On Physics, Metaphysics, and Metametaphysics

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Abstract: Nonrelativistic quantum mechanics (QM) works perfectly well for all practical purposes. However once one admits that a successful scientific theory is supposed not only to make predictions but also to tell us a story about the world in which we live, a philosophical problem emerges: in the specific case of QM, it is not possible to associate with the theory a unique scientific image of the world; there are *several* images. The fact that the theory may be compatible with distinct ontologies, and that those ontologies may themselves be associated with a plurality of metaphysical approaches, gives rise to the problem of metaphysical underdetermination. This paper concludes that the available metametaphysical criteria fail to deliver objectivity in theory choice, and it puts forward its own criterion based on a tension between two methods of metaphysical inquiry: one that is closely related to science and another that is not.

Keywords: metaphysics, metametaphysics, ontology, quantum mechanics, theory choice.

1. Introduction: Underdetermination, Ontology, and Metaphysics

Let us get straight to the facts: nonrelativistic quantum mechanics (QM), in its standard formulations (precisely, Hilbert-space formulations), is *compatible* with several distinct interpretations, and QM alone does not help us to objectively choose one of them as the correct one.[1] Moreover, while each of those interpretations provides for general guidelines as to the furniture of the world, they generate even more trouble by being—each of them—compatible, in their turn, with a different set of metaphysical profiles. In other words, it is possible to provide distinct metaphysical approaches to each of the possible furnitures or *ontologies* provided by the interpretations.

To sum up, our situation is as follows: we have a scientific theory that populates the world differently (that is, with different ontologies), according to the interpretation chosen, and each interpretation, in its turn, may be compatible with a multiplicity of metaphysical views, depending on the approach to metaphysics chosen. It is far from clear how QM may help us cut down the proliferating number of options. This problem may be seen as part of a fairly familiar phenomenon called "metaphysical underdetermination," and this is a worry that concerns the naturalistically oriented scientific realist, to whom QM is expected to tell a *single* story about the furniture of the actual world in

[1] Of course, there is an issue on whether some interpretations are not really distinct theories. For instance, Ćirković (2005) argues against that point, showing that we have possible ways of empirically distinguishing between some of the so-called "interpretations" of QM, in a way that they should be called "quantum *theories*" instead of interpretations of a unitary QM. We shall not pursue this issue here, and nothing of what we shall say depends on deciding that question.

which we live.[2] Notice that the source of the problem is directly related to interpretation. But why do scientific theories need to be interpreted? In the case of QM, the most straightforward answer is: *measurement*. The description of how measurement works in QM seems to require a process that appears to be at odds with the whole theory, having neither an intuitive nor a natural place in the world and not being clearly accounted for by the dynamic processes described by the theory—and this is, roughly, the so-called *measurement problem*. Dealing with such a problem is a task left for *interpretations*. And, as Sklar remarkably pointed out, this is not to be taken as an imperative from philosophers alone: "The demand for interpretation [of QM] arises within theoretical science" (2010, 1124). Scientists who aspire to develop a *scientific image* of the world rely on interpretation—and, as a consequence, on *ontology and metaphysics*. As a result, they are caught up in the underdetermination problem too.

In order to put the problem clearly, let us take a rough characterization of the word "interpretation" in this context, as given by van Fraassen (1991, 242, 336–37): an interpretation of a scientific theory tells us "what the world is like" modulo such theory. (We use "modulo" in the sense of being attached to a specific scientific theory, and not universally.) This characterization seems to lead directly to a kind of "naturalist" stance toward ontology and metaphysics if we regard it to be the theoretical view that attributes to science the task of answering what there is and what the world is like. In this sense, an interpretation of QM (ideally) enables us to "extract" a scientific image of the world, thus playing a nontrivial role in scientifically informed metaphysics. That sounds really tempting, and things would be really simple if there were a single picture of the world modulo QM: if we could really somehow extract an interpretation from the theory, then the metaphysician's job would be done—the world is just as QM says it is. And we would totally agree with Maudlin's naturalist claim: "Evidence for what exists, at least in the physical world, is provided solely by empirical research. Hence the proper object of most metaphysics is the careful analysis of our best scientific theories (and especially of fundamental physical theories) with the goal of determining what they imply about the constitution of the physical world" (2007, 104).

But unfortunately, things are not that simple with QM: there are *several scientific images compatible with QM*, as many as there are interpretations of QM. This is a result of the fact that interpretations operate fundamentally with non-testable statements, talking about unobservable entities and processes; to properly evaluate them, we must inquire about the evaluation of ontological and metaphysical theories. Without this inquiry, we don't have the necessary elements to adhere to a particular scientific image of the world, inasmuch as there are different interpretations positing different entities, and the theories, with those interpretations added, cannot be simultaneously true in any sense of truth interesting to the realist. As Sklar (2010, 1123) has already stressed, metaphysical underdetermination in QM implies that "[o]ur foundational theories usually exist in a scientific framework in which they are subject to multiple, apparently incompatible, interpretations. And given the interpretation you pick, your view of what the theory is telling us about the basic structure of the world can be radically unlike that of someone who opts for a different interpretation of the theory" (2010, 1123).

[2] We shall not concern ourselves here with the so-called *instrumentalist* or the *working physicist* and other *For All Practical Purposes* approaches to QM ruled by the maxim "shut up and calculate!" for which the effort to interpret QM, in the sense of assigning to it something like a "worldview," is meaningless (Mermin 2004).

As a result, we find ourselves in the scenario we described at the beginning: QM is an invaluable source of empirical results, but as a guide to what there is and how those entities look like, it just falls prey to different forms of underdetermination. Given that the mathematical story told by QM alone is unable to break underdetermination, in this paper we suggest bringing the required metaphysical spin to the discussion. Leaving naturalistic concerns aside, we inquire whether metaphysics, as a philosophical discipline, could help us to better understand this general framework of metaphysical underdetermination entailed in the efforts of interpreting QM. In order to do so, we advance a distinction between metaphysics and ontology, as well as some claims concerning their interrelationships. This approach provides two kinds of possible ways metaphysics may help QM, from a methodological point of view: it is possible to discard some metaphysical views associated with interpretations based on quantum mechanical reasons, or, when that fails, interpretations based on metaphysical reasons.

