finding the "physical causes" of quantum behavior, but rather reconstructing its formalism on first principles bearing on experimental information. This should be all the more true that the first principles which allow the reconstruction dig deeper than experimental information (here, to pure present experience), and that the reconstruction concerns the minimal nucleus of the theory (here, the basic structure of observations and expectations). Such is the momentous contribution of QBism.

Bibliography

Adler S., "Why decoherence has not solved the measurement problem", *Studies in History and Philosophy of Science (part B),* 34, 135-142, 2003

Barbaras R., *L'appartenance : Vers une cosmologie phénoménologique,* Peeters, 2019

Bégout B., *Le concept d'ambiance,* Éditions du Seuil, 2021

Bell J., *Speakable and Unspeakable in Quantum Mechanics,* Cambridge University press, 1987

Berghofer, P. & H.A. Wiltsche, "Phenomenological Approaches to Physics: Mapping the Field", in H. Wiltsche & P. Berghofer (Eds.), *Phenomenological approaches to physics*, Springer, 2020

Bitbol M., “Some steps towards a transcendental deduction of quantum mechanics”, *Philosophia Naturalis,* 35, 253-280, 1998

Bitbol M., “Science as if situation mattered”, *Phenomenology and the Cognitive Science,* 1, 181-224, 2002

Bitbol M. & Luisi P-L., “Autopoiesis with or without cognition: defining life at its edge”, *Journal of the Royal Society Interface,* 1, 99-107, 2004

Bitbol M., P. Kerszberg & J. Petitot (eds.), *Constituting Objectivity: Transcendental Perspectives on Modern Physics,* Springer, 2009

Bitbol M., “The quantum structure of knowledge”, *Axiomathes,* 21, 357-371, 2011

Bitbol M., *Mécanique quantique, une introduction philosophique,* Flammarion, 1996a

Bitbol M., *Schrödinger’s Philosophy of Quantum Mechanics,* Kluwer, 1996b

Bitbol M., “Quantum mechanics as generalized theory of probability”, *Collapse,* 8, 87-121, 2014

Bitbol M., “A phenomenological ontology for physics: Merleau-Ponty and QBism”, in: H. Wiltsche & P. Berghofer (eds.), *Phenomenological Approaches to Physics,* Springer, 2020

Bitbol M., “Is the life-world reduction sufficient in quantum physics?”, *Continental Philosophy Review,* 54, 563-580, 2021

Bitbol M. and De la Tremblaye L., “QBism: an eco-phenomenology of quantum physics”, in H. Wiltsche & P. Berghofer (Eds.), *Phenomenological approaches to QBism*, To be published, 2022

Blouin P., *La phénoménologie comme manière de vivre,* Zeta Books, 2021

Bohm D. and Hiley B., *The Undivided Universe: An Ontological Interpretation of Quantum Theory,* Routledge, 1995

Brukner Č, “Facts are relative”, *Nature Physics,* 16, 1172-1174, 2020

Carnap R., “Carnap’s Intellectual Biography” in: P. A. Schilpp (ed.), *The Philosophy of Rudolf Carnap*, Open Court, 1963

Carnap R., *Logical Structure of the World,* University of California Press, 1967

Crease R. and J. Sares, “Interview with physicist Christopher Fuchs”, *Continental Philosophical Review*, 54, 541-561, 2021

Crease R., Kamins D. and Rubery P. (eds.), *Phenomenology of Quantum Mechanics,* Special Issue of *Continental Philosophy Review*, 54(4), 2021

Depraz N., *Transcendance et incarnation : Le statut de l’intersubjectivité comme altérité à soi chez Husserl,* Vrin, 1995

D’Ariano G.M., G. Chiribella, et P. Perinotti, *Quantum Theory from First Principles,* Cambridge University Press, 2017

DeBrota J., C. Fuchs and R. Schack, “Respecting one’s fellow: QBism’s analysis of Wigner’s friend”, *Foundations of Physics,* 50, 1859-1874, 2020

De la Tremblaye, L., “QBism from a Phenomenological Point of View: Husserl and QBism”, in H. Wiltsche & P. Berghofer (Eds.), *Phenomenological approaches to physics*. Synthese Library, Springer, 2020

