Chapter 24
Defending the Situations-Based Approach to Deep Worldly Indeterminacy

George Darby and Martin Pickup

Abstract This paper concerns *metaphysical indeterminacy* and, in particular, the issue of whether quantum mechanics gives motivation for thinking the world contains it. In a previous paper (Darby G, Pickup M. Synthese 198:1685–1710, 2021), we have offered one way to think about metaphysical indeterminacy which we take to avoid some issues arising from certain features of quantum mechanics (such as the Kochen-Specker theorem). This approach has recently been criticised by Corti (Synthese, forthcoming), and we take this opportunity to respond. Our paper will therefore reply to Corti's argument, but we also take it as a case study in 'naturalistic metaphysics' and hence to contribute to a more general discussion of the relationship between philosophy of science and analytic metaphysics.

24.1 Introduction

The question whether quantum mechanics involves *metaphysical indeterminacy* has received much recent attention.[1] This attention is focused both on the issue of whether quantum mechanics can be a motivation for positing worldly unsettledness of the type captured by theories of metaphysical indeterminacy, as well as on the issue of how a theory of metaphysical indeterminacy could capture the supposed unsettledness allegedly arising in quantum mechanics.

Quantum mechanics is a particular motivation for positing metaphysical indeterminacy on a certain sort of naturalistic metaphysical approach. According

[1] For examples illustrating the development of the debate, see French and Krause (2003), Chibeni (2004), Calosi and Wilson (2019), Torza (forthcoming).

G. Darby (✉)
Oxford Brookes University, Oxford, UK
e-mail: gdarby@brookes.ac.uk

M. Pickup
University of Birmingham, Birmingham, UK
e-mail: m.pickup@bham.ac.uk

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to this view, metaphysics should be read off physics, and (quantum) physics tells us that the world itself is indeterminate. This is highly contentious, and can be doubted for a number of different reasons. (We are each sympathetic to some of these reasons.) Nevertheless, even granting the moves necessary to get such a view going, internal problems arise.

A prominent way of thinking about indeterminacy in the metaphysics literature ends up being incompatible with a natural way of getting indeterminacy from quantum mechanics. As one of us has argued (Darby, 2010) this is (roughly) because on that way of thinking reality is supposed to be indeterminate between maximally specific ways for things to be, whereas the Kochen-Specker theorem shows that there *is* no maximally specific way for things to be. So: You can interpret QM as involving genuine metaphysical indeterminacy if you really must, but will then require a different account of its nature.

In a later paper (Darby & Pickup, 2021) we have suggested that one way of providing that account which makes use of situation semantics – a tool put to various uses in analytic metaphysics. Briefly, the idea is that when reality is indeterminate between ways for things to be, these ways for things to be are fully precise but not maximal. Situations, as *parts* of possible worlds, can naturally model this approach. When reality is unsettled about whether something is the case, that thing is the case in some but not all of the (partial) ways things could be.

Corti (forthcoming) has recently responded to this model, arguing that it does not after all capture metaphysical indeterminacy as found in quantum mechanics. The reason for this turns out to revolve around which propositions are true or false in the relevant situations. We had in mind propositions such as "The particle is spin-up in the x-direction", "The particle is spin-down in the y direction", etc. The argument of Corti (forthcoming), on the other hand, revolves around propositions such as "The system is in state psi-".

This question, of what propositions and situations metaphysicians can legitimately use in setting up an account of metaphysical indeterminacy, is connected to prior questions of whether physics drives metaphysics or vice versa. Our focus in the paper is primarily on the first-order question of how to set up an account of metaphysical indeterminacy using situation semantics that does justice to quantum phenomena, but we also take it to illuminate some of those debates in metametaphysics.

24.2 The Darby/Pickup Account

One family of approaches to metaphysical indeterminacy are known as *meta-level* accounts.[2] A meta-level account of metaphysical indeterminacy sees the unset-

[2] Jessica Wilson is responsible for this terminology. See, e.g., her (2017).

tledness of the world as arising from unsettledness between distinct, determinate candidates for the way the world is.

A very influential meta-level account is given by Barnes and Williams in their (2011). On this view, metaphysical indeterminacy consists in there being a number of different ersatz possible worlds which do not determinately fail to represent reality. So if some proposition is metaphysically indeterminate, it is true in (at least) one possible world which is a candidate for actuality, and false in (at least) one possible world which is a candidate for actuality. To speak somewhat poetically, the metaphysical indeterminacy of the proposition consists in the world being undecided about whether it is represented accurately by a possible world in which the proposition is true or by a possible world in which it is not.

