

The powers of quantum mechanics: A metametaphysical discussion of the “logos approach”

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Abstract This paper presents and critically discusses the “logos approach to quantum mechanics” from the point of view of the current debates concerning the relation between metaphysics and science. Due to its alleged direct connection with quantum formalism, the logos approach presents itself as a better alternative for understanding quantum mechanics than other available views. However, we present metaphysical and methodological difficulties that seem to clearly point to a different conclusion: the logos approach is on an epistemic equal footing among alternative realist approaches to quantum mechanics.

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1 Introduction

Quantum mechanics (QM) presents to the philosopher a challenge that reaches the most basic level of understanding of any physical theory: to tell us what the theory is about, after all, and to do so in clear terms. After more than one hundred years of incredible theoretical and practical developments, there is still no consensus on what kind of entities quantum theory is about, and difficult challenges still plague with obstacles most of the attempted answers proposed so far. The natural attitude of describing the theory as dealing with objects of some kind (and what else could it be?), although still common, faces challenges due to the nature of superposition, to theorems such as the Kochen–Specker (KS), and the non-locality arising from a violation of Bell’s inequalities.

It may be tempting to claim that the answer to this question may be found in one of the many interpretations available for the theory (see Ruetsche, 2015; Dürr and Lazarovici, 2020). After all, an interpretation helps us populate the world with a plethora of entities that contribute to a proper understanding of what the world looks like according to it. It would seem reasonable, then, that anyone willing to be a realist about the theory should look for an interpretation, right? Indeed, this is a common strategy, but not everyone shares this point of view. In a variety of recent works, Christian de Ronde, along with collaborators, has advanced claims to the effect that quantum mechanics needs no interpretation, in the traditional sense of ‘interpretation’.¹ According to de Ronde, the furniture of the world according to the theory, and also, a proper understanding of the theory itself, may be achieved without the need of an interpretation, provided that we look closer to the theory and what would count as an appropriate conceptual scheme that accompanies it. By a kind of interplay between theory and conceptual framework, it is suggested, one can arrive at the proper conceptual scheme describing reality according to quantum mechanics. The resulting proposal is called the “logos approach” to quantum mechanics, which is based on a larger project called “representational realism”.

Such a proposal contains, at its core, the recommendation of a methodological change in how we approach such traditional problems, suggesting that we may reach an answer to the issue as to the subject matter of quantum mechanics by a combination of physics, mathematics, and philosophy (ontology and metaphysics), all engaged to provide a better understanding of reality, in a kind of investigation that was already pursued by the pre-Socratic philosophers, i.e., a search for the nature of reality (*physis*) itself. After all, the search

¹ For similar remarks on that topic, see Muller (2015); Arroyo and da Silva (2021).

for understanding quantum mechanics is really about the very idea that nature may be investigated and properly understood by means of our best theories. In a nutshell, de Ronde's proposal may be summarized in the following steps:

1. A diagnosis of what is wrong with currently available solutions;
2. A proposal of a *new methodology* for addressing the problem;
3. A positive proposal to answer the question, which is arrived at by following the methodology suggested.

In broad terms, it is claimed that the conceptual difficulties in understanding and interpreting what quantum theory is about stem all from a kind of *metaphysical prejudice*. The theory, de Ronde claims, is being constantly approached from the wrong perspective; we have been trying to interpret it by bringing in a conceptual scheme that clearly does not suit the theory, and that is accountable for the fact that the theory ends up looking so paradoxical. This conceptual scheme is none other than a version of atomism and the idea that the theory deals with objects carrying actual properties; uncovering this prejudice involves the first step mentioned above — criticism. Part of the way out of the trouble consists in critically examining the hidden presuppositions that we typically bring with us when approaching quantum mechanics, and attempt to change the perspective: we should *learn directly from the theory* — which is assumed as a kind of given — what kind of stuff is it really talking about; this is the second step — methodology. The result is that a kind of ontology of *un-actualized potencies* will be seen as the more appropriate subject matter of the theory. A newly developed version of hylomorphism is required both to make sense of quantum mechanics as well as to give us an intuitive understanding of the reality being described by the theory (and that is what science is about, according to de Ronde); and this is the third step — the positive proposal.

As we have mentioned, this whole proposal has, as a background, direct connections to the methodology of metaphysics and its relation to science, a topic that has been one of the major concerns of metaphysicians of our times.² It is precisely with these aspects that we shall be concerned in this paper, which is dedicated to discussing the methodological features of de Ronde's proposal on what concerns the relation of science and metaphysics. Our aim is to both situate it in a broader picture of the relationship between philosophical and metaphysical approaches to science and to have, as a result of this move, better conditions to evaluate both its merits as well as the challenges it will have to face. This is an interesting discussion not only due to the fact that de Ronde's proposal is indeed an attempt at filling the gap between a description of reality and quantum mechanical formalism, but also because it contains methodological aspects that are present also in current disputes on the relationship between metaphysics and science.

It is worth mentioning that de Ronde has been working on this subject for almost two decades now, so naturally his ideas have changed in response to criticism over the years. In fact, de Ronde's work has been received and

² The literature on the topic is gigantic; see the classic Ladyman and Ross (2007), and the recent survey Guay and Pradeu (2020) for some examples.

discussed by the literature concerning his joint work with Newton da Costa about the paraconsistent approach to quantum superpositions (see da Costa and de Ronde, 2013).³ However, to our best knowledge de Ronde’s work on the logos approach to quantum mechanics was not discussed thus far from a metametaphysical point of view —which is precisely what we are proposing to do. With such a discussion, we hope to bring more clearly to light the methodological aspects of the logos approach itself, to properly situate it in relation to other already-established positions in the philosophical foundations of quantum mechanics and, finally, discuss the view in the lights of the current concerns related to the epistemology of metaphysics.

The map of this paper is as follows. In section 2, we review some terminology and some of the core aspects of de Ronde’s proposal. In section 3, we discuss the merits of the approach and how it figures in a quite reasonable view of the nature of scientific realism, as described by Steven French. In section 4, we examine closely the requirement of the de Rondian approach that a coherent image of science must provide an understanding of the theory and the world it describes. As we shall suggest, the claim contains in itself some tensions that are hard to avoid, and which seem to pull in distinct directions, none of them sitting very comfortable with the tenets advanced by de Ronde. We conclude in section 5.

2 Setting the stage

In this section, we deal with terminological matters, presenting carefully de Ronde’s position on how to approach the main problem in focus. We also delineate a framework establishing the relation between key concepts in this kind of investigation, ‘ontology’ and ‘metaphysics’ being the most prominent of them. The distinction will prove itself helpful in discussing further requirements by de Ronde on how to achieve an ontology tied to quantum mechanics and on how to gain an intuitive understanding of reality. Also, it will allow us to situate de Ronde’s proposal in the wider debate in the current literature concerning the relation between metaphysics and science. In order to do so, we have to take a closer look at de Ronde’s (2019b, pp. 125–128) representational realist program, which comprises the definition of the concept of ‘metaphysics’ *within* the scope of the definition of what is a physical theory —the objective of this program being the representation of nature.

We should start by remarking that, as it is understood by de Ronde, the notion of ‘metaphysics’ is in fact quite broad. It concerns, for him, the systematic development of conceptual networks capable of providing representations of reality (de Ronde, 2019a, p. 3). Metaphysics, in this particular sense, and still according to him, is a *prerequisite* for discussions of physics, because it informs our worldview with the basic concepts in terms of which we interpret

³ For criticisms of such view, which are focused on the plausibility of the use of paraconsistent logics in quantum mechanics as presented by da Costa and de Ronde, see Arenhart and Krause (2016); Krause and Arenhart (2016); for a reply, see de Ronde (2019a).

our experience and the phenomena described by the theory. A physical theory, according to the representational realist program, is an enterprise to represent nature, which encompasses the following three aspects: (i) a mathematical formalism (ii) a network of metaphysical concepts, and (iii) a field of phenomena. Let's focus on the metaphysical aspect. We would like to emphasize, for now, the fact that the notion of 'metaphysics' is defined as an essential component of the definition of the notion of 'physical theory' —which means that a physical theory without metaphysics is not even a physical theory (and also, that one cannot mention a physical theory without already mentioning a metaphysical component).⁴ The metaphysical component of physical theories is sometimes called by de Ronde as the "conceptual" component.

