Perspectives on Quantum Theory

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Abstract

This paper considers the prospects for a quantum perspectivism that seeks to reconcile competing approaches to quantum theory as distinct scientific perspectives on quantum reality. In other areas of the philosophy of science, perspectivism holds the promise of a way to embrace pluralism without contradiction—what appear to be competing theories can be accepted because they each provide a distinct "window on the same reality." The contemporary situation in quantum foundations is arguably a case of underdetermination. If this is so, this brand of perspectivism may offer a resolution.

Keywords: quantum, underdetermination, perspectivism, perspectival, structuralism, realism

Give me the Heisenberg, Schrödinger, Feynman, and Bohm versions of quantum mechanics: so many different ways of appreciating the physical world, more windows on nature, more enriched understanding of it. Why is this any worse (or better) than having galleries full of the crucifixion of Jesus Christ depicted in so many different ways by so many wonderful artists?

– Chang (2012)

Despite their radical differences, I think each of many opposed views [of quantum theory] gets something importantly right. I cannot improve on an ancient but overworked metaphor. Their proponents are like men who give conflicting accounts of an animal they all scrutinize in the dark. One says it is a throne, another a pillar, a third a fan, a fourth a waterspout. While none of them is wholly wrong, none of them is completely correct. For the animal is an elephant, whose back is like a throne, whose leg is like a pillar, whose ear is like a fan, and whose trunk is like a waterspout. Each has incorrectly generalized to the nature of the whole animal from how it appears from one perspective. Quantum theory is an elephant, whose complete understanding requires the integration of many partially correct perspectives. A philosopher must shed light on the whole beast.

– Healey (2017b)

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1 Introduction

When perspectives have been invoked in the interpretation of quantum theory, they have typically been the perspectives of *agents* using quantum theory. Indeed, according to some interpreters, quantum theory involves an ineliminable reference to agent perspectives.[1] Such views stand in opposition to the common interpretative assumption that quantum theory provides a "God's-eye" description of reality. Of course, such an interpretative move is controversial, and critics allege that it leads to antirealism (or even solipsism).[2]

Another possible application of perspectives to quantum theory has received comparatively little attention. This kind of quantum perspectivism applies at the meta-level and seeks to reconcile the competing approaches to quantum theory as distinct *scientific* perspectives on quantum reality. There are clear connections between this interpretative stance and the discussion of perspectivism in the general philosophy of science.[3] In that context, perspectivism holds the promise of a way to embrace pluralism without contradiction—what appear to be competing theories or models can be accepted because they each provide a distinct perspective on the same underlying reality.

The current situation in quantum theory is arguably one of underdetermination; there are several seemingly incompatible approaches to quantum theory. One possible reaction is to step back from scientific realism. Perhaps we are not in a position to say anything about reality on the basis of quantum theory. But, elsewhere in the philosophy of science, pluralism is on the rise (Ludwig and Ruphy, 2021). In other contexts, philosophers have sought to embrace the plurality of theories used by scientists by taking each to represent a distinct *scientific perspective* on the target phenomenon. Rather than being in conflict, this version of perspectivism views the different theories as complementary "windows on nature."

This suggests a quantum perspectivism applied at the meta-level, that is, to quantum foundations itself. Whereas agent-perspectival approaches emphasize the role of agent perspectives in the correct understanding of quantum theory, a *scientific-perspectival* approach takes the various "interpretations" of quantum theory to reflect distinct scientific perspectives on quantum reality.[4] The former rejects a unique God's-eye perspective on a quantum system, while the latter rejects a unique perspective on quantum theory itself.

I begin, in section 2, by presenting the problem of underdetermination of the correct approach to quantum theory. While some have tried to diffuse the problem, I argue that it remains a challenge for those who would like to take a realist attitude toward quantum theory. Next, in section 3, I consider the apparent disanalogies between quantum

[1] QBism and quantum pragmatism are two notable examples. For an overview, see Healey (2017a). Relational quantum mechanics may also be considered a view of this kind (Rovelli, 1996; Laudisa and Rovelli, 2024).

[2] For criticisms of QBism's realist credentials, see Hagar (2003); Bacciagaluppi (2014); Norsen (2016); Brown (2019); Earman (2019). This is at odds with the avowed realism of QBists such as Fuchs (2017) and Mermin (2014). Healey also defends quantum pragmatism from charges of antirealism (Healey, 2020).

[3] Some notable discussions of scientific perspectivism include Giere (2010); Massimi (2022); Teller (2018); van Fraassen (2008).

