Scientific Realism and Primitive Ontology

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Abstract

In this paper I wish to connect the recent debate in the philosophy of quantum mechanics concerning the nature of the wave-function to the historical debate in the philosophy of science regarding the tenability of scientific realism. Being realist about quantum mechanics is particularly challenging when focusing on the wave-function. According to the wave-function ontology approach, the wave-function is a concrete physical entity. In contrast, according to an alternative viewpoint, namely the primitive ontology approach, the wave-function does not represent physical entities. In this paper, I argue that the primitive ontology approach can naturally be interpreted as an instance of the so-called 'explanationism' realism, which has been proposed as a response to the pessimistic-meta induction argument against scientific realism. If my arguments are sound, then one could conclude that: (1) contrarily to what is commonly though, if explanationism realism is a good response to the pessimistic-meta induction argument, it can be straightforwardly extended also to the quantum domain; (2) the primitive ontology approach is in better shape than the wave-function ontology approach in resisting the pessimistic-meta induction argument against scientific realism.

1. **Introduction**

Scientific realism would be a commonsensical philosophical position if there weren't powerful counter-arguments to it, the most famous of which is the pessimistic meta-induction (PMI) argument: since past successful theories turned out to be false, it is unwarranted to believe that our current theories are true simply because they are successful [Laudan 1981]. Some scientific realists have responded to the PMI argument by restricting realism to a subset of the theoretical entities of the theory. One particular way of doing this is explanationism realism (ER), according to which one should be realist with respect to the working posits of the theory, namely the ones involved in explanations and predictions and that are preserved in theory change. In contrast, one does not need to commit herself to believe in the existence of other presuppositional posits that theory makes, since they are somewhat 'idle' components [Kitcher 1993], [Psillos 1999].

The proponents of this version of restricted (or localized, or selective, or preservative) realism focus on examples like Fresnel's theory of light that postulated the existence of ether, and argue that ether hasn't played a crucial role in the success of the theory, and did not carry over to Maxwell's electrodynamics. Because of this, the realist should commit to the existence of electromagnetic waves but not to the existence of ether. Similar arguments have been put forward for phlogiston and caloric. I think that analyzing these 'classical' examples is important and interesting; nonetheless, the case for ER is fundamentally incomplete if one does not show that also in the theory change from classical to quantum mechanics the working posits of classical mechanics are preserved in quantum theory, and that they play an essential role in the predictions and explanations of both theories. In this paper, I argue that ER can be extended to the quantum framework. In order to show this, I discuss the different realist approaches to quantum mechanics, which fundamentally differ in the interpretation they provide of (what seems to be) the fundamental object of quantum mechanics, namely the wave-function. On the one hand, according to the so-called wave-function ontology (WFO) approach, the wave-function is a concrete physical entity [Albert 1996], [Ney 2013], [Lewis 2004]. In contrast, according to the primitive ontology (PO) approach [Allori et al. 2008], [Allori 2013], the wave-function does not represent physical objects. I argue that the PO approach can naturally provide what ER needs to defeat the PMI argument when applied to the transition from classical to quantum physics. In fact the PO can be identified with the working posits of the theories, and as such: (1) it is primarily responsible for the success of both classical and quantum mechanics, and (2) the PO is (suitably) preserved in the classical-to-quantum transition. Therefore, the realist should commit to the existence of the PO, while she can be 'neutral' with respect to the other theoretical components of both theories. In this way, the PO approach provides an interesting framework for the scientific realist, given that it allows ER to naturally extend to the quantum domain.

To conclude, I wish to underline that ER so understood provides an argument in favor of the PO approach when compared to the WFO approach: in virtue of being preserved in theory change and playing a crucial role in the success of the old and the new theory, the PO does not fall prey of the PMI argument. In contrast, if one insists, like a proponent to the WFO approach would, that the wave-function represents physical objects, then it is hard to see how the working posits can be the same in both theories, given that the wave-function does not have any classical analog. Because of this, the wave-function ontologist seems to be in trouble: if the ontology of quantum mechanics is fundamentally different from the one of quantum theory, how can we respond to the PMI argument? Other options could be available to the proponent of the WFO approach, like for instance structural realism, but surely not ER, which is available only to the primitive ontologist.