The representational realist stance argues in favor of a conceptual-metaphysical understanding of physical theories. Indeed, to provide a coherent metaphysical picture is the only way to truly understand what a physical theory is talking about. (de Ronde, 2017b, p. 119).

In this sense, then, metaphysics has a kind of explanatory priority over science, given that it is the one providing a subject matter to physical theories. Given this understanding of the role of metaphysics, de Ronde finds a diagnosis for the conceptual difficulties of our understanding of quantum theory precisely in the fact that we use the wrong conceptual scheme to approach the theory. In fact, according to the critical part of de Ronde's proposal, our common sense metaphysics —the one we typically use to address quantum theory— is a kind of object-oriented view, dealing with reality in terms of independent objects existing separated from each other. It is this metaphysics that we intuitively bring to a first approximation to physical theories, and it is in terms of this conceptual scheme that we attempt to solve typical problems in quantum mechanics; as we have mentioned, according to de Ronde, it is in terms of this object-oriented ontology that most of the paradoxes of the theory are generated. This conceptual scheme is perhaps responsible for the fact that we currently face many challenges to provide a coherent representation of quantum mechanics.⁵

[...] it is not obvious nor self-evident that we must presuppose this specific "object-property" metaphysical scheme in order to interpret the

⁴ Some approaches to quantum mechanics are markedly anti-metaphysical, such as Q-bism and other pragmatic approaches. Basically, these views incorporate an understanding of science that conflicts with de Ronde's basic tenet that science aims at giving us not only practical recipes for experiments and control of nature but also an understanding of reality (see, among others, de Ronde, 2020a). Now, we shall not focus on this more fundamental conflict on the nature and aims of science itself, although we recognize that there is an important issue here; rather, we shall point to internal tensions created by de Ronde's proposal itself.

⁵ As a consequence of these difficulties, and to retain the objectual approach, some have proposed to abandon the idea of representing reality and shift to purely practical or pragmatic approaches to quantum mechanics; this, according to de Ronde, is a misguided approach, as we shall see.

quantum formalism. Unfortunately, the main discussions in the literature—following implicitly the first postulate of QM—presuppose implicitly the notion of object. This metaphysical choice has produced many interpretational problems. Obviously, such problems cannot escape their own presuppositions, and exactly because of this reason, QM has been confined to a discussion within the limits of this very specific metaphysical perspective. (de Ronde and Massri, 2016, p. 115).

The suggestion is that we cannot approach quantum mechanics without trouble when using our current conceptual scheme, and as a result of such difficulties, we should attempt to develop a conceptual scheme more closely informed by quantum theory itself. Quantum theory puts restrictions on what the theory is about, by the very fact that it presents the features of what it is describing. The point is: if we look closely at the theory, without metaphysical prejudices imported from our object-oriented conceptual scheme, it will tell us something about its own metaphysics.

The representation and understanding of reality can be only achieved through the analysis of metaphysical conceptual schemes which are provided by physical theories themselves. (de Ronde, 2019b, p. 126).

From the methodological point of view, what we have here is that metaphysics is a two-way enterprise: it plays a fundamental role as a background for understanding what a theory is talking about, and also, it somehow must flow from the theory, in the sense that one may obtain its outlines, at least, from the theory's own mechanisms. The plan is that we cannot understand reality without a metaphysics that is also latent in the theory (de Ronde and Fernández-Mouján, 2020, p. 6), so metaphysics plays an essential role in the development of physical theories. We shall come back to this double route of metaphysics in the next section, given that it seems to generate some kinds of tensions.

Before entering into the details, we would like to distinguish between two distinct parts in what is typically called ‘the metaphysical investigation of science’: ontology and metaphysics. Such a distinction is very likely to render the investigation of the coherence and plausibility of de Ronde’s proposal much clearer (see also Arenhart, 2019; Arenhart and Arroyo, 2021a). Let us emphasize this: the distinction is not due to de Ronde, but, as we shall see, it contributes for greater clarity in explaining his project and for locating the sources of the tensions in it. So far, as we have suggested in the previous paragraph, there seems to be tension between the metaphysics that is somehow “read off” from the theory and the metaphysics that should be “applied” for the very understanding of the theory. We believe that the appropriate distinction between ‘ontology’ and ‘metaphysics’ may shed some light on the question of what is obtained from the theory and what is posited beforehand as a tool to access the theory. We reserve the term ‘ontology’ specifically to refer to the part of metaphysics that deals with questions of existence, of providing the furniture of the world. In this sense, ontology and scientific realism are

closely tied, since the furniture of the world according to a theory comprises its ontology; using this terminology, the scientific realist is attempting to grant that we may in fact use science as a guide when it comes to describing the furniture of the world, even in its non-observational aspects (after all, that is what scientific realism is about!). The proper dispute of how to understand ‘existence’ is an issue we shall not enter into now, but distinct proposals are certainly available.

In terms of ontology and of the terminology we are suggesting, and which we shall employ consistently from now on in this paper, for de Ronde, the *ontological* questions are answered by close considerations of the theory. By doing so, de Ronde finds one of the major advantages for his approach; results typically seen as imposing limitations of restrictions on the objectual ontology are, now, defining features of a new kind of entity. Paradoxes dissolve, it is suggested, because quantum theory is merely indicating how the entities it deals with *are*. In particular, we find the claim that the Kochen–Specker result, which puts major obstacles for an objectual reading of the theory is, in fact, a determining key of the features of the subject matter of quantum mechanics in the kind of approach suggested by de Ronde. He claims:

[...] we have been able to escape the contextual character of KS theorem, not by changing the formalism in order to restore our classical way of thinking about *what there is*, but on the very contrary, by changing the way we think about *what there is* in order to restore an objective representation of what QM is really talking about. [...] From our perspective, the key to finding an adequate representation rests in the possibility to create a set of concepts that match the formalism as well as its main non-classical features. (de Ronde and Massri, 2021a, p. 24, original emphasis).

So, here, de Ronde seems to be arguing that one can reap the advantages of such a methodological change on the approach to quantum ontology, as suggested by him. There are some further hints, however, as to how such an approach to ontology must be pursued. According to de Ronde’s approach to existence in quantum theory, the existents are sought in the invariants of the theory, given that this would confer them objectivity (de Ronde and Massri, 2021a). Invariant features of a theory are the best candidates for objective reality, given that they are not relative to perspectives and are not dependent on specifics of reference frames.

This idea that the furniture of the world, according to the theory, must somehow be ‘read off’ from the theory is also present in discussions in de Ronde (2019a, p. 4), where it is suggested that there are two distinct approaches to the ontological questions (in our terminology). One may have a metaphysical scheme and try to adapt the formalism of the theory to suit it, or one may go on and allow that the theory somehow guides the description of what is being described.

The former strategy is the one followed by common interpretations of quantum mechanics, such as the ones advanced by the Bohmian mechanics and col-

lapse theories such as GRW. Another kind of strategy is to extract the ontology from the theory, such as Everettian quantum mechanics and its many-worlds interpretations. An example of this case is DeWitt's (1970, p. 33) claim in favor of Everettian quantum mechanics: "[t]he mathematical formalism of quantum theory is capable of yielding its own interpretation". A famous objection to the latter strategy was put forth by Kent (1989, pp. 1749–1750), stating that the 'many-worlds' assumption "[...] goes beyond what the axioms justify: the axioms say nothing about the existence of multiple physical worlds corresponding to wave function components". So, as there are no 'worlds' mentioned in the axioms, this interpretation is not being 'read off' from the formalism, in any straightforward sense. Nevertheless, there is not really much in the axioms of quantum theory. Many things whose existence we are used to believe are not really there. Wallace's (2012, p. 48, original emphasis) example is to say that tigers exist, but they are not in formalism; the way out for the proponents of such a reading is to say that, on the contrary, these entities "[...] should be understood as patterns, or structures, *within* the states of that microphysical theory". As Wallace (2012, p. 48) claims, then, such ontological aspects of quantum mechanics ought to be understood as *emergent* features of the theory:

[...] they are not directly definable in the language of microphysics (try defining a haircut within the Standard Model) but that does not mean that they are somehow independent of that underlying microphysics. (Wallace, 2012, p. 48).