Such a distinction between ontology and metaphysics is not standard, but it is becoming more widespread, so the relation between these two concepts is now less vague than it was before—although many authors use them interchangeably. Following recent literature on the subject, such as Arenhart 2012 and 2019, Berto and Plebani 2015, and Tahko 2015, we understand the task of the concept "ontology" as providing a kind of *catalogue* of the furniture of the world (answering the question: What are the entities that make up the furniture of the world?), whereas the concept "metaphysics" is, among other things, the *theorizing* on a corresponding story about such furniture (whether its entities have properties or not, how they relate or not to each other, but mainly to offer answers to "What are those things that exist?"). On this view, "metaphysics" has the broader sense of the two, and "ontology" is a branch of "metaphysics."[3] A way to address these matters is through Steven French's (2014) "Viking approach to metaphysics," which depends on what he calls "Chakravartty's challenge." The challenge states that scientific theories actually *need* some level of metaphysical description of the entities to which they have an ontological commitment (in a Quinean sense) in order to claim scientific realism about them. So, if QM fails to give a metaphysical account of what a scientific realist is inviting us to be a realist about, then such realism is empty (that is, it is like an empiricist attitude in disguise). So, the Viking approach to metaphysics is a way around Chakravartty's challenge: metaphysical theories are encouraged to flourish for the scientist's plundering; in this way, a scientific realist may pick whatever metaphysical theory is already available in the metaphysics literature, in order to give us a *metaphysical profile* of the entities in the theory's ontology, thus adding substantial content to the scientific theory's realism. QM enters the scene as providing more than one ontology, which may be compatible with more than one metaphysical profile.

Obviously, it is impossible to fully break the underdetermination, insofar as a solution to ontological underdetermination depends on a theoretical choice in the domain of physics, but at least we can limit the range of metaphysical options—assuming French's (2014) view: that is, Chakravartty's challenge and the Viking approach to metaphysics. This provides a relation between science and metaphysics that does not need to appeal to intuitions, and that in some cases may somehow benefit from the epistemic privileges attributed to QM, which seems to have a reliable source of epistemic

[3] It should be clear that we are not defending such a distinction but assuming it as a working hypothesis insofar as it matches the current debate in the literature (French 2014).

justification—if compared to contemporary analytic metaphysics taken by itself (Ladyman and Ross 2007).

The overall structure of the paper is as follows. In section 2, we briefly recall the measurement problem and advance two interpretations to serve as test cases for metaphysical methodology. In section 3, we discuss two methodologies that could help us settle the question of which interpretation and which metaphysics to choose. In section 4 we advance our own proposal. As we mentioned, it seems to be the one that better applies the resources of scientific theory in metaphysical theory choice. We present our final remarks in section 5.

2. The Problems in a Nutshell

Let us begin with the measurement problem. This is the source of the need for interpretations, which, in their turn, span a wide array of possible ontological and metaphysical theories, generating underdetermination.

There are many ways to state the measurement problem. Perhaps the most intuitive (and rather cruel) way to see it is through the thought experiment made famous by Schrödinger in his "Schrödinger's cat" scenario. Consider the following situation. Suppose that we lock up in a box the following elements: a cat, a flask of venom, a hammer, and a quantum system. After one hour, the quantum system $|\psi\rangle$ has equal probabilities of decaying or not, causing two distinct possible chains of effects:

(a) If the quantum system decays, the flask is broken by the hammer, and the cat dies. Its vectorial representation is $|\psi_{\uparrow}\rangle$.

(b) If the quantum system *does not* decay, the hammer stands still, the flask remains intact, and the cat remains alive. Its vectorial representation is $|\psi_{\downarrow}\rangle$.

The vectors presented here are mere simplifications of a much more complex mathematical description. By simplifying it, we gain in clarity what we lose in details. What is at stake is the fact that each possible chain of effects, if actual, excludes the other. After one hour, QM describes the state of affairs involving the cat inside the box as a linear combination of the two possible outcomes for the fate of the cat, being $|\psi_{\uparrow}\rangle$ for the case in which the cat remains alive and $|\psi_{\downarrow}\rangle$ for the case in which the cat dies, so the sum is:

$$\sqrt{1/2}\,(|\psi_{\uparrow}\rangle + |\psi_{\downarrow}\rangle) \qquad (1)$$

This result does not describe a possible measurement outcome but rather describes a linear combination of state vectors for possible measurement outcomes. In order to find the cat in a determinate state, one must open the box (which is the metaphor for the act of "performing a measurement"), and so the quantum-mechanical description of the cat changes from the vector sum to $|\psi_{\uparrow}\rangle$ or $|\psi_{\downarrow}\rangle$, with equal probability, that is, $|\psi_{\uparrow}|^2 = |\psi_{\downarrow}|^2 = 0{,}5 = 50\%$. One may naturally wonder about *what exactly happened* to make the description change from a vector sum to a single-state description (called an eigenvector). And as soon as one begins with this kind of inquiry, one enters into the realm of the interpretation of QM.

The standard textbook approach to the measurement problem is as follows. While undisturbed, quantum systems evolve in time according to the Schrödinger equation, a linear and deterministic equation which implies that, if the eigenvector $|\psi_1\rangle$ evolves to $|\psi'_1\rangle$ and the eigenvector $|\psi_2\rangle$ evolves to $|\psi'_2\rangle$, then $|\psi_1\rangle + |\psi_2\rangle$ evolves to $a|\psi'_1\rangle + b|\psi'_2\rangle$. Because the latter equation is not an eigenvector, it is posited that when a measurement is effected, it collapses to one of its eigenvectors (say, $|\psi'_1\rangle$), in the form of $a|\psi'_1\rangle + b|\psi'_2\rangle \rightarrow |\psi'_1\rangle$.

And then the problem turns out to be that of assigning meaning to this change in the description, which seems to be an unnatural process, sometimes even called a *deus ex machina* or a "Humean miracle" (Ruetsche 2002, 209), that is not governed by the Schrödinger equation—again, this is the domain of the *interpreter* of QM.