The paper is structured as follows: in the next section, there is an overview of the PMI argument and of the replies to it in terms of restriction of realism, with a particular emphasis to ER. Then in Section 3, the discussion focuses on the necessity of extending ER to the quantum domain. The PO approach is presented and succinctly discussed, in Section 4, underlining how the PO is preserved through theory change and how it is fundamentally responsible for the empirical and theoretical success of the theory. The last section discusses the advantage of the PO approach over the WFO approach in responding to the PMI argument: while the primitive ontologist can use an explanationist realist strategy, the wave-function ontologist will have to find something else.

2. The Pessimistic Meta Induction and Explanationism Realism

Scientific realism is, roughly put, the view that scientific theories give us a (nearly) truthful description of the world. So, scientific theories discuss the behavior of a number of unobservable entities (e.g. electrons), and the scientific realist claims that we have good reasons to consider these entities as truly existing. The main argument for scientific realism, the no-miracle argument (NMA), can be summarized as follows: "realism is the only philosophy that does not make the success of science a miracle" [Putnam 1975: 73]. That is, the empirical success of a theory can and should be taken as evidence of its truth. Nonetheless, there are very powerful arguments against scientific realism, one of them being Laudan's PMI argument. The main idea is that it is not the case that, against the NMA, the empirical success of a theory is a reliable indicator of its truth. Here is a way to spell the argument out, as a proof by contradiction:

Premise 1: Empirical success is a reliable indicator of truth (*reductio* assumption);

Premise 2: Our most current theory is true;

Premise 3: Most past successful theories are false;

Conclusion: Therefore, empirical success is not an indicator of truth.

More succinctly: our current theories, even if successful, are more likely to be false than true since many past theories were successful but false.

One way to respond to the PMI challenge is to restrict realism, and argue that one should be realist about a restricted set of entities, not about the whole theory. This is what Psillos calls a *divide et impera* strategy: scientific realists may argue that "when a theory is abandoned, its theoretical constituents, i.e. the theoretical mechanisms and laws posited, should not be rejected *en bloc*. Some of those theoretical constituents are inconsistent with what we now accept, and therefore they have to be rejected. But not all are. Some of them have been retained as essential constituents of subsequent theories" [Psillos 1991: 108]. So, if one can show that the entities that are retained in moving from one theory to the next are the ones that are responsible for the empirical success of the theory, the PMI argument is blocked. In fact, this argument works only if one assumes that past theories are false in their entirety, even if they were successful, so that their success has to come from something else other than their truth. By restricting realism, instead, one provides an alternative explanation for the success of past false successful theories: past theories were successful not because they were (approximately) true in their entirety, but because some parts of them were. And these true constituents of past theories are responsible for the theories' success and they are carried over in theory change. Because of this, we are justified in believing that the entities these theoretical constituents represent really exist.

There are various ways to restrict realism, namely, there are different ways to resist the PMI by limiting the number or the kind of entities in the theory the realist should be taking 'ontologically seriously.' One such example is Worrall's structural realism (SR) [Worrall 1989]. According to this view, what is preserved in theory change is the mathematical structure of the theory, rather than the theoretical content of the theory: the PMI is correct in saying that we often have discontinuity in theory change at the level of unobservable entities, but most of the mathematical content of the old theory carries over to the new one. Because of this, the scientific realist may not be justified in believing what the theory says about the nature of physical objects, nonetheless she is justified in believing that the structure that holds between these objects which is preserved in theory change is (approximately) true. There are different varieties of SR, but a first rough distinction is the one between epistemic SR and ontic SR. In the epistemic version, which some attribute to Worrall himself, the claim is that we do not have justification for believing that objects have the nature our theories suggest they have, but we are only justified in believing that these objects stand in certain structural relations with one another. Ontic SR instead goes further and claims that the very notion of objects is problematic and is worth dismissing [French 1998], [Ladyman 1998].

There are other responses to the PMI argument[1], but in this paper I will focus on ER, developed most prominently by [Psillos 1999] and [Kitcher 1993]. They distinguish between 'working' and 'presuppositional' posits (or 'idle wheels') of a theory, and argue that one should be realist about the working posits but not the presuppositional posits, and this is because these posits are not involved in the success of the theory. In fact, if one analyzes the mechanism of empirical success of past theories one will see, they argue, that only certain entities are involved, namely the working posits. The theory postulates the existence of other entities too, for a variety of reasons, but these entities are never used to derive predictions or to provide explanations in the framework of the theory. If the working posits are preserved during theory change, while the presuppositional posits are not, the argument goes, one is justified in believing in the working posits of a theory exist. The other theoretical constituents, the presuppositional posits, are 'idle' components, which make no difference to the theory's success and thus the realist has no need to commit to.