To some contemporary Everettians, such as Wallace himself, 'worlds' would be entities of this kind. Thus, although fundamentally disagreeing about the ontological content that emerges from the formalism of quantum mechanics, *methodologically*, the Everettian approach would be aligned with the logos approach. However, the logos approach characterizes both Bohm, GRW and Everett as sharing a common metaphysical scheme: they are solutions to the measurement problem, which allegedly concerns 'clicks', measurement results, and, most importantly, presupposes a metaphysical scheme (or 'ontological scheme', in our terminology) of particles and objects. As a result, this so-called "metaphysical scheme" would be the preconception (or 'prejudice') that quantum mechanics is about objects bearing certain properties, which is a scheme known to generate cases of metaphysical underdetermination (de Ronde and Fernández-Mouján, 2020). The problem diagnosed by de Ronde is the focus of attention, which is misleadingly accentuated in the measurement results —recall that the standard way of stating the problem of measurement in quantum mechanics is, in fact, the "problem of outcomes" (Maudlin, 1995). The solution within representational realism would be to change this strategy, now focusing on the *conceptual scheme* rather than on measurement outcomes. So the logos approach refuses the legitimacy of the (in)famous 'measurement problem' in QM, which is re-stated in the form of the "problem of superposition" as follows:

Given a situation in which there is a quantum superposition of more than one term, $\sum c_i|\alpha_i\rangle$, and given the fact that each one of the terms relates through the Born rule to a meaningful physical statement, the problem is: how do we *conceptually* represent this mathematical expression? Which is the physical *concept* that relates to each one of the terms in a quantum superposition? (de Ronde, 2019b, p. 145, emphasis added).

The proposed strategy within representational realism is to follow the formalism very closely and try to learn in some way what it is talking about. This requires that we somehow ‘read off’ an ontology from the formalism of the theory:

[...] we believe that QM can be developed by considering new (nonclassical) physical concepts that, in turn, will provide us with an intuitive (non-classical) representation and understanding of the theory and the experience it talks about. Our guide in the development of such new conceptual forms is the orthodox quantum formalism itself assisted by some general physical considerations. (de Ronde and Massri, 2021a, p. 18).

Following this methodology, it is said, we will be led to a different ontological basis, distinct from the object-based ontology: the non-actual understandings of the theory (in terms of propensities, potentialities, dispositions, latencies, etc.). So, while the common prejudice leads to paradoxes and the insoluble measurement problem, with its resulting many interpretations, closer attention to the formalism of quantum mechanics would result in a new ontological basis, i.e., an ontology of powers, which can get rid of such difficulties. Here, we see another alleged advantage of the proposal by de Ronde: not only do we have a way to avoid the paradoxes of the theory, as commented earlier, but we also re-conceptualize the whole understanding of the theory, avoiding one of the most intricate problems of current philosophy of quantum mechanics, the measurement problem. This is, again, a result of the new methodological approach to the ontology of quantum mechanics. By following the formalism of the theory and attempting to read its ontology, we find that:

[...] just like particles, fields and waves are existents within the actual realm and represented by our classical theories, *immanent powers* with definite *potentia* are existents within the potential realm which require a quantum mechanical description. (de Ronde, 2019b, p. 146, original emphasis).

That is, the result of such an extraction process is an ontology of “immanent powers”, which then gives rise to the suggestion of a new formalism for quantum theory, the logos approach (de Ronde and Massri, 2021a). This is one lesson that should be learned out of quantum mechanics: that the theory does not deal with actual states of affairs, e.g. with objects with actual properties,

but with the potential states of affairs. The quantum world is a world of immanent powers and potencies. This is how the logos approach to QM defines its ontological furniture (for details, see de Ronde, 2018, 2019b, 2020b; de Ronde and Massri, 2021a, 2019): in terms of the Hilbert-space formulation of QM, a specific vector $|\psi\rangle$ with no given mathematical representation represents a “Potential State of Affairs”, which de Ronde (2019b, p. 146, original emphasis) defines as “[...] the definite potential existence of a multiplicity of *immanent powers*, each one of them with a specific *potentia*”. The specific immanent powers and potentia are given once one adopts a basis in which to describe the vector $|\psi\rangle$. That is, given $|\psi\rangle = \sum c_i |\alpha_i\rangle$, each α_i is an immanent power, and has c_i as its corresponding potentia. Of course, different bases codify different distributions of powers, along with their respective potencies. We emphasize it again: this is thought of as a result of a kind of direct reading-off of the ontology from the mathematical formulation of the theory. In this sense, the theory not only is responsible for its ontology, but it is also the case that we are to blame for the problems generated in quantum theory when we lay over it our prejudicial object-oriented conceptual scheme.

One of the most frequently found examples of this ontology of powers and potentia is a discussion on Messi and Neymar, the well-known soccer players (de Ronde, 2019a; de Ronde and Massri, 2021a). Both have the power to shoot penalties, for instance. They need not be actually shooting a penalty to have this power, so the power is not always actual but remains in a latent state, it is potential. Furthermore, each of them has a given rate of success in shooting penalties, which somehow codifies how much ability one has to do so —and this is the counterpart of the potentia, which here codifies how likely it is that a penalty is shot with success. Finally, they do not lose the capacity when a penalty is shot. The same kind of analogy may be adapted to other soccer moves, such as shooting corners or making short-distance passes. Another way of visualizing more clearly the ontology of immanent powers is presented by de Ronde (2017a), where a baseball match is considered for the sake of the example.

Imagine two baseball players called Matthias and John. Regarding the baseball game everyone can understand if I argue that both Matthias and John possess a definite set of potentia concerning the powers of batting, running and pitching. What does it mean that, for example, Matthias possesses the power of batting with a potentia of 0.9? It obviously means that he is a very good batter. That if I throw 100 balls to him, he will be capable to batt approximately 90 balls. This also means that if I would like to learn (at the epistemic level) about the (ontic) power of Matthias to batt I obviously need to do statistics. The more statistics I make the better I will learn about the potentia of his power to batt. Of course, exactly the same applies to John, if we would like to learn about his powers of batting, running and pitching, we would also need to perform a statistical analysis for each one of these powers to know their respective potentia. Indeed, the statistical data we can

obtain from the performance of each player in many baseball games become in our model an (epistemic) measure of the (ontic) potentia of the powers in question. From this perspective, QM talks about the powers and their potentia, how they evolve and interact; and not about the particular observations by subjects of actual effectuations. [...] Through the introduction of the immanent cause it is possible to argue that the actual effectuation of a power within a quantum superposition is only an expression of its potentia at the epistemic level. The fact that Matthias can batt 0.9 of the times does not imply in any way that if I throw a ball to Matthias he will batt the ball. This possibility is completely indetermined since the notion of power is a statistical notion quantitatively defined in terms of its specific potentia. If John can batt with a potentia of 0.5, this means that only half of the times he will be able to batt the ball. *It is more probable that Matthias bats a ball than John, however, this is in no way determined before the actual effectuations take place.* (de Ronde, 2017a, pp. 681–682, emphasis added).

Many metaphysicians and those interested in the metaphysics of science may reject Ronde’s approach simply because he uses crude analogies, such as the football and baseball examples; with this in mind, we will attempt to articulate such examples in terms such metaphysicians would recognize⁶—e.g. objects that have the dispositional property of being fragile, such as glass cups or windows. Consider the breaking of the glass cup. The fragility of the cup is its power, represented by the vector $|\alpha\rangle$; each power, recall, is associated with a potentia represented by the scalar c which denotes the grade of the power. Suppose, for example, that the fragility $|\alpha\rangle$ of the cup ranges in potentia c from 0 to 1, being 0 the cup not breaking when dropped and 1 the cup being completely shattered by the fall. Intuitively, then, the potentia codifies this specific kind of glass’ resistance to a fall, with different kinds of material endowed with different such potentia. In this case, again, there is only one power but a non-enumerable (e.g. \mathbb{R}) quantity of potentia associated with the specific disposition/power of fragility. Insofar as the power does not need to be actualized in order to exist, one can also eliminate the object as a bearer of properties thoroughly. As a result, when it comes to specifying the ontology of quantum mechanics, we have, according to de Ronde, that the theory speaks about such potential states of affairs, that are gathered to form a system.