[4] Below I will argue that the standard terminology of "interpretations of quantum theory" is misleading. It is not plausible to regard the various approaches to quantum theory—associated with different solutions to the measurement problem—as different interpretations of a common theory.

foundations and standard cases used to motivate scientific perspectivism. While there are differences, I urge that they do not rule out applying perspectivism to the case of quantum foundations. Section 4 sketches the version of quantum perspectivism I have in mind. It combines three ideas: methodological pluralism, structural realism, and perspectivism. Finally, in section 5, I conclude that the persistent underdetermination in quantum foundations motivates taking seriously a perspectivist outlook.

2 Quantum underdetermination

The discussion of underdetermination in the general philosophy of science focuses on cases where the empirical data are equivocal among multiple, apparently inconsistent, theories. Strong underdetermination occurs when there is no *possible* way to empirically distinguish the theories in question; weak underdetermination occurs when either *for now* or perhaps *in practice* the theories are empirically indistinguishable. It has been suggested that quantum theory provides a case of weak underdetermination—the various approaches are for now, or in practice, empirically indistinguishable and yet at most one can be the correct understanding of quantum theory.[5]

This is important for several reasons. First, there are no uncontroversial cases of scientific underdetermination. The sort of cases provided by advocates of underdetermination tend to be artificial constructions rather than genuine scientific theories. Second, the empirical success of quantum theory gives scientific realists strong reason to accept it as a description of reality. To the extent that there is underdetermination, this is a major problem for this project. Third, the different approaches suggest different ways of developing quantum theory going forward. Each approach corresponds to a distinct research program with its own commitments, values, and interests. This may have important implications for the future of physics (e.g., the development of a theory of quantum gravity).

Despite its initial plausibility, quantum underdetermination may be resisted. It may be denied that distinct approaches to quantum theory provide a genuine case of scientific underdetermination. Perhaps this is because the different alternatives aren't rival theories, or aren't empirically indistinguishable (for all practical purposes), or there is a common core that could be found not to depend on any particular approach, or that none of the approaches are viable. I will briefly consider several attempts to diffuse the problem and argue that each should be resisted, and hence, that quantum underdetermination remains as a challenge for the traditional scientific realist.

The standard terminology of "interpretations of quantum theory" suggests a quick dissolution of the apparent underdetermination. If different approaches to quantum theory are merely different *interpretations* of the same physical theory, then perhaps one can accept quantum theory without deciding among its many interpretations. For example, the Hamiltonian and Lagrangian formulations of classical mechanics are often regarded as different formulations of the same theory given that they are mathematically equivalent.[6] However, unlike Hamiltonian and Lagrangian mechanics, we cannot straightforwardly consider different "interpretations" of quantum theory as

[5] Wallace (2023) takes the quantum underdetermination thesis (which he rejects) to be "very widely held." For a defense of quantum underdetermination see Cordero (2001); Egg and Saatsi (2021).

[6] However, see North (2009, 2021) for a dissenting view.

distinct formulations of the same theory. The three main "realist" approaches each differ not only in their ontological commitments, but also in their dynamical laws.[7] The Everett and de Broglie-Bohm approaches are committed to linear and determinisitic dynamics, while spontaneous collapse theories (e.g., GRW, CSL) posit non-linear and stochastic laws. And compared to the Everettian (many worlds) approach, de Broglie-Bohm adds a new guidance equation that applies to an exact configuration of particles. It has become almost a consensus view in quantum foundations that the various "interpretations" are best understood as distinct *theories* aimed at reproducing the empirical data supporting quantum theory. Indeed, because there are empirical differences between the various approaches, even a committed instrumentalist would be unable to regard them as merely different interpretations of a common theory.[8]

This brings us to a more substantial objection to quantum underdetermination. Even weak underdetermination requires a degree of empirical equivalence, at least for all practical purposes or given the kinds of measurements we can actually perform right now. However, even this weak sense of empirical equivalence has been contested. In particular, Wallace (2020; 2023) argues that only the Everettian approach is able to account for empirical successes associated with quantum field theory (QFT). This is a controversial matter, as advocates of Bohmian and spontaneous collapse approaches argue that significant steps have been made toward extending their approach from ordinary non-relativistic quantum mechanics to (relativistic) QFT. But, even if we grant that there is work to be done in extending other approaches to QFT, this does not eliminate the threat of underdetermination. All approaches to quantum theory face certain challenges, and these may include accounting for certain empirical data. But if we conceive of the different interpretations as *research programs* rather than settled theories, the difficulties of extending collapse theories and Bohmian mechanics to QFT are open problems in need of addressing rather than empirical disqualifications. And hence, the challenge remains for the scientific realist: which of these provides the correct account of quantum theory? Without a knock-down argument that one and only one approach is capable of accounting for the data, the threat of underdetermination remains.[9]