There are many distinct possible interpretations, but to illustrate the metametaphysical point that we wish to stress in this paper, we shall be concerned here with only two among such interpretations:

1. The *Consciousness Causes Collapse Hypothesis* (CCCH), put forward mainly by Wigner (1961, in 1983).
2. The *Many Worlds Interpretation* (MWI), put forward mainly by DeWitt (1970; 1971).[4]

The choice of these interpretations for a case study is based on the clear differences of the ontological theses entailed by them: whereas the former is committed to the idea that human consciousness has some kind of privileged reality and exerts a causal role in quantum measurement, the latter is committed to the idea of actual splitting of worlds and to the existence of a plurality of physical worlds, all of them equally real. As a disclaimer, it is worth mentioning that we will *not* engage the debate about whether those are reliable options to interpret QM based on theoretical standards, such as whether QM *needs* consciousness, as in the CCCH, or whether the decoherence-based MWI approach to the measurement problem actually solves it. That is not our point here. Rather, our goal in this paper is a *methodological* one: how to evaluate metaphysical theses in the case of metaphysical underdetermination. To this end, we proceed *conditionally*: *if* both the CCCH and the MWI are available options in the efforts of interpreting QM, *then* the methodological discussion developed here is sensible for solving the problem of determining the relationship between metaphysics, ontology, and science. That is, we are not committed to the truth or adequacy of these interpretations, we are just assuming that they are plausible candidates, in order to illustrate the methodological point that is the main target of this paper. Once we have established that point, we attempt an overview these interpretations of QM schematically.

In the CCCH Wigner's (1961) reasoning is simply put as follows:

1. Assuming that QM holds for *all* physical systems, the attachment of a macroscopic measurement wouldn't be enough to bring a measurement outcome about, because it must obey the linear evolution predicted by the Schrödinger equation.

[4] There are controversies that von Neumann (1955) actually endorsed CCCH (see Bueno 2019) and that Everett (1957) endorsed MWI (see Conroy 2012), even though it is a fairly common association. In order to avoid possible misunderstandings, we can safely attribute these theses to Wigner (1961) and DeWitt (1970; 1971) respectively.

2. And this must be true for all further measuring apparatuses that one could in principle attach to the first.
3. Moreover, this should also hold for the experimenter's eye, its optical nerve, and its brain, but this chain must stop somewhere.
4. The CCCH's hypothesis is that the *consciousness* of the observer causes the superposition dynamics to collapse in a single-state description, as it is not subject to the laws of QM.[5]

In the MWI, the crux of DeWitt's (1970; 1971) reasoning is:

1. Assuming the universal validity of the Schrödinger equation, the superposition is taken literally: both terms in equation (1) are *equally real*.
2. To the MWI, the world branches itself into each possible outcome of a superposition. If we find, say, a live cat in the box as a measurement outcome, then we happen to live in this branch of the world—the dead cat still exists in another branch of the world, where such measurement outcome is simultaneously found.
3. Then, although the collapse is apparently happening (insofar as we don't actually get to *see* a superposition), it is not *really* going on—what in fact happened is the branching of the world in two, and those branches don't communicate with each other.

In terms of ontology, the catalogue of what exists, we can populate the world with two distinct kinds of being based on what each interpretation says.[6] So, from the ontological point of view, on the one hand, to the CCCH, human consciousness is real—it is not an epiphenomenon—and it plays a causal role in the quantum measurement process (and it says nothing about the existence of multiple worlds); on the other hand, to MWI, the world branching is real—it is not a merely logical, counterfactual possibility—and it is causal in the quantum measurement process (it says nothing about consciousness). In this sense, we have an *ontological underdetermination* in QM. This is literally all that we can *extract* from both the CCCH and the MWI.

At this point, one may ask: "But does QM entail that there are multiple worlds?" or "Does QM entail that our consciousnesses act upon matter?" To which we must answer: "We don't know." QM does not provide an answer. In fact, QM cannot be said to entail such facts about interpretations, given that

[5] This thesis is usually attributed to von Neumann (1955). Although the term "consciousness" isn't mentioned by von Neumann, it is almost unanimous that he refers to the *consciousness* of the observer when he enunciates the causal feature of the "subjective perception" of the observer in the famous "temperature example" (von Neumann 1955, 418–20). The main historical motivation for this interpretation, according to Jammer (1974, 480), is the series of long conversations that von Neumann (1955, 208, n.) had with Szilárd, who had published a study on the intervention of intelligent beings in a thermodynamic system. As Jammer states, Szilárd's study has "marked the beginning of certain thought-provoking speculations about the effect of a physical intervention of mind on matter and thus paved the way toward von Neumann's far-reaching contention that it is impossible to formulate a complete and consistent theory of quantum mechanical measurement without reference to human consciousness" (1974, 480). A critical discussion on this subject can be found in Bueno 2019.

[6] There is no clear and definitive metaontological method of *extracting* some kind of *catalogue* of the furniture of the world modulo an interpretation of QM, but we assume as a working hypothesis in this paper that any such method would agree with this part of the catalogue in the case of these examples.

those interpretations are being added as a further theoretical layer to QM in order to make sense of the theory (in order to tell us a story about the physical world that suits the mathematical description). The CCCH and the MWI cannot be both true in the sense of correspondence with the world, so they are *competing* interpretations of QM. And since both the CCCH and the MWI interpretations of QM differ without our being able to provide (at the moment) experiments to distinguish them, QM alone seems to give us no clue as to which is to be preferred. This is ontological underdetermination in a nutshell. But the problem gets worse.

Recall that Chakravartty's challenge demanded that we should provide a clear understanding of the entities we are being realists about. Doing so meant, according to French, that a realist cannot evade the responsibility of providing a metaphysical profile for those entities. The problem is that once an ontology is assumed, there is not only one metaphysical profile to be added to it. In terms of metaphysics, each of the two ontologically different *catalogues* can be associated with at least two different metaphysical theses. On the one hand, the CCCH is compatible with a dualist metaphysics, inasmuch as it regards consciousness and the physical processes as lying in different ontological domains of reality, thus obeying different dynamic laws (Albert 1992). That is not, however, the only way to understand the role of consciousness in QM. For an alternative, London and Bauer (1983) present a *phenomenological* account of the CCCH (see also French 2002; 2020 and Arroyo and Nunes Filho 2018 for details), which is a different metaphysics within the same ontological commitment to a causal consciousness. So, the same ontology of consciousness is compatible with distinct metaphysical dressings of the ontological posits. The same holds for the MWI. In fact, the MWI seems to require a form of metaphysical realism for possible worlds, the idea that *there are indeed* parallel worlds, physically real, in some sort of modal realism. But the MWI can be understood in several metaphysical ways other than the typical modal realist way (see Bub 1999 for other metaphysical accounts of the MWI). Again, the splitting-worlds ontology may be metaphysically understood in incompatible ways. This is a familiar worry, which is metaphysical underdetermination: we are presented with two empirically equivalent and rival metaphysical theories for interpreting QM.