According to the logos approach, QM does not talk about “small particles”, it talks about a potential realm—independent of actuality—represented in terms of immanent powers with definite potentia. (de Ronde and Massri, 2021b, p. 6676).

That accounts for the ontology of de Ronde’s approach: there is a claim about what populates the world, and, equally important, a claim about how one finds this out: ontology is extracted from the theory. Now, we also have

⁶ We would like to thank an anonymous referee for pointing this out.

what *we* term ‘metaphysics’.⁷ This is a distinct enterprise, related to the traditional field of philosophy called metaphysics, dealing with issues of *the nature* of entities: the nature of particulars, of properties, of space, time, modalities, mind, and so on. In our terms, metaphysics goes beyond ontology, by providing a kind of profile to the posits of the theory. From now on, it is in this sense that we shall understand ‘metaphysics’ in this paper.

This distinction between ontology and metaphysics is quite traditional, and it is precisely the kind of distinction that was also suggested in Arenhart (2012); Arroyo and Arenhart (2019), and Hofweber (2016), who puts it in the following terms:

In metaphysics we want to find out what reality is like in a general way. One part of this will be to find out what the things or the stuff are that are part of reality. Another part of metaphysics will be to find out what these things, or this stuff, are like in general ways. Ontology, on this quite standard approach to metaphysics, is the first part of this project, i.e. it is the part of metaphysics that tries to find out what things make up reality. Other parts of metaphysics build on ontology and go beyond it, but ontology is central to it [...]. Ontology is generally carried out by asking questions about what there is or what exists. (Hofweber, 2016, p. 13).

So, according to de Ronde’s proposal, and using our terminology, quantum theory itself informs us about its *ontology*: immanent powers and their potentia populate the world. But does it? Moreover, provided that we grant that we have an ontology of immanent powers, one could clearly ask ‘what are they?’ (i.e., could one ask about the metaphysics of powers and potentia?). Could one follow the same kind of methodology and claim that quantum mechanics informs us as to the answer to *this* question too? The next sessions deal with these questions, that pose different kinds of challenges.

3 Shallow and deep realism

One could refuse to go into such depths, as required by metaphysics. After all, why do we need to answer the question concerning ‘what is an immanent power’? More than that: why should such a question be answered in terms of metaphysics? Indeed, there is a wide margin for disagreement on how much metaphysics is required for a clear picture of the ontology of a theory. One could argue that we should stop at the level of describing the conceptual scheme required by physics. According to the characterization offered by French (2018a), and inspired by Magnus (2012), a form of realism that repeats

⁷ Recall that a few paragraphs before we have proposed to distinguish ‘ontology’ from ‘metaphysics’ in order to get a clearer picture of the discussion. As a result, we have been focusing on the ontology of de Ronde’s approach until now; this is the time to bring metaphysics into the picture (see Arenhart and Arroyo, 2021a, for further discussion into this specific distinction).

the physical description would be “shallow” realism, which refuses to investigate metaphysical issues. Shallow-type realists would be realists who would accept the entities postulated by the theory (i.e., the theory’s ontology), but would refuse to go beyond what science already says. That is, some people consider it enough to just point at the theory, and claim a scientific realist attitude precisely about as far as the theory goes: these are the realists that choose to remain at a “shallow” level.

However, for some, this falls short of what is needed for realism, or, similarly, for a coherent belief in the existence of the entities posited by a theory. One may suggest that we need to go beyond de Ronde’s suggestion, and to do this by adding a metaphysical layer over the top of powers and potencies. Only then would we have a clear picture. As we have seen, de Ronde suggests a new ontological scheme that gets developed from the theory, and demands that it provides intuitive understanding; his search is for a clear and intuitive picture of what the physical theory is talking about —recall that in the representational realist program, this means a clear and intuitive picture of reality itself. If we attempt to clarify how immanent powers and potentia work by merely pointing to the theory, we just leave the issue where it was. In this sense, the demand for intuitive understanding seems to commit de Ronde to provide an answer regarding what Steven French has called ‘Chakravartty’s challenge’ for scientific realists. In very brief words, the challenge for the realist concerns the claim that one cannot hold that one believes a theory to be talking about a kind of entity X and not have a clear picture of what X is. To provide such a picture is part of what being a realist amounts to; the picture may be metaphysically informed:

But how do we obtain this clear picture? A simple answer would be, through physics which gives us a certain picture of the world as including particles, for example. But is this clear enough? Consider the further, but apparently obvious, question, are these particles individual objects, like chairs, tables, or people are? In answering this question, we need to supply, I maintain, or at least allude to, an appropriate metaphysics of individuality, and this exemplifies the general claim that in order to obtain Chakravartty’s clear picture and hence obtain an appropriate realist understanding we need to provide an appropriate metaphysics. Those who reject any such need are either closet empiricists or ‘ersatz’ realists. (French, 2014, p. 48).

The distinction between the ‘shallow’ and ‘deep’ kinds of scientific realism, as proposed by French, leaves open the possibility of placing the logos approach already within a deep-realist account. That is, one could suggest that powers and potentia already are the art of deep approach to realism, answering questions of nature (metaphysics), not merely of existence (ontology). However, this suggestion would be misguided according to our way of framing the methodology behind such investigations, and it has an easy-to-find source: philosophers sometimes conflate the philosophical disciplines of ‘ontology’ and ‘metaphysics’. To distinguish between these two philosophical

disciplines enables us to better organize the methodological picture of the options for interpreting QM and the limits of connecting metaphysics and ontology, each in its turn, with science. In our distinction (see Arenhart and Arroyo, 2021a, for details), ‘ontology’ deals with existence questions while metaphysics (specifically, the metaphysics of science) build upon what exists according to scientific theories. Only then we can better appreciate the distinction between the ‘shallow’ and ‘deep’ aspects of scientific realism. So if, for instance, the logos approach posits immanent powers in the ontological basis of their approach to QM, it has made an ontological statement. Shallow-type realists would stop their philosophical inquiry at this ontological level. But in order to characterize such ontological commitments, one has to enter into the ‘deep’ discussions in the metaphysics of powers, e.g., are powers fundamental in the sense of the *grounding* literature, or there can be a dualist approach to that? Only by answering these kinds of questions one could place the logos approach within the deep-realist stance. But the logos approach does not provide that, which is why we placed it within the ‘shallow’ side of the spectrum (see also Arenhart and Arroyo, 2021c). The situation for the philosopher, when facing Chakravartty’s challenge, is the following: once the posits of a scientific theory are identified, that is, once we have an ontology accompanying a scientific theory, we are asked to advance also a clear image of the ontology. What is such a clear image? Typically, as French (2018a) has argued, it comprises a metaphysical picture, which must be provided as a description in metaphysical terms. Our distinction between two levels, ontology, and metaphysics, gets in right here (see also Arenhart, 2012, 2019; Morganti and Tahko, 2017; French, 2019; Arenhart and Arroyo, 2021b, for further articulations of the view that metaphysics complements the ontology of science).

In our terminology, we have already seen that de Ronde suggests that we should adopt realism about immanent powers. But then, regarding Chakravartty’s challenge, what are immanent powers? Do we have a clear metaphysical picture of what these entities are? Perhaps we have a metaphysical profile available to understand what “powers” are—at least, something is being developed in this regard: de Ronde’s (2019b) own solution would lie somewhere in newly-developed hylomorphism, specially tailored to fit the immanent powers without ‘actualist’s prejudice’. So one could argue that *this* is the metaphysics that is being tailored to fit the basic entities in the logos approach ontology, i.e., immanent powers.