Wallace responds to viewing approaches to quantum theory as rival research programs in two ways. First, that it dissolves the problem of underdetermination. And second, that rivals to the Everettian approach (unitary quantum mechanics) represent degenerate research programs. However, to the extent that the realist owes some account of quantum reality *now*—while it's still an open question which approach will prevail in quantum foundations—the problem of underdetermination remains. We

[7]For the purposes of this paper, I focus on approaches to quantum theory which seek to provide a God's eye description of reality. The three approaches considered correspond to the three most discussed ways of resolving the measurement problem. While it may be possible to extend the scientific-perspectival stance to include approaches to quantum theory which reject the demand for a God's eye description, this provides an additional challenge for standard scientific realism beyond the underdetermination problem, which is my main focus here. For attempts to reconcile realism with agent-perspectival approaches, see Evans (2020); Fuchs (2017); Glick (2021b); Healey (2020).

[8]For the purposes of this paper, I aim to remain neutral on the exact distinction between theories and interpretations. I assume only that a mere difference of interpretation cannot engender different empirical predictions or new fundamental laws.

[9]Wallace does provide a number of reasons why the present strategies for constructing Bohmian (and dynamical collapse) versions of QFTs are problematic (Wallace, 2023, 8–13). But these considerations fall short of ruling out any such construction.

may easily enough adopt a kind of *methodological pluralism* (see below), but the realist faces a problem in reconciling this pluralism with their commitment to explain (certain kinds) of empirical success by appeal to the approximate truth of the theory involved. The relative strengths and weakness of the various approaches can be weighed in different ways, and even if we follow Lakatos in associating progress with novel empirical predictions, it's not obvious that the Everettian approach can claim all of the predictions of "orthodox" quantum theory, as this requires an adequate solution to the probability problem(s) that the approach faces. Moreover, even if we grant that the Everettian approach is the most *progressive* research program in quantum foundations, this doesn't imply that the other approaches are so *degenerate* that they should be discontinued. So long as there are multiple viable approaches which seem incompatible, and the realist owes an explanation of quantum theory's instrumental success, the underdetermination problem remains.

Another way of resisting quantum underdetermination seeks to find a common core among the various approaches. If this were possible, then they may be viewed as different formulations of the same theory, and hence, the scientific realist can rest assured with a commitment to that common theoretical core about which everyone agrees. The problem with this tact is that the various approaches differ far too widely for there to be any substantive common core. As argued by Callender (2020), about the only point of agreement among the various approaches is that the textbook quantum recipe for generating predictions in the lab is adequate for all practical purposes. When it comes to the sort of things scientific realists are concerned with—laws and ontology—there is almost no overlap. Even a more limited form of realism (e.g., structural realism) would find it difficult to locate a common quantum reality in each of the mainstream realist approaches (never mind all the other approaches to quantum theory).

Despite this, Egg (2021) argues that a quantum ontology free from underdetermination can be found in textbook quantum mechanics (TQM). All of the approaches, Egg argues, agree on the basic ingredients of TQM, at a *derivative* or *non-fundamental* level. Collapse of the quantum state upon measurement, for example, is an appropriate target of realist commitment, provided it is understood as an emergent phenomenon compatible with approaches that claim only the "effective" quantum state is affected by measurement. Such a move trades on the fact that all approaches must capture TQM's empirical successes (lest they be empirically inadequate), but by elevating the (approximate) recovery of empirical predictions to the level of non-fundamental ontological commitments, it obscures the essential distinction between appearance and reality. It is a core commitment of no-collapse approaches (e.g., de Broglie-Bohm, Everett) that collapse of the quantum state upon measurement *does not occur*—it may *appear* like it does, but in reality, there is no physical process of collapse. So, to ascribe to such a view an ontological commitment to collapse, even as an emergent phenomenon, is highly revisionary. Indeed, one might argue that an approach to quantum theory which features emergent quantum state collapse is an altogether distinct approach from the extant no-collapse approaches. In order for Egg's appeal to TQM to solve the underdetermination problem, a highly revisionary view of quantum foundations and scientific realism is required. The former because, on Egg's understanding, many approaches will involve ontological commitments that they explicitly forsake (e.g., quantum state collapse upon measurement). The latter because, according to Egg, the scope of realist commitment is limited to the emergent domain of TQM and excludes nearly everything the theory says about the laws, objects, and properties that constitute underlying quantum reality.