Given that QM is silent about which interpretations (and consequently, which ontology and which metaphysics) to adopt, what are we to do? This is clearly a question of theory choice involving not only physics but also ontology and metaphysics. It is here that philosophical theses step in. Debates on metametaphysics addressing the issue of theory choice in metaphysics could be, perhaps, of some help.

3. Evaluating Interpretations

We have roughly characterized the naturalist stance as saying that metaphysical and ontological questions should be settled by science alone. As a rejoinder, we have argued that science is compatible with distinct ontological *outputs*, which must be further extended to distinct metaphysical theses to come up with different images of the world. So, it seems that a radical naturalistic stance toward metaphysics is quite problematic and does not give us a way around metaphysical underdetermination.

So the first metametaphysical question that we should answer is the following: *What kind* of features concerning theory choice in metaphysics could, at least in principle, help us in thinning the

number of possible interpretations? There are at least two obvious contenders, and we can define them according to their degree of proximity to the empirical results (see Chakravartty 2013) obtained from QM: an *appeal to science*, according to which we can extract our ontology exclusively from scientific theories; and an *appeal to metaphysics*, for which we do not need to take into account empirical results in order to inquire about the world as a whole. These two contrary radical stances seem to lead us to a dilemma, as French indicates: "[E]ither the metaphysics floats free of the physics and requires justification itself; or it is continuous with the physics but then it can't actually break the underdetermination" (2011, 210). If we are not to stick with QM solely in our metaphysical investigations, how far from it can we go? We think our suggestion provides for a first approximation to answering that question. But before presenting it, let us consider two alternative approaches.

3.1 Beauty Is the Key

As we are dealing with the evaluation of metaphysical theses, it is perhaps convenient to start an inquiry by questioning *when* to do so. For instance, if two metaphysical theses are *equivalent* in some sense, then perhaps we do not need to make a choice between them: the debate, in this case, is merely *verbal*, not substantial. To the best of our knowledge, to date the CCCH and the MWI are *empirically equivalent* (see Allori 2015; Lewis 2016; de Barros and Oas 2017), in the sense that they both lead to the same set of empirical results (for example, they both take into account the same models of data; see Suppes 2002). But are they *metaphysically* equivalent? We shall take into account the recent metametaphysical methodology advanced by Benovsky (2016) in our discussion in order to try to settle this fundamental question.

Benovsky (2013; 2016, chaps. 1 and 4) argues for a notion of metaphysical equivalence based on the role of the *primitives* of the metaphysical theories at stake: if the primitives of theory T and the primitives of theory T' are the same, then the difference between T and T' is not substantial. What individuates such primitives is the theoretical roles they play in these theories (that is, the kind of functional approach to the individuation of primitives), and primitives come into play as problem-solvers: whenever a metaphysician meets a problem, he or she can solve them by positing primitives and relations between such primitives. Benovsky (2016, 66) himself warns us that his functional criterion for the individuation of metaphysical theses may be somehow vague, and as metaphysicians we should carefully analyze each case—which we shall do in the two cases of interpreting QM that we have selected. One of his arguments is that even the so-called *content view* of individuation, as opposed to the functional view, is reducible to the latter in the sense that if two primitives differ due to their content, it is so *because* they do not play the same functional role. So let us apply Benovsky's account of metaphysical equivalence (2013; 2016, chap. 4) to our selected cases of interpretation of QM: the CCCH and the MWI.

As we mentioned earlier, the interpretations of QM operate on a non-testable level; moreover, they come into play largely in response to the measurement problem. So it seems safe to consider their ontological aspects as *primitives*: whereas "consciousness" is a primitive entity of the CCCH, parallel

worlds are primitive entities of the MWI.[7] Obviously, the interpretations may be compatible with a common core ontology also involving particles, waves, space, and time, but we shall leave the uncontroversial part aside.

Both interpretations use primitive notions to act as problem-solvers for the measurement problem in the sense that *these solutions cannot be analyzed in the framework of the theory*. Let us exemplify these matters schematically as follows. Question: *What happens during a measurement process?*

> CCCH: Postulates the action of an arbitrary observer's subjective consciousness, from a separated ontological domain, that collapses the superposition of states in a single-state description.
> MWI: Postulates the world-branching process, in which the two states in superposition literally occur, each in different ontological domains (different parallel, physically real, worlds) that do not interact with each other.

If we investigate the functions and the details of each ontology, along general lines, it seems that they will not end up equivalent. Consider once again the dualist metaphysical approach to the CCCH: according to it, there is a real consciousness in the world (and only one world so far as we can extract our ontology from what the theory is telling us about our world). Moreover, the process by which this primitive operates has a mathematical counterpart in the theory: the *collapse*. Consciousness *causes* the collapse. On the other hand, now consider the MWI: according to it, there is *more than one* real world—probably *way more* than one—and consciousness has no privileged role in it, if, again, we are to determine *what there is* judging solely from QM. Moreover, by virtue of the process by which the MWI's primitives operate, there is also a mathematical consequence in the formalism: there is no collapse. In the MWI, all the terms of a superposition are actual, each one in its corresponding world. So their primitives are distinct by virtue of the process by which they operate. The metaphysical differences between the CCCH and the MWI seem to be, then, more than verbal: there are substantial differences in the primitives that they postulate, and so they are not *metaphysically equivalent* in Benovsky's sense (2013; 2016, chap. 1 and 4). As employed by Benovsky (2013; 2016), the term "metaphysics" is to be understood here, in our distinction, as "ontology." That is, the so-called "*metaphysical* equivalence" is then an "*ontological* equivalence."