Our choice to develop an ontological realm of potentiality absolutely independent of the actual realm of existence implies, obviously, the need to characterize this realm in an independent manner to classical physical concepts such as ‘particles’, ‘waves’ and ‘fields’—notions which are defined in strict relation to the actual mode of existence. According to our viewpoint, while classical physics talks about systems with definite properties (‘particles’, ‘waves’ and ‘fields’), QM talks about the existence of powers with definite potentia. While the classical representation of sets of systems with definite properties can be subsumed under

the notion of an *actual state of affairs*, QM provides a representation in terms of a *potential state of affairs*. This representation seeks to define concepts in a systematic categorical manner avoiding metaphorical discourse and, in this way, to provide an *anschaulich* content of the theory. (de Ronde, 2019b, p. 148, original emphasis).

On the other hand, this seems to be a whole package that avoids the need for further metaphysical content, in our sense of the term. What could be seen here is a development of an ontology that, by being somehow extracted from the theory, has peculiar behavior dictated by quantum mechanics itself. As de Ronde puts it, we cannot hope to get a clear picture by appealing to classical images, and the quantum image, it may be argued, comes completely from the quantum theory. It seems that looking for something more, for some metaphysical image outside of the scientific theory, is not only unnecessary but also risks bringing in classical concepts that are inappropriate; after all, if all that the theory provides is for its ontology, this is what we should focus on. If this is so, Chakravartty's challenge is addressed by claiming that we do obtain a clear picture directly from the theory, without the need to frame the realistic content in further metaphysical terms. In this sense, representational realism would be willingly a form of avoiding the "deep" sense of realism and still providing a clear image.

But we feel that even this attempt to remain at a shallow version of realism is not granted by the methodology presented by de Ronde, and now it is the time to face some of the difficulties. As we have already seen, de Ronde's suggestion is that we should shift to an ontology of immanent powers if we are to make sense of quantum mechanics. This comprises the ontology of the theory, its realistic content if we are to speak in terms of our terminology. But that strategy is not enough to determine ontology too. It seems that we have trouble even on what concerns the shallow content of shallow realism.

We have already pointed to a kind of tension in the suggestion by de Ronde that the ontology is both *approached through the theory* but is also a *requirement for our understanding of the theory*, as having a kind of explanatory priority. This poses some difficulties, as we now suggest. It seems we have a two-way route: from theory to ontology, and from ontology to theory. The first route we take to obtain an ontology seems to be quite in touch with some radical naturalist approaches to ontology. The second route is of a more explanatory nature and indicates that an ontology is a requirement for our understanding of a theory, in a way that the ontology must have some kind of explanatory priority.

The first problem in the framing of ontology suggested by de Ronde concerns the direction: from theory to ontology. But this is not to be taken as properly "read off" from the theory.

What is real? The coming together of theoretical representation and *hic et nunc* experience in a given actual situation. This understanding of the relation between theories and reality implies that theoretical representation is not necessarily unique. There can exist many different

representations, many different nets capable to capture different expressions of reality. While, representation is not committed to description, realism is not committed to the search of a single representation of reality. The search for our understanding of reality can be regarded as an infinite *creative process* of theories which express reality in an adequate manner. (de Ronde, 2020a, p. 16, emphasis added).

Curiously, although this is not extracted from the theory, such an ontological approach is thought to be better for not being a metaphysical prejudice. This could only be the case, it seems to us, if it revealed itself as more closely tied to the theory. Mere association to the theory engenders ontological underdetermination, just of the same kind that we have to face when discussing the *many distinct interpretations*. The idea that immanent powers are the subject matter of quantum theory just adds to the cart.

Strangely, sometimes de Ronde does not seem to think of his proposal as another option among others, but rather as one that overcomes metaphysical prejudices. As suggested by de Ronde in the continuation:

As a consequence of this unity between concepts and mathematical formalisms, one should be able to go from the concepts to the mathematics —like it was the case in classical mechanics— and vice-versa, from the mathematics to the concepts —as it seems to be required in the case of QM. This essential requirement of theoretical unity, not only avoids —right from the start— the possibility to introduce a measurement postulate —grounded on a naive empirical prejudice about single measurement outcomes—, it also erases many interpretations which add concepts to the theory which have no contact to the mathematical formalism whatsoever —most of them grounded on metaphysical prejudices. (de Ronde, 2020a, p. 17).

That is, an ontology of immanent powers is not even granted from the theory.

Some questions appear immediately. Perhaps one could claim that the nature of such entities is not granted, but clearly they behave in a way as suggested by de Ronde. They are powers, latencies, dispositions, or something of the kind, right? Notice that even if that is granted (and that is quite a big ‘if’), it is very unclear what kind of image is being obtained. Talk of powers and dispositions leaves us very far from a particular image. As French has put it:

“[...] if you were to collect 10 defenders of dispositionalism or ‘powers’ views more generally and put them in a room, you would get 15 different accounts!” (French, 2020, p. 191).

That is, we are left with a lot of issues that still need to be addressed, and this seems very far from the kind of assuring answer that one could expect if the proposal were a direct result from or a most natural approach to quantum theory itself. Instead of using quantum mechanics to bridge the epistemological

gap between metaphysics and reality, we merely seem to dig a bigger gap. In more details:

Different versions of dispositionalism have been put forward [...]. Maybe dispositions don't need any bearers at all (McKittrick 2003a, 2018; Mumford 2006), or at least some dispositions don't need bearers and we can generally be pluralistic about their nature (McKittrick 2018). It is, hence, anything but clear that there is *the* dispositionalist philosophy, or *the* powers metaphysics and that this metaphysics is Aristotelian. Instead, the ontological commitments vary from version to version. (Meinke, 2020, pp. 4–5, original emphasis).

This discussion concerning the difference between dispositions with and without a bearer is important, and we cannot find any easy option for de Ronde. If dispositions have a bearer, then, it seems, we are back to an object-oriented ontology, which he abominates. If, on the other hand, they do not have a bearer, we miss the analogy with the Messi–Neymar case, which would confer the intelligibility of the view (or, to the same effect, the baseball players analogy). In fact, as French (2018b, p. 227) argued, it is these connections with the application of metaphysical concepts to everyday cases that allow their understanding in situations far from these everyday contexts, as in advanced science. Absent the major source for the analogy, we seem to lose the basis for the understanding derived from the idea of power, one of the major goals for de Ronde (see Section 4). Furthermore, without a bearer we also miss the explanation of their 'sociability', to use a term Steven French borrowed from Chakravartty, which would account for their 'object-like' behavior in many situations:

Consider the beautiful curves carved out in a bubble chamber, for example. These might be attributed to something of a certain mass and a certain charge passing through the imposed magnetic field. What is it that binds together these properties, such that we get this behaviour? Standardly, the answer would be a 'particle', understood, within the framework of an object oriented metaphysics, as an object [...] (French, 2019, p. 27).

That is, why do powers corresponding to properties constituting an electron meet in such a way as to look like an object on some occasions? And why do they always appear together, behaving like a thing? These issues are left unresolved by a dispositionalist account such as de Ronde's, absent a bearer as a unifying spot for the powers.

One could go even further, and attempt to turn tables at de Ronde, by claiming that an ontology of power-like entities is far from being recommended by the theory, while an object ontology can be perfectly saved. This is what is advanced by many approaches to quantum entities as objects, even though such objects are less like the ones we meet in everyday life, are presented to account for the nature of quantum entities. Contrarily to what de Ronde claims, they are typically adapted to account for the limitations imposed by results

such as Kochen–Specker and the probabilistic nature of quantum entities (see, for instance, Kuhlmann, 2010; Mittelstaedt, 2011, and the references therein).

It seems that de Ronde claims that all schemes, except his, are prejudices (and this is part of the critical stage of his proposal) since they —allegedly— involve metaphysical theses that were not critically examined. However, as we have been arguing, most typical approaches have adapted themselves to the limitations imposed by quantum theory, and also, his own proposal, not being derived from the theory, does not have a better fate, even according to his own standards.