Destouches-Février P., *La structure des théories physiques,* Presses Universitaires de France, 1951

Dumoncel, J.-C. et Weber M., *Whitehead, ou le Cosmos torrentiel*, Chromatika, 2010

Espagnat d', B., *Veiled Reality,* CRC Press, 2019

Frauchiger D. and Renner R., "Quantum theory cannot consistently describe the use of itself", *Nature Communications,* 9, 3711, 2018

French S., "From a Lost History to a New Future: Is a Phenomenological Approach to Quantum Physics Viable?", in H. Wiltsche & P. Berghofer (Eds.), *Phenomenological approaches to physics*, Springer, 2020

Friedman M., *Kant's Construction of Nature,* Cambridge University Press, 2013

Frischeisen-Köhler M., *Wissenschaft und Wirklichkeit*, Teubner, 1912

Friston K., Kilner J., Harrison, L., "A free energy principle for the brain", *Journal of Physiology,* 100, 70-87, 2006

Fuchs C., "QBism, the perimeter of Quantum Bayesianism", arXiv:1003.5209v1 [quant-ph], 2010

Fuchs C., *My Struggles with the Block Universe,* arXiv:1405.2390v2 [quant-ph], 2015

Fuchs C., "On participatory realism", In: Durham, I.T. & Rickles, D. (eds.), *Information and Interaction: Eddington, Wheeler, and the Limits of Knowledge,* Springer, 2017

Fuchs, C. *Notwithstanding Bohr, the Reasons for QBism,* arXiv:1705.03483v2 [quant-ph], 2018

Fuchs C. & A. Peres, "Quantum theory needs no interpretation", *Physics Today*, 70-71, March 2000

Fuchs C., N.D. Mermin, & R. Schack, "An introduction to QBism with an application to the locality of quantum mechanics", *American Journal of Physics,* 82, 749-754, 2014

Fuchs C. & B. Stacey, "QBians do not exist", arXiv:2012.14375v1 [quant-ph], 2020

Goodman N., *The structure of Appearance,* Reidel, 1977

Granger G.-G., "Le problème de la 'construction logique du monde'", *Revue Internationale de Philosophie,* 37, 144/145 (1/2), 5-36, 1983

Grinbaum A., "Elements of information-theoretic derivation of the formalism of quantum theory", *International Journal of Quantum Information,* 1, 289-300, 2003

Grinbaum A., "Reconstruction of quantum theory", *The British Journal for the Philosophy of Science,* 58, 387-408, 2007

Hardy L., "Quantum theory from five reasonable axioms", arXiv:quant-ph/00101012, 2000

Healey R., *The Quantum Revolution in Philosophy,* Oxford University Press, 2017

Heelan P.A. "The phenomenological role of consciousness in measurement", *Mind and Matter,* 2, 61-84

Heisenberg W., "Quantum-theoretical reinterpretation of kinematic and mechanical relations", in: B.L. Van der Waerden (ed.), *Sources of Quantum Mechanics,* Dover, 1968

Heidegger M., *Being and Time,* SCM editions, 1962

Höhn P.A. & C.S.P. Wever, "Quantum theory from questions", *Physical Review A,* 95, 012102, 2017

Husserl E., *Cartesian Meditations,* Martinus Nijhoff, 1960

Husserl E., *Leçons pour une phénoménologie de la conscience intime du temps,* Presses Universitaires de France, 1964 [1905]

Husserl E., *The Idea of Phenomenology,* Martinus Nijhoff, 1973

Husserl E., *Recherches phénoménologiques pour la constitution (Idées directrices pour une phénoménologie et une philosophie phénoménologique pures, livre second),* Presses Universitaires de France, 1982

Husserl E., *Ideas Pertaining to a Pure phenomenology and to a phenomenological philosophy,* Martinus Nijhoff, 1983

Husserl E., *The Crisis of European Sciences and Transcendental Phenomenology: An Introduction to Phenomenological Philosophy,* Northwestern University Press, 1989