And then ontological underdetermination strikes back (as if it never really left the scene). So far we have dealt with the ontological aspects of the selected interpretations of QM; but what about the metaphysical profiles *within* the CCCH and the MWI? Because both the CCCH and the MWI have, first, *ontological* differences, it is to be expected that they have metaphysical differences too. And then metaphysical underdetermination too strikes back. Could Benovsky's theory (2013; 2016) help us with that? Unfortunately, it seems that it cannot. In fact, Benovsky (2016, 70) himself acknowledges this: finding objective reasons for choosing one theory over another is not an easy goal to achieve; as for this positive proposal, he states: "I do not have a good answer to this question" (2016, 70) and then goes on to

[7] There are indeed authors who consider the many worlds to be *emergent*, rather than *fundamental*, entities (Wallace 2012, 3). Nevertheless, it is not clear in what sense a multiverse can be an emergent entity: one may still ask for its metaphysical profile in order to answer this question.

say that this choice must be grounded in aesthetic considerations because metaphysical theories are literally beautiful and we allegedly choose one over another based on its beauty. The problem in this metametaphysical view is precisely the lack of objectivity in theory choice.[8] One can *always* choose, say, a *less beautiful* metaphysical theory over another; indeed, we can imagine cases in which some people find more beauty in the CCCH than in the MWI—and vice versa. In fact, Benovsky concedes that such an aesthetic move is not objective at the end of the day: "[T]he evaluator's taste plays a role from the beginning to the very end of the evaluative process" (2016, 123).

Moreover, to objectively assess the dispute between metaphysical theses related to scientific theories, we might need something like "the whole picture"—what Benovsky (2016, 84) calls, the '"widen the net' criterion" (2016, 84). The plan is that one theory may perform better than another once the scope of the evaluation is widened to involve other theories or phenomena. One theory may be more easily generalizable than the other, or account for more disparate sets of phenomena, and, everything else being equal, should then be preferred. Interesting as it may be, this kind of advice seems somehow unhelpful to us, especially when we are working with the metaphysics of scientific theories. Currently, both of the theories seem to be fully equivalent. Perhaps in the future one of them will be more amenable to unified theories, but that is simply speculation on the future of science. All metaphysical inquiry related to scientific theories should be *as provisional as the scientific theories themselves*, so there seems to be no need to ask metaphysicians to wait until fundamental science achieves a final *theory of everything* (if there be such a thing at all) to begin their work with a scientifically informed metaphysics. Rather, the work of the metaphysician, when it is related to science, is to give an account that provides for a better understanding of the scientific(s) image(s) of the world that may be compatible with such a theory.

As an additional problem, even if we could reach agreement on which interpretation, with its accompanying metaphysics, is more beautiful, Benovsky's solution leaves the answer "floating free" from science. That is, the choice is not based on science, in any possible sense of the way that a metaphysics could relate to science. Any interpretation that could somehow have its admissibility lent by a scientific theory, indirectly as it may be, would have more credentials than a choice based on beauty. The main problem, then, is that this approach leaves just too much to be done by the metaphysician, and nothing by science. The choice is completely based on a first philosophy.

Well, perhaps our expectations are too high to be met: maybe it is more advisable to step back and try to focus on the *wrong* alternatives, rather than focusing on the right one to settle—momentarily—the issue.

That's where we're heading.

3.2. Epistemic Risk

We are trying to evaluate metaphysical theories to see whether there is—objectively—an alternative that

[8] As Benovsky (2016, 122) himself remarked, the alleged beauty of metaphysical theories is not an *additional* metametaphysical criterion but rather a *way of seeing* the nonaesthetic metametaphysical features that a metaphysical theory *already has*, such as internal consistency, explanatory power, and so on. We shall maintain this nomenclature nevertheless because aesthetic values are in fact being used in the process of (metaphysical) theory choice; it then seems odd that this notion escapes to the nomenclature of "metametaphysics."

fares *worse* than another in order to better understand metaphysical underdetermination in the interpretation of QM. Here we shall first analyze the general criterion of *simplicity* and subsequently the notion of "epistemic risk" recently proposed by Chakravartty (2017) to check whether these criteria can do the job. Spoiler alert: they can't. Let us see why, beginning with simplicity as a metametaphysical criterion to evaluate between rival metaphysical theses.

As the argument goes, we should prefer the *simpler* alternatives. This attitude toward metaphysics and ontology resembles the famous Ockham's razor, which, by itself, seems to be weightless in establishing a metametaphysical criterion to evaluate metaphysical theories—it has, at best, a heuristic value in evaluating *ontological* aspects of theories. As Parsons puts it: "There is no prima facie reason to suppose that the universe contains a small number of things, or a small number of kinds of things. There is no prima facie reason to believe that a theory that endorses a smaller number of things, or kinds of things, or employs a smaller number of primitives, is simpler or likelier to be true or likely to yield more insight than another" (1979, 660–61).

In short, simplicity is not related to truth, so it can hardly be an acceptable objective metametaphysical criterion in the evaluation of rival metaphysical theories. As Benovsky remarks, "[T]he requirement of parsimony and simplicity comes from *us* rather than from the metaphysical reality" (2016, 87) (just as beauty does, we could add). Therefore it seems safe to assume that simplicity is a criterion that should be dropped in this kind of inquiry.[9] So let us analyze the latest discussion of these matters in the recent literature.

Chakravartty (2017, §§ 3.4 and 3.5) recently presented the idea that somehow the *epistemic risk* of some metaphysical theories should guide the process of theory choice: roughly, the smaller our ability to assign a truth-value to a hypothesis, the greater its epistemic risk; such risk is increased when the hypothesis moves away from the empirical test and decreases the greater its explanatory power. Let us look more closely at this proposal to see whether it could allow us to decide between rival *metaphysical* theses.

As intended, epistemic risk should be applied to *metaphysical propositions* rather than to metaphysical theories. So, what is at stake here are such propositions as, in the case of the CCCH, "A causal act of subjective consciousness upon the measurement device is responsible for measurement outcomes."[10] When one is not in a position to judge whether a metaphysical proposition is true or false, such a proposition is epistemically risky (Chakravartty 2017, 84). And, again, as we are dealing with a *non-testable* field (that is, the *interpretation* of QM), such effort tends to be of high epistemic risk—and Chakravartty's norm is "the less epistemic risk the better" (2017, 85). As an alternative measure of epistemic risk, one might call upon a proposition's *explanatory power*, which basically claims that the higher the explanatory power, the lower its epistemic risk. Again, in the case of the selected interpretations of QM, this doesn't seem to differ—they both explain the measurement problem, albeit in different (and

[9] The same seems to apply to the *appeal to intuitions*, which is a metametaphysical criterion that states, roughly, that in cases of theory choice we should stick to the metaphysical theory that somehow better preserves our "intuitions." An example of this is Shimony's (1997) "phenomenological principle." We do not give an extensive account of this issue because, as we understand it, QM is not intuitive *at all*—so its corresponding metaphysical theory does not need to be either. Nevertheless, readers interested in a critical account of this particular metametaphysical criterion should consult Benovsky 2016, chap. 6.