Finally, one may argue that *none* of the extant realist approaches are viable. This pessimistic view of quantum foundations is discussed by Wallace (2023) as a possible reply to his claim that only Everettianism is empirically adequate, and central to Adlam's (2025) presentation of the measurement problem: "... the measurement problem is not just an issue of underdetermination, as it is sometimes billed—the issue is not that we have too many possible solutions but rather that right now we arguably have *no solution at all* which is both empirically adequate and able to satisfactorily address the epistemic aspects of the problem" (original emphasis, 2). The lack of a viable realist approach to quantum theory is also cited as a source of motivation for agent-perspectival views such as QBism and quantum pragmatism (Healey, 2017b; Fuchs and Stacey, 2019).

While it must be acknowledged that each of the approaches faces serious challenges, this neither eliminates underdetermination in quantum foundations nor does it help the scientific realist to overcome it. Adlam agrees with Wallace that alternatives to Everettian quantum mechanics face serious obstacles to being generalized to apply to QFT. The problem is not merely that such an extension has not yet been done, but rather, that the features of QM that an approach like de Broglie-Bohm makes fundamental simply cannot be found in QFT.[10] Moreover, Adlam finds attempts to explain the role of probability in the Everettian approach unsuccessful, rendering it *empirically incoherent*—the theory undermines the very evidence that gives us reason to believe it. So, we are left with the pessimistic conclusion that *no* extant solutions to the measurement problem are viable. However, underdetermination still remains at the level of *research programs* that seek to develop an adequate account of quantum theory. As mentioned above, even the substantial challenges discussed by Wallace and Adlam fall short of ruling out these as research programs worth pursuing. And, of course, the scientific realist is certainly no better off with no viable approaches to QM than too many. So, whether one considers the current situation one of underdetermination or lack of any adequate theory, there is a problem for the realist who owes us an account of the success of quantum theory.

The scientific perspectivalist approach sketched below seeks to address the problem of underdetermination, but may also be of help even if Adlam is right that no extant approach is acceptable. By weakening the strength of realism required, the bar for a theory's acceptability is lowered. For example, theories no longer have to provide a description of reality that is complete and universally applicable. This allows that a theory with a limited domain of applicability may be acceptable for a particular purpose. So, the worry that certain approaches to QM cannot be extended to QFT need not undermine their acceptability in the non-relativistic regime for the perspectival realist.

[10] See Adlam (2025, 177–180).

While there is much more to be said, I hope to have shown that underdetermination is a plausible assessment of the current situation in quantum foundations. The question, then, is what this means for our understanding of quantum theory. One possibility is to abandon realism. If there is no unequivocal description of nature provided by quantum theory, perhaps none should be given. The difficulty with such a view is that it leaves us with very little to say about the nature of reality. Presumably quantum theory has something to teach us about reality, so it would be unfortunate if underdetermination meant that we had to remain silent about quantum reality. Perspectivism offers an appealing alternative. Elsewhere in the philosophy of science, perspectivism has been deployed to resolve the apparent conflict between seemingly inconsistent descriptions of a target system. Perhaps this strategy could be adapted to the present case: could rival approaches to quantum theory be reinterpreted as distinct scientific perspectives on the quantum world?

3 Disanalogies

Not every case where there are multiple theories (or models) of a single target is amenable to a perspectival or pluralist attitude. In some cases, it must be granted that the theories in question are genuine rivals. A proponent of quantum perspectivism must argue that quantum underdetermination is not such a case, but this is complicated by the apparently significant differences between the case of quantum theory and the standard examples used to motivate scientific perspectivism.

First, unlike many examples in the literature on scientific perspectivism, different approaches to quantum theory apply at the same *level of description*. For example, treating a gas as a continuous substance with a certain temperature or a collection of molecules with a certain mean kinetic energy are plausibly understood as complementary models in part because they apply at different levels. Presumably, the thermodynamic description is less fundamental than the statistical-mechanical description, so it's fine that they differ in certain details. Different features become apparent at different levels, and hence, we shouldn't be surprised that models at different levels differ significantly. In the case of quantum foundations, by contrast, we are considering different approaches to the level described by quantum theory.[11]