Husserl, E. *Sur l'intersubjectivité*, Presses Universitaires de France, 2001 [1930]

Joos E., "Elements of environmental decoherence". In P. Blanchard, D. Giulini, E. Joos, C. Kiefer, I.-O. Stamatescu (Eds.), *Decoherence: Theoretical, experimental, and conceptual problems,* Springer, 1999

Kant I., *Critique of Pure Reason,* Cambridge University Press, 2013

Kauark-Leite P., *Théorie Quantique et philosophie transcendantale,* Hermann, 2012

London, F. and Bauer, E. *La Théorie de L'Observation en Mécanique Quantique,* Hermann, 1939

Martin-Dussaud P., Rovelli C., Zalamea F., "The notion of locality in relational quantum mechanics", *Foundations of Physics,* 49, 96-106, 2019

Maturana & Varela, *Autopoiesis and Cognition*, Kluwer, 1991

Merleau-Ponty M., *Le visible et l'invisible,* Gallimard, 1964

Mermin N.D., "QBism as CBism: solving the problem of the Now", https://arxiv.org/abs/1312.7825v1, 2013

Mermin N.D., "QBism: Physics puts the scientist back into science", *Nature,* 507, 421-423, 2014

Mermin N. D., "Making better sense of quantum mechanics", *Reports on Progress in Physics*, 82, 012002, 2018

Mittelstaedt P., *The Interpretation of Quantum Mechanics and the Measurement Process,* Cambridge University Press, 1998

Mittelstaedt P., *Rational Reconstructions of Modern Physics*, Springer, 2011

Norsen T., "Quantum solipsism and non-locality". In: M. Bell & S. Gao (eds.), Quantum Nonlocality and Reality, Cambridge University Press, 2016

Patočka J., *Introduction à la phénoménologie de Husserl,* Jérôme Millon, 1993

Peres A., *Quantum Theory: Concepts and Methods,* Springer, 1995

Peres A. and Zurek W.H., "Is quantum theory universally valid?", *American Journal of Physics,* 50, 807-810, 1982

Petitot J., “Morphological eidetics for a phenomenology of perception”, in: J. Petitot, F. Varela, J.M. Roy and B. Pachoud (eds.), *Naturalizing Phenomenology,* Stanford University Press, 1999

Pienaar J., “Extending the agent in QBism”, *Foundations of Physics,* 50, 1894-1920, 2020

Poincaré H., *La valeur de la science,* Flammarion, 1905

Pradelle D., “La constitution des idéalités est-elle une creation ?”, *Les Études Philosophiques,* 85, 227-251, 2008

Pringe H., *Critique of the Quantum Power of Judgment,* De Gruyter, 2007

Reichenbach H., *The Theory of Relativity and A Priori Knowledge*, University of California Press, 1965

Rovelli C., “Relational quantum mechanics”, *International Journal of Theoretical Physics,* 35, 1637-1678, 1996

Schwinger J., *Quantum Mechanics: A Symbolism of Atomic Measurements,* Springer, 2001

Serban C., *Phénoménologie de la possibilité,* Presses Universitaires de France, 2016

Smerlak M. and Rovelli C., “Relational EPR”, *Foundations of Physics* 37, 427-445, 2007

Staiti A., “Max Frischeisen-Köhler’s Vindication of the Material Component of Cognition”, *Philosophia Scientiae,* 20, 119-142, 2016

Von Neumann, J., *Mathematical foundations of Quantum Mechanics,* Princeton University Press, 1955

Wallace D., “Decoherence and its role in the modern measurement problem”, *Philosophical Transactions of the Royal society A,* 370, 4576-4593

Whitehead A.N., *Process and Reality*. *An essay in Cosmology*, Gifford Lectures 1927-1928, McMillan, 1929

Wiltsche H. and Berghofer P. (eds.), *Phenomenological approaches to physics*, Springer, 2020

Zahavi D., “Réduction et constitution dans la phénoménologie du dernier Husserl”, *Philosophiques,* 20, 363-381, 1993

Zwirn H., “The measurement problem: decoherence and convivial solipsism”, *Foundations of Physics,* 46, 635-667, 2016