[10] More precisely, the "measurement device" is the vector that represents the state of a measurement apparatus *entangled* with the vector that represents the state of a quantum system.

incompatible) ways. What they all *explain*, really, is the working of QM when a measurement is happening.

So it seems that even if we take the notion of epistemic risk to be our metametaphysical criterion to choose between the ontologies of the CCCH and the MWI, at the end of the day both interpretations seem to yield the same measure of epistemic risk. The same goes for their metaphysical profiles. As a result, in this case, such a criterion doesn't really help in our search for an objective way to evaluate these interpretations of QM. We remain stuck with both ontological *and* metaphysical underdetermination. Chakravartty's way to approach such a stalemate is *voluntarism*, the claim that "the relevant beliefs and actions are freely chosen, or voluntary, as opposed to being forced in virtue of reason alone" (2017, 215). So, no objective evaluation here. Again, the decision concerns *us*, not the world. But notice that it seems hard to recommend voluntarism when it is the very constitution of reality that is at stake.

Suppose that the metaphysical theses put forth by both the CCCH and the MWI *indeed* differ in their degree of epistemic risk: suppose that we are able to find out that, say, the CCCH has more epistemic risk than the MWI. Would that really help us to objectively evaluate them? Again: no. Think of a *diehard* proponent of, say, the CCCH: someone may always choose an alternative with greater epistemic risk than another (someone may be willing to take the risk!). Thus, degree of epistemic risk does not break metaphysical underdetermination. It seems that we find ourselves in a hard spot, but we'll make a last try.

4. An Interplay Between Two Parties

4.1 Metaphysics over Ontology

Here, we employ explicitly the distinction between ontology and metaphysics drawn throughout the previous sections. Regarding ontology, we shall also acknowledge two senses of the term: in its first sense, "ontology" is characterized by the investigation of *ontological categories*; it provides the most general ways to approach and classify existent beings and is closely related to what we call the *metaphysical dressing* or *profile* of entities; in a second sense, "ontology" is characterized by the investigation of the furniture of the world modulo some scientific theory in the sense of its ontological commitments. The first is said to be ontology in a *traditional* sense, and the second in a *naturalized* sense. Perhaps it would be more appropriate to follow Jacquette (2002) and call them "pure" and "applied" ontology, respectively, but it all depends on what naturalized ontology comes down to. To avoid possible misunderstandings grounded in terminological issues, let us proceed by calling the first sense of ontology (that is, the traditional or pure sense) a metaphysical profile.

At first sight, the metaphysical profile and the applied ontology may be taken as incompatible, because one may reasonably point out that the former is taken to be universal, prescriptive, and independent of the contingent empirical findings of any scientific theory (in French's (2011) terms, it is "floating free" from the empirical content), whereas the latter is descriptive and relative to a scientific theory (Arroyo and Arenhart forthcoming provides a detailed discussion). In fact, there is an ongoing debate with some authors arguing that contemporary philosophy should study exclusively the

metaphysical profile (see, for instance, Lowe 1998) and others exclusively the applied ontology—for which we can cite Ladyman and Ross (2007) as the best-known proponents. The novelty of our proposal (following Arenhart 2012) is precisely an attempted reconciliation between those two parties by establishing a middle ground with a scheme for a "scientifically oriented metaphysics."

The first step in such reconciliation is to acknowledge that the applied sense of ontology does not imply that the only existing things are those to which a given scientific theory is committed, because different theories may present different ontological commitments. In order to exemplify this claim, we argued previously that the CCCH and MWI approaches to QM fill this bill. The second step is to realize that the metaphysical profile studies a plurality of possible ways to understand these ontological outputs of the scientific theory; for example, it is possible to assign different metaphysical theses to each ontology extracted from, say, one interpretation of QM. Whereas studying the metaphysical profile of entities provides an investigation that accounts for what kinds of entities may possibly exist, the applied ontology accounts for the connection between those ontological categories with the actual ontological commitments that the empirical investigation of some specific scientific theory may present. In this way, when an ontologist endeavors to study the ontology associated with a scientific theory, both senses of "ontology" are in play—in our terminology, ontology and metaphysics—and both are complementary to each other.

This said, it comes as no surprise that a scientific theory alone does not provide an answer to the question of what kind of metaphysical profile would be more (or less) adequate to its interpretation's ontology, because this kind of discussion has to be carried out not within science but rather on a rather different ground, which is precisely the domain of metaphysics.[11] One way to narrow the field of possibilities entailed by underdetermination consists in recognizing that it is not the case that anything goes in the applied ontology: we may discover that some kinds of entities are not compatible with a scientific theory.

In this sense, *the applied sense of ontology could preclude some forms of metaphysical profile*. Notice that this is almost a paraphrase of Arenhart 2012 (354): "[O]ntology in the naturalized sense bans some form of ontology in its [traditional] sense." In some sense, we have updated such work with substantial terminological distinctions in order to better apply it to the discussion on the metaphysical underdetermination in QM, and to the relationship between science and metaphysics in general. As a classical example of this *negative feature* of applied ontology, we might recall Shimony's "experimental metaphysics," which considers some experiments (such as the experimental tests of Bell's Inequalities) to be "a near decisive test of those worldviews which are contrary to that of QM" (1984, 35–36); to Shimony this means that "the [empirical] evidence has narrowed the [metaphysical] choices" (44).[12] One may object that this may be a hasty move on our part and that a diehard metaphysician might not be convinced, given that there remains a lack of objectivity in metaphysical theory choice. If this is so, our positive proposal fails as badly as the other metametaphysical alternatives that we critically analyzed in the previous sections.

[11] As we have tried to make clear thus far, when we are dealing with the *interpretation* of a theory, such as QM, we are dealing also with elements that lie *outside* the structure of the theory itself (see Bueno 2011, 93)—even though this interpretative effort often emerges *within* the scientific community (Sklar 2010).

[12] For an account of several experiments in this field, see Aspect 2002.