In this way one can resist to the PMI argument: past theories were successful because they got something right, namely the working posits, but they are also false when considered in their entirety because they got something wrong too, namely the presuppositional posits.

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[1] Most notably, another restriction of realism is entity realism [Hacking 1982], according to which realist commitments should be limited to unobservable entities that could be causally manipulated. In addition semirealism [Chakravartty 2007], which in certain respects is in-between structuralism and entity realism, recommends realism with respect of the so-called detection properties, namely the properties in the theory which are tied to our perceptual and causal experiences, and not to auxiliary properties, which are not essential in establishing existence claims. Therefore, one should restrict realism to the detection properties.

3. The Classical-to-Quantum Theory Change as a Problem for Explanationsim Realism

Scientific realism has been motivated and discussed almost exclusively discussing theories other than quantum mechanics. In particular, Psillos and Kitcher argue for ER discussing that Fresnel's theory of light was successful because it got the working posit right, namely the electromagnetic waves: they are responsible for the success of the theory, and they were preserved by Maxwell's electrodynamics. In contrast, ether was a presuppositional posit: the success of Fresnel's theory did not depend on it, and it was abandoned by the subsequent theory. Realists are therefore justified in believing that electromagnetic waves exist, but do not have to be committed to believe that ether exists too. Another example extensively discussed in the literature is the caloric theory of heat, or phlogiston's theory of combustion, to again arrive to the conclusion that caloric and phlogiston are presuppositional posits. In reply, these historical examples have been revisited with the intent of arguing that ether, caloric, phlogiston, and the like, contrarily to what it is maintained by ER, played an important role in the success of past theories (see, e.g. [Elsamahi 2005], [Chang 2003]).

Regardless of what the outcome of the debate over these examples is, it seems to me that the main threat to ER comes from the transition from classical to quantum theories. The fact that the discussion was limited to 'classical' theories is, in a sense, not surprising: quantum mechanics has been considered, for a long time, incompatible with realism: while, on the one hand, quantum theory is incredibly powerful in making new and very precise predictions, on the other hand it is extremely difficult to understand what image of the world it provides us. Indeed, quantum mechanics has been taken by many to suggest that physical objects have contradictory properties, like being in a place and not being in that place at the same time, or that properties do not exist at all independently of observation. Given that, many have thought that the real lesson of quantum mechanics is that the dream of the scientific realist is impossible: the theory is extremely successful, but it seems impossible to explain this success in terms of the theory being (approximately) true, unless one is willing to give up, say, classical logic or the like to account for the existence of objects with contradictory properties. Luckily, the situation has changed: today we have various proposal of quantum theories that allow for a realist reading. Among these theories, most famously we find Bohmian and Everettian mechanics (BM and EM respectively), and the GRW theory (GRW): they are empirically adequate fundamental physical theories according to which there is an objective physical world, which can be described by non-contradictory, mind-independent properties.

The problem for ER is that even assuming that one could be a realist with respect to quantum mechanics, quite strikingly, when examples from quantum mechanics are discussed, they are brought up to motivate ontic SR rather than ER: "we have learned from contemporary physics is that the nature of space, time and matter are not compatible with standard metaphysical views about the ontological relationship between individuals, intrinsic properties and relations" [Ladyman 2014]. In addition, and presumably more importantly, it does not seem obviously the case, as an explanationist realist would have to maintain, that some theoretical entities of past theories are carried over to quantum mechanics, and they are the ones responsible for quantum mechanics' enormous success. Indeed, exactly the opposite seems to be true: in quantum mechanics we have the Schrödinger equation, which is the evolution equation of the wave-function, an object which is involved in the derivation of most, if not all, predictions and explanations the theory is able to provide, and which arguably does not have any classical analog. If so, ER seems to be doomed: not only the wave-function is something new to classical mechanics, but it seems to be the fundamental object that drives quantum mechanics in all its explanations and predictions. We have radical discontinuity and therefore the PMI argument has not been blocked.

In light of all this, I think that case for ER has no hope of being compelling if does not cover quantum mechanics. In the next section I show how ER can be extended to quantum theories if paired with a particular view about the metaphysics of quantum mechanics, namely the PO approach.