However, it isn't plausible to suppose that distinct scientific perspectives must occupy different levels of description. While some familiar cases concern different models which neatly fall into distinct levels, others do not. Consider, for example, Morrison's (2011) discussion of models of the atomic nucleus. Morrison distinguishes between microscopic models, which focus on degrees of freedom of the individual nucleons, and collective models, which focus on bulk properties of the nucleus as a whole. However, there are a number of distinct nuclear models within each of these levels of description. Moreover, there are also mixed models, which combine elements from

[11]It's not clear that quantum theory occupies a single level of description. It is sometimes claimed that quantum theory concerns the *fundamental* level, but this is certainly not true of non-relativistic quantum mechanics, which provides the setting for the most developed versions of the de Broglie-Bohm and dynamical collapse approaches. Even quantum field theory, in the version actually used by physicists, is an effective field theory that only applies in a non-fundamental energy regime. However, the present point remains that quantum perspectivism cannot straightforwardly appeal to different levels of description to render the various approaches consistent.

both levels, such as the “unified model” which combines elements of the liquid drop and shell models in a patchwork manner. Morrison argues that each of the plurality of models used by physicists provides insight into the atomic nucleus, despite none offering a complete description that excludes (or incorporates) the others. Given that some of these models apply at the same level of description, or defy attribution to a single level, scientific perspectivism should not be restricted to models (or theories) which apply at different levels of description.

Second, the cases used to motivate scientific perspectivism are typically ones in which scientists use different theories for different applications. Again, consider the variety of nuclear models or fluid and molecular models of gasses. It does not seem to be the case that physicists use different approaches to quantum theory in different contexts. Indeed, it is uncommon to hear of physicists or philosophers who freely switch between interpretations in the way one might switch between different nuclear models to solve different problems.[12]

But scientific perspectivism’s idea that different models are adequate for different uses doesn’t require that individual users switch between theoretical models. Given that many researchers tend to stay within a particular area of application, it may be the case that we find different models used by different communities of users. In fact, there is some evidence of this in quantum foundations. Within physics, there are problems in quantum chemistry for which the de Broglie-Bohm approach is well suited (Benseny et al., 2014). And the primary motivation cited by Everett (1957) for his approach is to allow for applications of quantum theory to the entire universe, for example, in quantum cosmology.

In philosophy, it is beginning to be appreciated that different approaches are better suited to different philosophical projects. For example, the determinate configuration of particles posited by the de Broglie-Bohm approach makes it a natural fit with minimalist Humean approaches to metaphysics (Callender, 2015; Esfeld and Deckert, 2017; Miller, 2014). And the many worlds of the Everettian provide a possible naturalistic basis for David Lewis’s modal realism (Wilson, 2020). Thus, if we’re willing to adopt a broader conception of the various *uses* of an interpretative approach, there is some evidence that different approaches are better suited to different tasks. This makes space for a brand of perspectivism that allows each of the approaches to serve as a adequate model in a particular context.

While I grant that quantum perspectivism would be revisionary as compared to the standard view in quantum foundations, this is not a decisive argument against the view. After all, it’s been 100 years since the advent of quantum theory and no single approach has established a consensus position. Combining this with the fact that the case of quantum foundations isn’t as disanalgous to standard examples motivating scientific perspectivism as it may initially appear, there is reason to consider the prospects of a perspectival approach to quantum foundations.

[12] In one well known survey of researchers in quantum foundations, when asked how often they switched interpretations, the most popular answer was “never” (33% of respondents). However, the authors note that “one respondent reported, by write-in, that he sometimes switches interpretation several times per day” (Schlosshauer et al., 2013, 226). Another survey (Norsen and Nelson, 2013), with very different results for a host of foundational questions, found a similar result on this issue—38% reported never switching interpretations.

4 Approaches to quantum theory as scientific perspectives

How can we move beyond the metaphors to articulate an account of scientific perspectivism about quantum theory? The question of realism looms large, in particular: is there a way to maintain both that quantum theory can tell us about reality and that alternative approaches to it are complementary?

4.1 Methodological pluralism

Perhaps the least controversial position here is a kind of *methodological pluralism* that recommends the continued *use* and *development* of the different approaches to quantum theory associated with different solutions to the measurement problem. Even opponents of quantum underdetermination like Adlam and Wallace recognize that different approaches have not been entirely ruled out, and given the lack of consensus in the foundations of quantum theory, there are good pragmatic grounds for continuing to pursue a plurality of approaches in the hope that one of them will prove correct or fruitful. Such a pluralism receives further support from the fact that current quantum theory (however it's understood), is not a *fundamental* or *final* theory. Given that there is still work to be done in developing quantum theory so as (e.g.) to apply at higher energy scales or incorporate gravity, these alternative approaches may be helpful in this regard. Thus, a standard bet-hedging argument recommends methodological pluralism in quantum foundations.