At least in the theoretical and ontological domain, this seems to be the case. We seem to have advanced no good criterion for objectively choosing between the CCCH and the MWI as competing scientific and ontological theories. But recall Chakravartty's challenge: once we assume it—and we *are* assuming it as a working hypothesis—we must still fill the metaphysical profile gap in our ontology in order to know what it means to be a realist about, say, the CCCH or the MWI. And within such a *metaphysical* realm there seems to be a kind of objectivity at stake in the negative feedback resulting from the interplay between the applied ontology and the metaphysical profile. Let us take the methodology sketched above and apply it to the discussion that we analyzed in the previous sections to see whether we could provide a way of better understanding the matter of underdetermination in the selected examples for interpreting QM.

4.2 Ontology over Metaphysics

As we argued, in the CCCH approach to QM, consciousness is an entity that inhabits the furniture of the world: the CCCH is *ontologically committed* to consciousness—whatever it may be—in terms of a *metaphysical profile*. This is the best that one may infer about consciousness per the applied ontology. The metaphysical profile, then, comes as an *extra layer* that attempts to metaphysically dress this very entity called "consciousness." Traditionally, the metaphysical profile associated with consciousness in the CCCH is a form of dualism separating consciousness from matter (Wigner 1961). Alternatively, one may metaphysically dress consciousness in the CCCH with a phenomenological metaphysics (London and Bauer 1983). But if we consider the Viking approach, there are other metaphysical theories on the table when it comes to assigning a metaphysical profile to consciousness with already existing metaphysical theories for consciousness. To add just one more option to the Viking list, we can cite reductive physicalism—the thesis that everything, including consciousness, is physical or supervenes on the material domain of reality (Stoljar 2017).

At this point, we have a metaphysical underdetermination (of possible metaphysical profiles) *within* the CCCH's ontology.

So, the CCCH interpretation of QM is incompatible with several metaphysical frameworks in which consciousness is epiphenomenal and devoid of causal power—for example, materialistic accounts of consciousness, physicalist accounts of consciousness, and so on. In this sense, the ontology furnished by the interpretation of the theory one uses rules out some metaphysical options for our understanding of the world. Thus, the *applied* sense of ontology tells us that the CCCH is incompatible with physicalism as the metaphysical profile for the CCCH's consciousness; on the other hand, it is compatible with the metaphysical dressing of dualism and with phenomenology.[13] Something similar may be said for the MWI. Once it is posited that there is no collapse and that all of the terms present in a superposition are

[13] It may be that in some sense dualism is not a reliable metaphysical ingredient for framing the ontological categories. And when we go back to the scientific theory, it seems reasonable that we can discard the dualist metaphysical dressing of the CCCH in the *philosophical* ground based in its bad metaphysical profile—although, as de Barros and Oas (2017) stress, the attempts to falsify the CCCH on empirical grounds have been unsuccessful so far. But there are no objective reasons to do so: at best, we might evaluate the dualist metaphysical dressing only *subjectively*—by aesthetic standards (Benovsky 2016) or voluntarism (Chakravartty 2017). So, the dualist CCCH still remains an available option for interpreters of QM.

equally real when a measurement comes up, then we are invited to ontologically understand the resulting theory in which reality somehow branches—the branching processes of reality pop up in the catalogue of the world modulo MWI. In fact, according to this account, the terms in which a wave function is decomposed, representing a possible outcome of a measurement, each represent an alternative branch of reality. Some authors will choose to metaphysically dress them as possible worlds, all of them equally real, containing a copy of the whole world and of the measurement apparatus plus a determinate outcome (Lewis 2004). Others may dress those branches as distinct minds (the many minds interpretation, Lockwood 1989). To stick only with the worlds, in order to illustrate our approach to the relation between ontology and metaphysics, it is clear that metaphysically speaking there are many ways one may understand a plurality of worlds: just take all of them as equally real, as a form of realism, or through a fictional approach to possible worlds, where only the actual world is real, or through a combinatorial approach, where again only the actual world is real and provides the ingredients with which to assemble the possible worlds.

What our approach suggests is that by checking the relation of a branching ontology with those distinct metaphysical clothes, what results is that those who do not conceive of the many worlds as equally real fail to account for the lack of collapse. Indeed, if only *a single* measurement outcome is real, then the theory is just a collapse theory in disguise. So, accounts such as the fictional and the combinatorial approaches to worlds seem to be ruled out as deficient, to say the least, in this approach (a detailed investigation of this will be left for another occasion). The metaphysical possibilities are narrowed down by the choice of ontology (given by the branching interpretation) and by the attempts to make sense of the theory (due to the requirements for understanding a measurement through branching without collapse). It seems that even a Lewisian account of possible worlds would fail in this account, given that the branching must *create* the worlds, and that the resulting worlds must be copies of each other, with the whole setup differing in nothing but the measurement outcome. This is clearly not the case for the approach advocated by David Lewis, of course: although distinct worlds are all equally real, there is no creation of worlds; the worlds exist independently of measuring or branching processes. This, of course, seems to run counter to the idea of branching worlds. So, it is not *any* kind of realism about possible worlds that will do.

4.3 A Negative Approach to Metaphysics

To sum up, our proposed interplay goes like this:

Step I: Through applied ontology, we are able to identify the ontological commitments of an interpretation of a scientific theory and what the metaphysical profiles are that are compatible with such ontological commitments. In the cases that we selected as examples in QM, we found that the CCCH says that human consciousness is causally real; in the case of the MWI, the theory says that the many worlds must all be equally real.

Step II: We go outside scientific theories with those ontological theses obtained in the previous step and try to give a *metaphysical profile* to those entities: if the CCCH says that human consciousness is real, it may be metaphysically profiled as a dualist consciousness or as a phenomenological consciousness;

in the case of the MWI, if the many worlds are real, they may be metaphysically profiled as modal-realist worlds.

Step III: Returning to the domain of scientific theories, we check whether there is any theoretical restriction to those metaphysical profiles that were, at least in principle, compatible with the theory's ontology. This is the step in which we can now find a positive contribution: from the previous steps, we established the abandonment of some metaphysical theses attached to some scientific theories. We checked that physicalism, for instance, is ruled out by the CCCH. Of course, if for other reasons we discover that physicalism is true, then the CCCH is ruled out. For the case of the many worlds, we discovered that fictional accounts of possible worlds are ruled out by the MWI.

We may advance some of the discussion through table 1. It illustrates that a mathematical formalism may be compatible with a general guideline for ontology (an interpretation), which is perhaps as far as a naturalistic ontology may go (although this is still not clearly extracted from science), and that each ontology, in its turn, may be metaphysically dressed in distinct, incompatible ways. Some of these clothes are ruled out by science and the corresponding ontology.