In fact, other proposals are said to be ‘read off’ from the theory.⁸ The first is the ‘eliminative ontic structural realism’ (OSR), as famously defended by French (2014). The argument is as follows: the traditional ontology of objects leads us to underdetermination. We do not know how to interpret quantum objects metaphysically: are they individuals or non-individuals? Quantum theory itself does not solve that problem, being compatible with both options, and the claim is that such underdetermination indicates that this ontological basis contains the error, and to insist on it is a prejudice instilled by logical positivism. We must therefore shift to an ontological basis in which this does not happen. Which basis is it? According to French, not a basis of immanent powers and potentia, but rather of structures and relations without the rela-

The proposal offered by de Ronde and Fernández-Mouján (2020) is that the ontological basis of objects should give way to an ontological basis of immanent powers. Frequently, metaphysicians of powers makes use of objects as bearers of powers (see Marmodoro and Mayr, 2019; Vetter, 2015). Some of them, such as dispositional realists, argue that the ontological category of “objects” is crucial as it acts as a “seat” of causal powers (see Chakravartty, 2017, 2003). One can also be eliminativist about objects and still maintain dispositional properties as structural properties, however (see French, 2006, 2013, 2020). Just as the eliminative ontic structural realist, the proponents of the logos approach suggests an eliminativist ontology towards objects. Of course, this kind of structural realism is also eliminativist towards dispositions (see French, 2013, 2020) as a meaningful ontological category. This is done by applying “Poincaré’s Manoeuvre” (French, 2014, p. 67), which enables one to *talk* about dispositional properties and objects as its bearers *as if* they are real but without conferring to them ontological robustness:

Although we might introduce the terminology, or perhaps better, symbology, of objects as part of our representation of the relevant structure, these should be regarded as mere devices that allow us to construct, articulate, or appropriately represent the relevant structure, and *any representational priority they might have should not be taken to imply that they are ontologically foundational*. (French, 2014, p. 67, emphasis added).

⁸ Recall DeWitt’s statement that the Everett interpretation is just the standard quantum formalism interpreted literally.

It is not clear however, how the friend of the logos approach may respond to this issue of the “sociability” of the powers, as it maintains dispositional powers while abandons objecthood.

Concerning the eliminativism towards objects, it seems that if we exchange ‘immanent powers’ for ‘structures’, we would have a scheme of the proposal offered by French (2014) in his eliminative OSR. So what exactly is being ‘read off’ from nature: structures or immanent powers?⁹ It seems that both are compatible with the theory; clearly, if quantum mechanics is teaching us an ontological lesson, we are not still able to learn it.

Perhaps, what this all indicates is that Chakravartty (2019, p. 11) is correct when claiming that it seems that the ontology being ‘reading off’ from QM is not an output process, but, on the contrary, an *input* process!

When French speaks of reading ontology from fundamental physics, what he is doing, in fact, is implicitly appealing to some (one hopes) defensible criterion or criteria which he takes to point toward a *preferred* interpretation of the relevant physics—an interpretation which is (one hopes) demonstrably superior to others. (Chakravartty, 2019, p. 11, original emphasis).

As the argument goes, getting rid of object ontology is the first step. After all, that’s where all the confusion comes from; it is the atomist, object-oriented ontological basis that feeds the plethora of interpretive options for quantum mechanics, from many worlds to causal consciousnesses (see de Ronde and Massri, 2019; de Ronde and Fernández-Mouján, 2020), in a fragmented way that Cabello (2017) called the “Map of Madness”. But look where we are now: isn’t this still fragmentation? We were promised a way out; instead, we ended up discovering yet another interesting spot on the map of madness: the representative realism of the logos approach, alongside eliminative OSR.¹⁰ They are different locations mapped on the same map.

Still, one might argue, why not adopt an ontological pluralism? At first glance, this is done by de Ronde (2014, 2017b, 2019b).

There is in our neo-Spinozist account an implicit ontological pluralism of multiple *representations* which can be related to *one reality* through a *univocity principle*. (de Ronde, 2019b, p. 146, fn., original emphasis).

But such ‘ontological pluralism’ concerns a different issue, related to the fact that the same state can be represented on many different bases, as in the potential state of affairs at play in the “problem of superposition” (and also

⁹ Another proposal that considers possible to extract at least some fundamental ontological aspect from formalism alone, called “wave function realism”. This view is sometimes presented as a natural attitude towards QM (see Albert, 2013), or through the famous Quine–Putnam argument of indispensability for obtaining the ontology from QM—that is, that ontology can be “read off” directly from the demands of the formalism. So there are wave functions in the ontology. But just two options are enough to make our point: ontology being underdetermined between structures and powers.

¹⁰ And wave function realists, let us not forget.

in the soccer example). That is: it is an ontological pluralism that admits the existence of different, potential representations for the description of the same and unique nature; therefore, it admits ontologically distinct representations. But note that this ontological pluralism is a pluralist attitude within the ontology of immanent powers. It is not a pluralist attitude in a broader sense, as, for example, an attitude that would admit both representations via immanent powers and representations based ontologically on objects or structures. After all, if that were the case, why argue for immanent powers-based ontology?

So far, we have seen that the representational realism of the logos approach to quantum mechanics is motivated, among other things, to provide us with an intuitive (that is *anschaulich*) understanding of reality. The first obstacle is, as we saw in this section, the challenge of underdetermination. After all, since the ontology of immanent powers is not extracted directly (as well as other ontologies, such as the ontology of structures, are also not so extracted), we have no guarantee whatsoever that it is the ontology of reality. We have other candidates who would say the same thing about their proposals, and, even worse, the picture of reality as composed by powers of some kind is itself very obscure, given the multiplicity of approaches attached to this line.

In addition, the demand for intuitiveness may end up showing itself as a prejudice disguised as an epistemic criterion for metaphysics. And as we know, quantum theory is not exactly intuitive: it can lead us to adopt paradoxical and strange views of entities, which is something that the logos approach wants to avoid. The next section will try to clarify this.

4 Intuition and understanding

We have mentioned in the introduction that ontology (understood according to our terminology), in de Ronde's proposal, suffers from a kind of tension. At one time, it must be somehow extracted from the theory; it must follow from what the formalism of the theory tells us about the world being described. This is thought of as being a way to avoid the traps that usually appear when we face quantum mechanics with a prejudicial conceptual scheme. Also, this kind of move should endow the resulting ontology with a kind of epistemic superiority over rivals, precisely because it is a consequence of the theory itself, and not a result of our impositions on the formalism. However, as we have seen in the previous section, one can hardly claim that an ontology of immanent powers really follows from the theory; rather, we have good reasons to believe that quantum mechanics delivers us ontological underdetermination.

But that is not the only way to see the role of metaphysics and ontology in a physical theory, according to de Ronde. The second role for ontology includes seeing the ontological picture of a conceptual scheme as *a condition* for the very understanding of the theory (this is the route from ontology as a conceptual scheme to understanding the theory, described in the previous section). Quantum mechanics only makes sense if we have an appropriate conceptual scheme underlying it beforehand, and ontology—in our terminology—plays

this explanatory role. It is nothing short of curious that a conceptual scheme must be there working beforehand, as a kind of prejudice, one could suggest, in order to make sense of the theory!

In this section, we benefit from the work done in the previous sections in describing the kind of ontology de Ronde has in mind, and we evaluate whether the ontological picture suggested by de Ronde is clear enough to achieve this kind of result, i.e., a clear and intuitive understanding of quantum mechanics. In the face of ontological underdetermination, we have argued that the route from theory to ontology and metaphysics are closed. The philosophical message of the theory, then, results less clearly than expected, and, one may envisage here a space to argue that, well, perhaps the message of the theory may evade us completely, or be totally counter-intuitive in ways unexpected for us. After all, reality may be very strange. This is not precisely clear in de Ronde's proposal; it seems to us that he is willing to safeguard a kind of intuitive plausibility of his own proposal:

We believe that by adding the conceptual scheme that derives from the notion of *immanent intensive power* our logos approach can provide an intuitive understanding of the meaning of intensive valuations. (de Ronde and Massri, 2021a, p. 453, original emphasis).