4. Primitive Ontology and Explanationism Realism

Most philosophers of physics recognize the legitimacy of BM, EM and GRW, but disagree about the metaphysical pictures these theories actually provide. In this section, I wish to show how the PO theories provide examples of quantum theories with the same (or suitably similar) working posits as classical mechanics. That is, the claims are going to be that: (1) the PO is the primary responsible of the theory's success; and (2) the PO (suitably) carries over during theory change. If so, assuming that a strategy like ER is successful in defending scientific realism, the PMI argument is blocked: the realist is justified in believing that the PO is real because it does all the work to explain empirical success of theories and it is preserved in theory change.

Here is a brief summary of the PO account [Allori et al. 2008]. In quantum theories understood within the PO framework, there are two fundamental ingredients that are supposed to represent, respectively, what matter is, and how matter behaves. Matter is represented by entities in three-dimensional space (or four-dimensional space-time), which are the PO of the theory. Examples of possible primitive ontologies include point-particles, continuous fields, and spatio-temporal events (flashes). Quantum theories with different primitive ontologies are discussed and analyzed by the proponents of the PO approach in different papers, and some examples are worth mentioning: BM is a theory with a particle PO, GRWm is a theory in which matter is described by a continuous (three-dimensional) matter field localized where the macroscopic objects are, while GRWf is a theory of flashes, namely discrete spatio-temporal events. How matter behaves is explicated in terms of the law of evolution of the PO, which in turn is implemented by the so-called 'nomological' variables, most

importantly by the wave function. Therefore, even if the wave-function evolves in time (according to either the Schrödinger equation or some variant of it), it *never represent matter*. One cannot dispense of the wave function from quantum theories[2] but that does not mean, according to the proponents of this approach, that we should think the wave-function represents material objects. Rather, it is a necessary ingredient to implement the law of temporal evolution of the PO [Allori 2013]. To continue with the examples mentioned above, we have that in BM the wave-function evolves according to the Schrödinger equation, while in GRWf and GRWm it evolves according to Schrödinger equation and then randomly collapses, following the so-called GRW evolution.
Here are some fundamental features of the PO approach that is crucial to articulate:

(1) [REDUCTIONISM wrt PO] The motivation of the PO approach is to account for the existence of macroscopic objects, which are thought to be fundamentally composed of the microscopic entities the PO specifies. As such, the PO approach is reductionist, at least to the extent that it allows to make sense of claims like the PO being "the building blocks of everything else," and of the idea that macroscopic regularities are obtained entirely from the microscopic trajectories of the PO.

(2) [EXPLANATION and PO] The PO explains the macroscopic regularities using reductionist approaches similar to those used in classical mechanics. In fact, in classical mechanics, macroscopic bodies are made of a collection of particles, and their properties are accounted for in terms of the interaction of these particles among each other and the particles of the environment. For instance, the transparency of a pair of glasses is explained in terms of the electromagnetic forces acting between the particles composing the glasses, which are such that incoming light rays will pass through them. Similarly, the PO grounds the explanatory schema of quantum theories: macroscopic objects are made of entities described by the PO, and their properties are in principle accounted for in terms of the PO's behavior (see [Allori 2013]).

(3) [THEOREITICAL VIRTUES] What variable is the PO of a theory is postulated, rather than inferred from the formalism. One PO is chosen over another on the basis of some super-empirical virtues such as simplicity, explanatory power, and unification: the PO that provides the simplest, most unifying explanation should be selected (see [Allori 2015]). Because macroscopic regularities are accounted for in terms of PO and because the role of the wave-function is to implement the law for the PO, the nature of the PO (particles, field, flashes,…) is not necessarily connected to the law of evolution of the wave-function (Schrödinger, GRW…): for instance in BM the PO of particles is connected with

[2] To be precise, some attempts have been made to eliminate the wave-function entirely from quantum theories (see e.g. [Dowker Herbauts 2005] and [Norsen 2010]).

a Schrödinger evolving wave-function, but one can imagine a theory of particles with a GRW-evolving wave-function, (see [Allori et al 2014] for more examples).

(4) [UNDERDETERMINATION of PSI] The way the wave-function evolves in time is irrelevant as long as the law of the PO such wave-function defines remains the same: a theory of particles which follow certain trajectories, like BM, can be obtained by a Schrödinger-evolving wave-function, like in the usual formulation, but also in terms of a collapsed wave-function (see [Allori et al 2008] for details). Two theories with the same trajectories for the PO, regardless of how they have been obtained (i.e., via a Schrödinger evolving wave-function or not) are called physically equivalent. Since different wave-functions can give rise to the same trajectories for the PO, and since the trajectories of the PO are the ones that account for the macroscopic regularities, the wave-function evolution is underdetermined by the data.