If nothing else, developing a number of approaches may help to understand the limits imposed by quantum theory. A useful lesson is provided by the research that led to Bell's theorem. Bell was greatly impressed by Bohm's hidden variables approach to QM.[13] Despite its status within the physics community as a fringe idea, and the widely-held believe that hidden variables approaches were impossible, Bell sought to understand the limits of such an approach. The result, of course, was Bell's theorem, which is now the cornerstone of quantum information theory. This is a powerful case for embracing methodological pluralism with respect to quantum approaches—developing and investigating a number of different approaches may have significant impacts for mainstream physics. Notice as well that benefits can accrue even if the approach under consideration is ultimately unsatisfactory for some reason, as some view the de Broglie-Bohm approach. This would suggest that, for example, even if spontaneous collapse approaches are implausible, it may still be worth investigating their empirical differences from standard QM and to attempt to devise experiments to look for them (see Bassi et al. (2013)).

[13] "[I]n 1952 I saw the impossible done. It was in papers by David Bohm. Bohm showed explicitly how parameters could indeed be introduced, into nonrelativistic wave mechanics, with the help of which the indeterministic description could be transformed into a deterministic one. More importantly, in my opinion, the subjectivity of the orthodox version, the necessary reference to the 'observer,' could be eliminated. . . But why then had Born not told me of this 'pilot wave'? If only to point out what was wrong with it? Why did von Neumann not consider it? More extraordinarily, why did people go on producing 'impossibility' proofs, after 1952, and as recently as 1978?. . . Why is the pilot wave picture ignored in text books? Should it not be taught, not as the only way, but as an antidote to the prevailing complacency? To show us that vagueness, subjectivity, and indeterminism, are not forced on us by experimental facts, but by deliberate theoretical choice?" (Bell, 1987, 160).

However, such a position is unhelpful in securing a meaningful form of scientific realism. Methodological pluralism is compatible with a straightforward instrumentalist view on which quantum theory is merely a tool for making predictions about measurement outcomes—we should still develop various approaches to quantum theory to better hone our predictive tool. Indeed, van Fraassen explicitly mentions a similar benefit for methodological pluralism on his more sophisticated alternative to realism:

> Theories are formulated, their formulation is investigated in the context of the alternatives that are open: for example, quantum mechanics is understood better now that we have seen Bohmian mechanics and the GRW theory. We could see all three, and compare them, discuss agreements and possible disparities in the empirical predictions, try to imagine at least thought experiments in which their differences would become manifest. . . We could much more clearly, because of the displayed contrasts, address the question what the world could possibly be like if it were as quantum mechanics says it is. (van Fraassen, 2015, 83)

According to van Fraassen, it is worthwhile to develop "alternatives" to quantum theory (different "approaches" in my terminology) to better understand the *content* of (orthodox) quantum theory, even though acceptance of quantum theory involves commitment to only its empirical adequacy (not its approximate truth).

Standard scientific realism is harder to square with the attitude of methodological pluralism in this setting. Presumably, the standard realist will maintain that there is a *unique* correct description of quantum reality, even if we aren't yet sure what it is. While this is compatible with a realist attitude toward physical sciences in general, admitting that none of the current approaches to quantum theory are approximately true is problematic.[14] Given the impressive empirical success of quantum theory, the standard scientific realist would seem to be obligated to provide (and endorse) a description of reality in light of quantum theory. Absent a unique account of quantum reality, it's hard to see how the realist can take the empirical success of quantum theory as evidence that it is approximately true, thus abandoning a central plank of their view.

4.2 Structural realism

Perhaps the structural realist is better off. They are free to allow for distinct formulations of a physical theory without sacrificing their realist ambitions—so long as the each formulation captures the *structure* of reality, there is no issue if they differ in other respects. Recall the case of the Hamiltonian and Lagrangian formulations of classical mechanics. They differ in respects that may be significant to the traditional realist (their conception of states and dynamics), but arguably share an underlying formal/mathematical structure (French, 2011). The derivation of the Hamiltonian formalism from the Lagrangian formalism via the Legendre transform is often regarded