We focus on the requirements of intuitiveness and *Anschaulichkeit* (clarity) for an ontology, and argue that they pose difficult questions of two major sorts: first, the precise motivation for the requirement of intuitiveness in relation to science, given the latter's revisionary character, and second, the defense that the powers and potentia approach is, in fact, intuitive in the required sense. We deal with these issues now.

Remember that the conceptual scheme must be somehow elaborated with the help of the physical theory that we are discussing. This is clearly a strategy that requires that we follow very closely the requirements of science. However, the tension comes when we notice that it also attaches too much importance to what we, as humans, can imagine or visualize. Why think that reality would cope with our intuitive capacities? This is basically the challenge by (Ladyman and Ross, 2007, p. 2): "there is no reason to imagine that our habitual intuitions and referential responses are well designed for science or for metaphysics".

Ladyman and Ross suggest that attaching the development of metaphysics related to science to our capacities of intuition leads to a falsification of science. Indeed, they claim that modern physics (relativity theories and quantum theories) deal with an aspect of reality that goes far beyond what is available to us, as creatures, to imagine. In terms of the evolution of species, none of our capacities have evolved to deal with such domains that are so far off from our common experience, and so, it is only natural that the theories will be not intuitive. In other words: how can we make sure that demanding intuitiveness, we are not imposing our prejudices over nature?

As Feynman claims:

In the beginning of the history of experimental observation, or any kind of observation on scientific things, it is intuition, which is really based on simple experience with everyday objects, that suggests reasonable explanations for things. But as we try to widen and make more consistent our description of what we see, as it gets wider and wider and we see a greater range of phenomena, the explanations become what we call laws instead of simple explanations. One odd characteristic is that they always seem to become more and more unreasonable and more and more intuitively far from obvious. [...] There is no reason why we should expect things to be otherwise, because the things of everyday experience involve large numbers of particles, or involve things moving very slowly, or involve other conditions that are special and represent in fact a limited experience with nature. (Feynman, 1985, p. 127).

By demanding intuitiveness, it seems, we risk getting farther from science itself, putting into trouble a movement de Ronde has so much emphasized when it comes to obtaining the ontology. In this sense, intuitiveness and the approach of the conceptual scheme through direct inspection of science seem to enter into conflict. Moreover, ‘intuitiveness’ is a meta-theoretical virtue that concerns *us*, *not nature* (a discussion of the latter criteria can be found in Arroyo and Arenhart, 2019), thus not being able to guarantee objectivity if used as criteria of choice between ontologies associated with scientific theories. The same could be said about ‘simplicity’ and ‘beauty’ as well.

Let us now pursue the problem a little further. Surely, if de Ronde is correct that his approach offers an intuitive understanding of the quantum world, that is worth something. After all, the reason for doubting our intuitions in the context of quantum theory is that there aren’t any interpretations capable of preserving them! Advocates of the de Broglie–Bohm theory often emphasizes its ability to preserve determinate positions for all particles at all times as a virtue of the theory. This is not our standpoint. The way we see it, there are two problems related to the above-stated claim for intuitiveness: the first is that de Ronde’s proposal is not really intuitive, i.e., it does not provide us a clear picture in the sense required by Chakravartty’s Challenge; the second problem is that *even if it does provide* an intuitive picture, we shouldn’t really care i.e. we should not take intuitiveness as a metametaphysical criterion for choosing physical theories —nor for *metaphysical* theories, for that matter.

Let us begin with the latter. In order to discuss it, it is opportune to make a comparison with another metametaphysical criterion, similar to that of intuitiveness: simplicity. Taking this criterion into account, we should prefer simpler theories to more complex theories. In ontological terms, this is expressed in Ockham’s Razor, according to which we should not multiply the entities of our theories unnecessarily —or, that we should prefer the theories that postulate fewer entities unnecessarily. However, such criterion presents, at best, heuristic value for evaluating theories. As stated by Parsons (1979):

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. (Parsons, 1979, pp. 660–661).

Roughly put, simplicity is not related to truth. This means that it can hardly be an acceptable objective metametaphysical criterion in the evaluation of rival theories.¹¹ As remarked by Benovsky (2016, p. 87, original emphasis), “the requirement of parsimony and simplicity comes from *us* rather than from the metaphysical reality”. Therefore it seems safe to assume that simplicity is a criterion that should be dropped in this kind of inquiry. So is intuition. Below, we highlight an example in the philosophy of mind, but it fits the purposes discussed here.

In philosophy of mind, a counterintuitive “result” (e.g., a mind-boggling implication of somebody’s “theory” of perception, memory, consciousness, or whatever) is typically taken as tantamount to a refutation. This affection for one’s current intuitions, sometimes amounting [...] to a refusal even to consider alternative perspectives, installs deep conservatism in the methods of philosophers. Conservatism can be a good thing, but only if it is acknowledged. By all means, let’s not abandon perfectly good and familiar intuitions without a fight, but let’s recognize that the intuitions that are initially used to frame the issues may not live to settle the issues. (Dennett, 2006, p. 34).

Our biggest objection to intuitiveness as a guide to scientific endeavor is that it is used when science itself conflicts with it. From a naturalistic standpoint, Wallace (2012, p. 4) summarized the situation as follows: “[...] insofar as our intuitive precepts about how the world works are in conflict with science, so much the worse for those intuitive precepts”. Before proceeding with the discussion of the first problem of intuitiveness mentioned above, let us mention in passing an argument with an evolutionary root about why we should not let intuitions carry the debate about the fundamentals of quantum mechanics in particular. As stated by Susskind and Friedman (2014, p. xix), “[q]uantum mechanics describes things so small that they are completely beyond the range of the human senses. So it stands to reason that we did not evolve an intuition for the quantum world”. And, again in accordance with Wallace (2012, p. 45), “[...] our intuitions as to what is ‘unreasonable’ or ‘absurd’ were formed to aid our ancestors scratching a living on the savannahs of Africa, and the Universe is not obliged to conform to them”.

But perhaps one could give one step behind, and attempt to rescue intuitiveness and *Anschaulichkeit* by adding more metaphysics to the view. One may think that a specifically metaphysical answer to Chakravartty’s challenge could come to de Ronde’s help here. A metaphysical description in terms of modality, or dispositions, could be provided, which filled the desiderata of intuitiveness and *Anschaulichkeit*. The literature on powers/dispositionalism

¹¹ See also Arenhart and Arroyo (2021b).

is immense, and locating de Ronde’s logos approach among it is a challenge that would deserve an article by itself. In large part, this would be challenging as the logos approach proponents themselves do not discuss directly with the recent literature on the topic (see Marmodoro, 2010b; Vetter, 2015; Meincke, 2020); rather, they are focused in the ontological aspects of powers, viz., in the discussion of how the objective existence of immanent powers with definite potentia is crucial to the functioning of the logos approach. Still, we have some hints on how this can be done in future articulations and developments of a metaphysical profile of the immanent powers for the logos approach. As Marmodoro (2010b, p. 1) outlines if a world of powers is admitted, one has two basic philosophical choices: either powers *or* something else is fundamental and everything else comes from them, or powers *and* something else is fundamental. These would be the Monist and Dualist stances, respectively. As the logos approach puts the immanent powers in the base of their ontology, it could arguably be suitable for a Monist/Pandispositionalist metaphysical profile according to which only the powers are fundamental, such as the view held by Bird (2010) called “Strong Dispositional Essentialism”. But this is, we stress again, a work yet to be done. However, this, recall, would move the position away from the kind of shallow realism that seems to be proposed by de Ronde to a more substantial (or *deep*) one.