(5) [PREDICTIONS] Once the PO and its law of evolution have been chosen, everything else is determined, including the empirical predictions which are determined as a function of the PO. The wave-function appears into the derivation of the predictions of the theory, but its role is not essential, since as we just saw, the way in which it specifies the law of the PO is underdetermined(see [Allori et al 2014] for more on this point).

Now, the idea that I wish to put forward is that there are striking similarities between the PO approach and ER. In particular, it seems to me that the PO can be identified with the working posit of quantum mechanics, while the wave-function is best seen as a presuppisitional posit. In fact, as we saw in (5) above, the predictions are determined by the PO, not by the wave-function, which does appear in the derivation, but whose evolution is underdetermined by data, as we saw in (4). In addition, as we saw in (2), explanation is in terms of the PO, and this reminds of Kitcher's idea that working posits are the entities that play a fundamental role in the theory's explanatory schemata. Moreover, there is the explicit fundamental postulation that the PO represent matter, while the wave-function does not, and that everything is made of the entities the PO specifies, as we saw in (1). The PO approach suggests we should be realist about the PO, regardless of what we think the wave-function really is. In fact, all primitive ontologists (or supporters of suitably related views) maintain that one should be realist about the PO, but they have different ideas about the wave-function: it has been considered to be, among other things, a law-like object [Goldstein et al. 2013], a disposition [Esfeld et al. 2014], a property [Monton 2006], or a new kind of entity [Maudlin 2013]. Nonetheless, one can be 'metaphysically neutral' with respect to the wave function: one does not need to postulate the existence of the wave-function in order to account for the success of the theory. But this is to say that the PO is a working posit, while the wave-function is a presuppositional posit of quantum theories. If so, the PO approach provides a very nice framework for the explanationist realist to extent her view in the quantum domain: one should be realist about the PO because it is the sole responsible for the theory's success.

However, this is not enough to successfully reply to the PMI argument: one would have to show that the PO is preserved during theory change. What is the PO of classical mechanics? The answer seems to be straightforward: according to classical mechanics, matter is made of particles, intended as objects with the fundamental property of having a position in three-dimensional space. Therefore, since we do not need to worry about the wave function, the preservation of PO during the classical-to-quantum theory change is obvious for quantum theories of particles, like BM. The interesting and more challenging cases are the ones that involve POs different than that, namely a mater density PO or a flash PO. In both cases, literally, the PO of classical mechanics has not carried over. The nature of the objects the theories postulate is fundamentally different: on the one hand in classical mechanics we have particles fundamentally identified by having a definite position in space and following given trajectories in space-time; on the other hand, we have either a continuous matter filed in GRWm, or a discrete set of spatio-temporal event in GRWf. Should we think this is an instance of radical discontinuity, and should we take this to be a reason to give up on ER? I believe this would be too harsh: what seems to be true is not necessarily that there are particles, or fields or flashes, but rather that there is 'stuff' in three-dimensional space, and this is what matter is. When there was the theory change from the theory that atoms are indivisible to the theory that atoms are made of other particles which themselves are thought as indivisible, one could maintain that what the theory got right is that there are particles, but it was wrong about which the fundamental particles really were: we thought they were atoms, but they are neutron, protons and electrons instead. The situation here is slightly different, being more similar to the case in which we move to a theory in which the fundamental entities are particles, to a theory in which the fundamental entities are instead strings. What are we getting right here? Not the nature of the fundamental: before we had one-dimensional particles, now we have bi-dimensional vibrating loops. However, I think it is important to underline that if we 'squint,' then we don't see the fine-grained details, and we take strings to be particles. They are, for all *explanatory* purposes, particles: we need to explain the macroscopic regularities, and we explain them in terms of the PO ignoring the details about what composes it. Just like when we observe a hose from a distance and we think it is one-dimensional while it is actually two-dimensional, or when we look at a poster in the subway and we think it's an image while instead it is a collection of colored dots. At the level of microphysics we may have flashes or a continuous field, but at some mesoscopic level they produce trajectories as if they are produced by particles. So, even if the microscopic PO is not one of particles, there is a mesoscopic scale in which they behave as if they are, and then from that level up to the macroscopic level, the explanation is the same as if they were particles.