Note that the basic formalism tells us a mathematical story. In order to have a physical story, an interpretation is added, where the measurement problem is addressed. Each interpretation, in our case, adds a further ingredient to the world: a causal role for consciousness, in the case of the CCCH; branching reality in the case of the MWI. Metaphysically, those ontologies may be understood in rather distinct terms. It is possible, however, to determine that some metaphysical approaches are in fact impossible according to the underlying scientific theory. As we commented, due to quantum-mechanical considerations, along with the proposed interpretations, materialistic approaches to consciousness are ruled out. They fail by providing the ingredients for a collapse to occur. In the case of the MWI, if we understand worlds without attributing all of the same ontological dignity, we again fail to account for the measurement problem. All of those possibilities are ruled out if we want to stick with QM. That is, their failure is objectively granted, as long as QM is the underlying theory.

Table 1 The metametaphysical picture.

Formalism	**Applied ontology**	**Metaphysics**
Collapse	Consciousness	Substance dualism
Collapse	Consciousness	Phenomenology
Collapse	Consciousness	Physicalism
No-collapse	Branching	Realism about worlds
No-collapse	Branching	Worlds as fiction
No-collapse	Branching	Lewisian worlds

Let us take a moment to repeat these claims. We argued that QM itself is not compatible with just any kind of metaphysical profile. In the case of the CCCH, the very possibility of metaphysically dressing

consciousness with physicalism is precluded, because consciousness (whatever it may be in terms of a metaphysical profile) must be causal, and therefore real. Decisions between dualism and phenomenology seem to be safe from this narrowing of metaphysical choices (see a discussion of this specific case in Arroyo and Arenhart 2019). In the case of the MWI, some metaphysical possibilities are ruled out by constraints of the interpretation itself, to which all branchings must be equally real—so, there seem to be precluded some metaphysical profiles such as fictionalism. A Lewisian (2004) account of possible worlds seems to be ruled out too with our metametaphysical criteria because one must account for the *creation* of parallel worlds in the act of branching, so the worlds cannot exist independently *before* the branching process.

At this point, what we have been able to do is to restrain the metaphysical profiles *inside* each interpretation of QM, with its own ontological commitments—that is, the metaphysical alternatives *within* the CCCH and those *within* the MWI—but not to evaluate between the CCCH and the MWI directly. But is that so? Consider for a moment the Viking approach to metaphysics, as espoused by French (2014). Roughly, it says that the scientifically informed metaphysician merely picks a metaphysical theory that is available in the literature in order to metaphysically dress the entities of scientific theories.

As a possible objection to our three-step proposal, one may state that the *ruling out* of some metaphysical profile is fairly obvious: for example, the CCCH requires that consciousness must be causal, and so metaphysical profiles that preclude causation by consciousness are ruled out right from the start; similarly, the MWI requires that the worlds must be real, and so metaphysical profiles that preclude the reality of other worlds are ruled out right from the start.

Yes, they are. But recall that metaphysical profiles that consider consciousness to be epiphenomenal, such as physicalism, and metaphysical profiles that deny other worlds' reality *are available at the Viking's table* for plundering. People use such metaphysical profiles all the time in philosophy and in science. At the end of the day, our proposal states that (i) you stick *either* with physicalism *or* with the CCCH. You cannot have both. Alternatively, (ii) you stick *either* with fictionalism *or* with MWI. You cannot have both.

5. Concluding Remarks

As a privileged form of access to the nature of the world, science should be a guide to answering the questions of not only what things there are but also how those things are. As we have seen, the naturalist has expectations of arriving at answers to those questions, somehow inferring them from science. However, in the case of QM at least, there is much interpretative work to be done if we are to determine an answer to those questions, and the interpretations always encompass ingredients that are extra-empirical, additions that cannot be judged on purely empirical grounds. As we have put the issue in this paper, distinct interpretations provide for general grounds with which to account for the population of the world.

The problem gets tougher when we discover that distinct interpretations provide only for the ontology, the catalogue of what there is. If we are to understand how those things are, we are already inquiring on a higher level, on the metaphysical profile of the posited entities. This investigation cannot be supplied by QM. QM might tell us, at best, how things *cannot be*—at least in metaphysical terms. Once

we notice that distinct metaphysical profiles are available for each interpretation, metaphysical underdetermination ensues. Naturalism is unable to deal with the situation, and so a spoonful of metaphysics is salutary here.

We have evaluated three metametaphysical methodologies in order to see what kind of help they provide us in trying to reduce the alternatives of the metaphysical underdetermination. What the three approaches in metametaphysics were unable to do is to break *ontological* underdetermination in the matters of interpreting QM. As a result, questions concerning *which interpretation one should adopt* could not be addressed. As we have seen, Benovsky's appeal to beauty leads to a form of anti-realism in metaphysics that is not conducive to the project of deriving a metaphysics of science, at least not for the realist perspective we are assuming as a hypothesis here. In fact, the whole goal of having metaphysics be engaged with science is precisely to try to benefit from the success of science in gaining objective knowledge of reality. Leaving things at the level of the subjective choice of the inquirer seems to give up the challenge too early.

Chakravartty's solution seems to provide better grounds for choice. While recommending that we should avoid epistemic risk, adopting theories that are more explanatory and closer to empirical confirmation, it seems to put metaphysics on the same track as science. That is not enough, however, to break metaphysical underdetermination. In fact, the metaphysical dressings are still able to multiply themselves, without clear criteria for us to discriminate between them according to their explanatory powers, and they are equally distant from empirical predictions that could allow us to attribute a truth-value to them. The solution advanced by Chakravartty in this case, voluntarism, is again an appeal to subjectivity. There is nothing to prevent one from choosing the riskiest theories, and nothing relating voluntarism to truth.

Perhaps the avoidance of epistemic risk could be wedded to our proposal, which consisted in investigating whether some of the metaphysical options could be ruled out on quantum-mechanical grounds. We have found that, in terms of the test cases we have addressed in this paper, the CCCH and the MWI, some metaphysical theories are clearly not compatible with QM. This provides for more objective grounds on which to reject some options. A careful investigation of the precise articulation between metaphysical theses and the ontologies provided by interpretations of QM may prove useful in order to cut down the number of options, and to do so in a rather objective way, benefiting from features of QM itself, not our subjective preferences, which we see as the most interesting advantage of such an approach.

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