[14]Presumably, if one of the extant approaches is *approximately true* in the sense given to that phrase by the standard scientific realist, that would foreclose the possibility that one of the other approaches is approximately true. For example, if a collapse theory is correct, then it's hard to see how theory without collapse (e.g., de Broglie-Bohm or Everett) could be even *approximately* true. A more modest flavor of realism may allow for the approximate truth (in some sense) of multiple approaches, but only at the cost of severely limiting what quantum theory can tell us about reality.

as establishing the equivalence of the two formulations, despite their apparent ontological or ideological differences.[15] While there remains much uncertainty about the correct understanding of structural realism, advocates aim to capture cases like this where one can seemingly accept (as approximately true) a physical theory without settling questions about ontology required of the standard realist. In the present case, the structural realist would like to adopt a realist stance towards the structure of classical mechanics without being wedded to the Hamiltonian or Lagrangian formulation as the unique correct formulation of it.

Can a similar move be made with respect to the approaches to quantum theory associated with different solutions to the measurement problem? The obvious problem here is that the different approaches are simply not equivalent in any meaningful sense. As noted above, dynamical collapse theories, the de Broglie-Bohm theory, and Everettian (many worlds) quantum mechanics are not even *empirically equivalent*, so it's hard to see how it could be argued that they attribute the same structure to quantum reality. One could try to locate some common structure underlying the different approaches, but the prospects for this are dim. As Callender asks of this strategy, "[s]ince the mathematical structure of Collapse, Bohm, and Everett differ so markedly, how could such a position ever get off the ground?" (Callender, 2020, 74).

Given that all the approaches share an ability to approximately recover the predictions of orthodox quantum mechanics (at least in the non-relativistic regime), one could try to take this to be the structure of quantum reality.[16] However, on each of the three mainstream realist approaches, the structure of orthodox quantum mechanics is (at best) a phenomenological structure that emerges from a more fundamental structure. Thus, if the structural realist were to commit to only this, they would effectively be abandoning realism about the approaches themselves–everything they say about the underlying basis for the textbook predictive recipe is to be regarded as unreflective of physical reality. This is a very thin realism indeed. On such a view, the textbook predictive recipe reflects the structure of the empirical phenomena (and possibly the modal relations between them), but nothing else in any of the approaches to quantum theory (including how they solve the measurement problem) corresponds to anything in reality.

A more promising approach invokes the idea of real patterns introduced by Dennett (1991) and taken up by structural realists such as Ladyman and Ross (2007). In Dennett's original usage, *real patterns* are descriptions of some data that are more compact than the "bit map" enumerating each data point. Crucially, real patterns will typically involve a trade off between simplicity and noise—in some context, a simple noisy pattern is better than a more complex one with less noise. Nevertheless, all real patterns are *real* insofar as they identify genuine patterns in the data that are projectable. Even this rough sketch makes clear that a plurality of real patterns can be present in the same data, even when the entities or processes they invoke seem incompatible.[17] It is reasonable to suggest, then, that different approaches to quantum

[15] For a dissenting view, see Pooley (2006).

[16] This would be a structuralist variant of Egg's (2021) view discussed above.

[17] For example, consider the different objects that appear in Conway's Game of Life. One set of entities—which may include gliders, guns, etc.—is associated with a real pattern in the data, but this does not exclude the possibility of other patterns associated with a different collection of objects. Indeed, as Dennett himself notes, there can even be differences in what counts as *pattern* vs. *noise*.

theory can be understood as identifying real patterns in the non-fundamental regime where they apply. Of course, it would be helpful to be able to better characterize the "data" in which these patterns inhere, but absent a truly fundamental theory, this may be impossible. The best we can do at present is to recognize a plurality of non-fundamental real patterns, each of which is associated with a particular approach to quantum theory.[18]

The appeal to real patterns may allow the structural realist to accept a plurality of theories as each capturing the structure of reality—albeit in a way that tolerates a certain amount of "noise." But real patterns are abundant, and presumably only some of them rise to the level of a legitimate target of scientific or philosophical interest. So, the real pattern view fails to explain why the approaches to quantum theory under discussion are worthy of our attention.

4.3 Perspectivism

Can perspectivism help here? Advocates of scientific perspectivism maintain that the view is compatible with realism—distinct scientific perspectives can each provide genuine knowledge about reality. Crucially, perspectival realists claim that different scientific perspectives can provide genuine knowledge even when they are associated with theories (or models) that appear incompatible. For example, modeling liquid water as a continuous fluid seems incompatible with modeling it as a large collection of particles, but the perspectival realist argues that each can tell us something true about water, from a particular perspective. This avoids the problems of the traditional scientific realist by relaxing the commitment to any knowledge-conducive model being a faithful representation of reality. The perspectival realist maintains that a model can provide genuine knowledge about its target without being a faithful representation of it—e.g., it may include idealizations or fictionalizations that render it unrealistic as a representation of how things really are.