The notion of “pure powers” —or “pandispositionalism”— has been criticized by Psillos (2006), who claim to provide a *reductio* against the conceivability of powers without bearers: “[...] to say, for instance, fragility is directed to its manifestation even when it is *not* manifested is to say that fragility (F) has the power to manifest itself [...] when unmanifested, F has the *power* Q to manifest itself” (Psillos, 2006, p. 139).¹² This, of course, puts pressure on the ontological import of the logos approach, which is an ontology of unactualized powers, hence very similar to the pandispositionalist approach criticized by Psillos (2006). While we are not sure how friends of the logos approach may respond to such criticism, this seem to be one of the open problems for this view; one of which metaphysicians of science may help articulate such view in more fine-grained metaphysical terms. Note that the logos approach is an eliminativist view not only towards objects but also on actuality: the basic entities, the potential state of affairs, are unactualized entities. So, for instance, it is not a matter of potentiality preceding actuality in the sense recently developed by Tahko (2022) in which “[u]ltimately, we want to know what is actual. This is what both philosophy and science aim to do. But our tools to determine what is actual are limited and we can make mistakes”. The logos approach is a much radical view which needs further metaphysical development.

Once that major step in metaphysics is provided, however, we face traditional difficulties of the connection of metaphysics with science. The biggest trouble with versions of realism that are designed in terms of metaphysics is that they also get underdetermined by quantum mechanics. We may indeed form such a picture, but then we have the problem of connecting it to reality

¹² For a criticism of Psillos’ criticism, see Marmodoro (2010a).

without appealing to the kind of preferences that de Ronde characterized as ‘prejudices’. It seems that, at the end of the day, the image will have to be informed by our favorite metaphysical picture, and this is not tied to the formalism of the theory, but rather imposed on it —metaphysics, in this sense, *floats free* from physics, and then metaphysical underdetermination must be taken for granted (a more detailed discussion on a methodology of metaphysics that goes in this direction can be found in Arenhart, 2019; Arroyo and Arenhart, 2022). To some, this statement may seem like an overreaction. After all, one could say that just because one cannot ‘read off’ metaphysics from physics it doesn’t mean that the two are independent. Indeed, much of the work in the philosophy/metaphysics of physics is premised on the idea that physical theory can *inform* our metaphysics. Saying exactly what this amounts to isn’t easy —it could be some kind of constraint relation, with science limiting the possibilities of metaphysics (see Arenhart, 2012; Arroyo and Arenhart, 2019) or else; saying exactly what this amounts to isn’t our proposal here. But when we enter the ‘deep’ level, that is, with metaphysics informing heavily the content of scientific realism, if that metaphysical information does not come from science, it comes from nowhere but metaphysics. It is, in some sense, an independence of the two disciplines. Of course, there is more to be said on this subject, but that would lead to an unwanted detour (see Arenhart, 2019; Arroyo and Arenhart, 2022). Thus, we just cannot grant that this is indeed how reality is, due to ontological (and metaphysical) underdetermination.

Before conceding the point for underdetermination, however, one may try to advocate between the logos approach and OSR. As is well known, OSR does not offer a solution to the measurement problem (see Esfeld, 2013; Ruetsche, 2018) but, on the contrary, depends on particular solutions to the measurement problem e.g. Bohmian mechanics, Everettian quantum mechanics, etc. This could count in favor of the logos approach, as it is characterized as a dissolution of the measurement problem. On this basis, friends of the logos approach could argue that OSR should be rejected in favor of the logos approach on this basis, i.e., one could simply suggest discarding OSR by virtue of not addressing the measurement problem, while the logos approach does.¹³

There are two ways in which such a result could be problematic to the logos approach, however. It is surely the case that the logos approach allegedly dissolves the measurement problem, rather than solving it. Recall, it re-states the measurement problem in terms of the problem of superposition, which is the problem of finding the appropriate conceptual framework that can meaningfully describe superpositions. Relatedly, in this case, the logos approach would have to explain why/how every time powers with their respective potentia acquires a specific potentia value of one when interacting with measurement apparatuses —which is a way to restate the measurement problem. Let us recall the situation between Matthias and John, two baseball players, where de Ronde (2017a, 682) states that: “[i]t is more probable that Matthias batters a ball than John, however, this is in no way determined before the actual ef-

¹³ We would like to thank an anonymous referee for making such case.

fectuations take place”. As it seems, the measurement problem was expelled through the front door but ended up reentering through the back door. For another illustration of the case, consider Schrödinger’s cat case. Before a measurement, it has both the powers of being dead and of being alive, with equal potentia (one half each, say). How do we explain that one of such a power vanishes—being alive, let us say, assuming that the cat is found dead in the box—, and the potentia related to ‘to be dead’ changes to one! Is it not the measurement problem in disguise?

Alternatively, allies of OSR might argue that this stance is a meta stance towards scientific theories; in particular, a meta-posture that can be invoked to make sense of the structural continuity between changes in scientific theories (see Manero, 2022)—thus answering the antirealist problem of pessimistic metainduction, but not the problem of underdetermination. In this way, it could be argued that the logos approach could be ‘translated’ into structuralist terms, such as the many-worlds interpretation of Everettian quantum mechanics was (see Wallace, 2012).

Be that as it may, none of the three alternatives mentioned were sufficiently developed by the metaphysics of science, which can result in extremely fruitful debates both for the foundations of quantum mechanics and for the metametaphysical debate about the naturalization of metaphysics. It all boils down to epistemic humility, as French (2014) has already anticipated. Ontological claims cannot be directly given by physical theories (e.g. QM does not tell whether an electron is an object, an immanent power, or a structure), therefore a humble attitude must be adopted towards ontology—and, consequently, to metaphysics. The amount of humility one should adopt, however, is a dilemma: if too much, one runs the risk of just telling the same story that relevant scientific theories already do (thus not addressing ontological and metaphysical issues); if too little, then one may have to face underdetermination. It seems that the logos approach and representational realism, by reducing humility in their attempt to express *physis*, end up being doomed to underdetermination—at least in the current state of the art.

5 Conclusion

Let us take stock and bring together all that we have said. As we have seen, de Ronde has a tripartite approach to the problem of the ontology of quantum mechanics. First, there is a criticism of current approaches, based on technical results such as Kochen–Specker and Bell’s theorem. It seems that these results somehow limit the capacity of object-oriented ontologies to really explain what is going on in quantum mechanics, and their use is, according to de Ronde, a result of uncritical prejudice brought to the understanding of the theory.

A physical theory has a conceptual component that is used to understand it and the empirical data. It is this that must be made clear. As the second step in his proposal, de Ronde suggests that we follow the formalism very closely and attempt to extract the ontological picture from the theory. According to

him, when the formalism is taken seriously, one ends up with a world populated with potential states of affairs, which are understood in terms of immanent powers and their respective potentia. However, as we have argued, there is a major epistemological gap here: one cannot claim to coherently extract an ontology from quantum theory, one has ontological underdetermination due to the many distinct ontological pictures that are compatible with the theory.

We then come to the demand that a conceptual scheme should provide for an intuitive understanding of a theory, we should have a visual image of it in terms of the scheme. This demand, as a methodological demand on any candidate for a conceptual scheme of quantum theory, faces two major difficulties. One of them is the very idea of having to be intuitive. What if reality is totally strange to our all too human demands of intuition? This is the kind of challenge advanced already by Ladyman and Ross. The other problem comes from how we typically understand the aim of having a clear picture. It could come as an answer to Chakravartty's challenge: in order to be a realist about the posits of a theory, one must have a clear picture of them. However, typically, one has two options to face such a challenge; either remain at a shallow level, pointing to the description of the theory, or else going to a (deep) metaphysical description. As we have argued, both possibilities mean trouble in de Ronde's case. Remaining at the shallow level seems to leave us with no clear picture, we just repeat the theory (and, for that matter, we face ontological underdetermination); going metaphysical introduces another layer of underdetermination and, perhaps, further prejudices.

There is no easy way out. The fact that de Ronde is willing to somehow subvert the current approaches and avoid most of the difficulties faced by other traditional approaches is a merit of his approach; however, as we argued, he ends up in the same boat as everyone else. The result is that contrarily to what de Ronde has suggested, his proposal is not a way to avoid commitment to uncritical images of reality,¹⁴ but rather, one further position in the already huge cart of options of quantum mechanics.

Conflict of interest

The authors declare that they have no conflict of interest.

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¹⁴ Which, by the way, is an unfair evaluation of current approaches to quantum mechanics.

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