The obvious worry here is: isn't that just some sort of (ontic) structuralism? If we do not preserve the nature of 'stuff,' isn't what we preserve some structural content of the theory? If structuralism is the view that there is just structure and no objects, then clearly not, since the PO approach postulates the existence of objects as a starting point. What about a moderate version of ontic SR, like the one proposed by [Esfeld 2004]? The idea behind this view is something like this: one should be realist about structure but, in contrast with the 'eliminativist' ontic SR mentioned above, there are 'things' that stand in the relation the structure prescribes, even if they have no intrinsic identities. In the quantum domain, such structure is the wave-function. Indeed, interestingly enough, [Esfeld forthcoming] proposes that in his moderate ontic SR, the *relata* the wave-function relates are given by the PO: he argues that the PO approach and his moderate ontic SR can help each other make sense of quantum non-locality and entanglement. So, in his view, we should be realist about the PO, and also about the structure that relates the PO, provided by the wave-function. In this sense, the reading I provide of the PO approach is not structural: the strength of the PO approach in responding to the PMI argument is that it regards the wave-function as a working posit. Only because of this, one can show there is continuity of PO during theory change. Instead Esfeld's moderate ontic SR does not have this advantage: if the wave function is the structure the realist should be committing to, then it is difficult to see where this structure was coming from in classical physics.

The PO approach entails something like this: we do not get the nature of objects right because we believe they are particles in classical mechanics and then we discover they are actually, say, flashes in quantum mechanics; but we get some 'structure' right, namely that on some mescoscopic level they behave as if their nature were the one of particles. One may call it structural realism, but it does not seem to have much in common with the other varieties of SR we just examined. Rather, more appropriate in my opinion is the connection with ER: what provides the explanation, namely the PO, is what 'ontologically counts,' if it is preserved in theory change.

Another interesting question is whether the PO approach can help reply to some of the objections that have been raised to ER, most notably the problem that it is not clear whether it is possible to precisely and objectively identify the working posits of a theory rather than doing that post hoc: the working posits are what we see have carried over (see, e.g. [Stanford 2003a, 2003b]). Indeed, the PO approach seems to provide an improvement with respect to ER: the PO is postulated when the theory is proposed, rather than inferred from the formalism, as the one that provides the best combination of simplicity, explanatory and unificatory account of the experimental data. In this way, what is a working posit is selected from the time the theory is proposed, and it is never "post hoc." If the PO, together with the explanatory schema, is preserved during theory change, then there is no radical discontinuity and the PO is truly a working posits.

5. A New Argument for the PO Approach

To summarize the last section, I have shown how the PO approach may naturally be seen as an instance of ER in which one restricts realism to the PO: since the PO is carried over in theory change, and it is the primary responsible for the theory empirical success, then one is justified in believing the entities it represents really exists. As such, the PO approach provides the ER with a straightforward strategy to block the PMI in the quantum framework.

In this section, I wish to notice that this analysis of the PO approach as an instance of ER also provides the PO approach with an important advantage over the alternative WFO approach. According to this view, the wave-function is a concrete physical field and should be regarded as representing matter. If we analyze this view in terms of ER, therefore, the wave-function has to be a working posit of quantum theory. The problem with this is that, mathematically, the wave-function is an object that lives in the highly dimensional configuration space, and as such is a very different entity from classical particles. In addition, the image of the world provided by the WFO approach is very different from the image of the world given to us by classical mechanics: in the latter there are particles moving in three-dimensional space, in the former there is this matter field in a highly-dimensional space. In the classical-to-quantum transition we discover that not only we were getting the nature of objects wrong (we believed there were particles and actually there are none) but we cannot get our classical picture back by 'squinting,' like in the PO framework, since the fundamental physical space is not three-dimensional. In this way, there is no continuity of working posits between classical and quantum mechanics, and the strategy to resist to the PMI argument along the lines of ER is precluded to the proponent of the WFO approach. If there is truly a quantum revolution, as the WFO approach seems to maintain to a give extent (see [Allori 2015] for an interesting take on this), and the way in which we understand the word using quantum theory is fundamentally different from the way in which we understood it in classical terms, what is our justification to believe that the theoretical terms used in quantum mechanics are (approximately) true? It is difficult to see how the PMI could be defeated in the WFO framework, unless they go eliminative structural realists, and they may not want to do that, given the numerous objection that have been raised against this view (see, e.g. [Psillos 1999], [Chakravartty 2007], [Cao 2003] among others).

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