The case of quantum foundations is arguably one of inconsistent theories—dynamical collapse theories, the de Broglie-Bohm theory, and Everettian (many worlds) quantum mechanics each seem to offer a competing account of the nature of quantum reality. If perspectival realism can be applied here, it would follow that each of these accounts can provide genuine knowledge of reality (from the relevant perspective). Again this will require a concession to the antirealist. The perspectival realist should grant that no single approach provides a unique correct and complete framework for understanding quantum theory. But, the hope is that each of the approaches can nevertheless provide knowledge of quantum reality, from a certain perspective.

Perspectival realists differ in how distinct scientific perspectives can serve as complementary "windows on reality." For example, one role given to the theories (or models) associated with a scientific perspective is:

[18] Another thing we can do is to seek out aspects of overlap between the patterns—these may provide evidence of more robust patterns than those associated with the particular approaches. This may be a way of thinking about approaches that seek to understand quantum theory as an abstract framework (e.g., information-theoretic approaches). The crucial point, however, is that a plurality of real patterns are possible even when they cannot be be reduced to some underlying common structure.

Modal knowledge: "Perspectival models represent a given target system—phenomenon of interest—to the extent that they allow different epistemic communities to make relevant and appropriate inferences about what is possible concerning the phenomenon." (Massimi, 2022, 72)

Applied to the present case, this would suggest that collapse theorists, Bohmians, and Everettians can each use their approach to quantum theory as a guide for making inferences about what is possible. As noted above, each may be fruitful for certain kinds of applications, and given that they are tracking real patterns, we should expect that their laws are projectable in a way that makes them reliable inferential guides. But the space of possibilities may differ between the approaches. Sometimes these modal differences may give rise to empirical differences (e.g., the impossibility of macroscopic superpositions on dynamical collapse models) and other times not (e.g., the impossibility of coming to know the exact configuration of particles on the de Broglie-Bohm approach). In either case, the approach may contribute to our knowledge of reality from a perspective by licensing certain inferences and not others.

Massimi's is just one among many accounts of perspectival realism. Quantum perspectivists needn't settle on a particular account, but rather, can allow that however the metaphor of providing a "window on reality" is spelled-out, it can be applied to the case of quantum foundations.

5 Conclusion

Writing about a different area of science (measurement theory), Wolff has advocated combining structural realism and perspectivism:

> Structural realists do well in supplying a more appropriate notion of correspondence between representation and represented phenomenon by freeing representation from literalism. Perspectival realists, on the other hand, provide an account of the justification of using different representations of ostensibly the same phenomenon or attribute. This is important since, even after all equivalent... representations have been explained by structural realism, different scientific theories still ascribe different structures to the same attribute. (Wolff, 2019, 124)

An attitude toward quantum foundations which combines methodological pluralism, structural realism, and perspectivism may be reasonably regarded as a modest form of scientific realism. First, a commitment to pluralism views the different approaches to quantum theory as a resource rather than a cause for concern. Distinct approaches should not be understood as "rival interpretations," but rather, distinct scientific perspectives on quantum reality. Until an approach is deemed unacceptable (within a given regime), it may provide valuable insight into quantum phenomena. Second, structural realism allows for a more flexible theory-world connection. Even though different approaches to quantum theory disagree about fundamental ontology and dynamical laws, each can be regarded as capturing structural aspects of quantum reality. Structural realists disagree about the details of the theory-world relation, but Glick (2021a) argues that plausible versions of the relation allow for there to be distinct structures each of which approximate reality in the relevant sense. Finally, perspectivism demonstrates how a theory (or model) can provide genuine knowledge without corresponding to how things are in the standard correspondence sense. Distinct approaches to quantum theory provide complementary "windows on reality" by telling us what is possible, offering explanations of quantum phenomena, and providing guidance on how to extend quantum theory into new domains. They do so in a way that is inevitably couched in a particular scientific perspective, and none can claim to provide a complete and correct representation of quantum reality. But, nevertheless, this is genuine knowledge that can be put to work by philosophers and physicists for a variety of tasks.

This is a revisionary view. The foundations of quantum theory are hotly contested and advocates of each of the approaches discussed typically *do* take their favored approach to provide a complete and correct description of reality. But, given the current state of entrenched disagreement in quantum foundations, it may be worth adopting a different stance.

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