The BW account, however, suffers difficulties when applied to the very case that seems the most naturalistically plausible example of genuinely worldly indeterminacy: quantum mechanics. As has been shown independently by Darby (2010) and Skow (2010), quantum mechanics gives rise to a distinctive *deep* indeterminacy. This deep indeterminacy arises because of constraints like the Kochen-Specker theorem, which dictates that certain groups of propositions just cannot all be assigned determinate truth-values together. This means that an ersatz possible world which assigned truth-values to all such propositions would determinately fail to represent reality, and the BW model is thus inadequate for these cases.

In a previous paper, we have offered a fix for this problem. The core idea is that *situations*, rather than possible worlds, should be used to model metaphysical indeterminacy. For the sake of brevity, not much will be lost by considering situations here as simply parts of possible worlds.[3] This solves the problem because the situations which are candidates for actuality, and which the world is unsettled between, need not be complete. In other words, they can give truth-values to some but not all propositions (unlike possible worlds). According to our account of metaphysical indeterminacy, then, a proposition is metaphysically indeterminate when it is true in some situation which is a candidate for representing actuality, and false in no such situation.

24.3 Corti's Objection

In a recent paper, Corti (forthcoming) offers a criticism of our account. He argues that our account fails, and that this highlights a broader point about the inadequacy of meta-level accounts in treating quantum indeterminacy as worldly indecision. In this section, we will outline what we take to be the core objection.

Corti's argument is that the model we present assigns incorrect truth-values to propositions. In particular, Corti claims that we are committed to taking a

[3] For more detail about situations, see Kratzer (2020) and Barwise and Perry (1983) as a starting point.

determinate feature of reality as indeterminate, which falsifies our approach. To see why this is so, we'll briefly restate the argument. This restatement is not entirely innocent: we are adapting the properties and propositions Corti uses into our own preferred terms. This is philosophically significant, as will be discussed later in the paper. But for the sake of showing how the objection is supposed to undermine our view, we will present it this way.

Suppose a quantum system is prepared so that it is x-spin-up. Then it is in a superposition for *z*-spin. This entails (again, assuming that one goes down the route of interpreting QM as involving genuine worldly indeterminacy in the first place) indeterminacy about the system's z-spin. In the situations-based way of thinking about this, this is captured by asserting that there are two distinct situations s_1 and s_2 where the following propositions are true:

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s_1: the system is z-spin-up
s_2: the system is z-spin-down

Both situations are candidates for representing actuality because neither of them determinately misrepresents it. This is what superposition consists in, on the model we explore. (NB: to say that something is z-spin-up is to say that it has a certain property – and this is not, or at least not obviously, the same as saying that its state vector is $|+_x>$)

There is another situation to mention, s_4 (we follow Corti's numbering here).[4] In s_4 the very same system is x-spin-up.

s_4: the system is x-spin-up

So far, we are happy to accept that these situations are all candidates to represent actuality, and that these are the propositions true in them. Note that there may or may not be *other* propositions true in these situations, depending on exactly which situations we are choosing for s_1, s_2 and s_4. But let's assume for now that these are the *minimal* situations in which these propositions are true.

The issue arises, according to Corti, because our view commits us to accepting problematic *additional* situations as candidates for representing actuality. One in particular is the following:

s_5: the system is in a superposition of x-spin-up and x-spin-down[5]

This is supposed to be a problem because it is determinately the case that the system is x-spin-up, and so determinately not in a superposition with respect to x-spin.

[4] We are leaving out s_3, which Corti takes to be a situation in which the propositions true in s_1 and s_2 are both true. We wouldn't accept that such a situation is a candidate for actuality: it is contradictory. (In fact, there *is* no such situation, candidate for actuality or otherwise.) We take it that s_3 is supposed to combine s_1 and s_2 in some way. We were careful to be explicit that in any such situation, neither proposition is true (or false): s_3 would be a situation in which each proposition is indeterminate.

[5] Corti actually describes two situation (s_5 and s_6), with different x-spin superpositions. The general criticism can be stated without this detail.

According to Corti, we are obliged to admit s_5 as a candidate for representing actuality, and (again, according to him) s_5 entails the falsehood that the system's x-spin is metaphysically indeterminate.

Why is it that we are forced to accept s_5 as a candidate for representing actuality? Corti's answer is that the proposition true in s_1 is importantly related to the proposition true in s_5. In particular, the proposition true in s_1 only differs from the proposition true in s_5 by there being a 'mathematical object' in one which is replaced by an 'equivalent' 'mathematical object'. Employing a principle he terms Equivalent Candidates for representing Actuality (ECA), this entails that the situation in which the latter is true is also a candidate for representing actuality.

24.4 Reply to Corti

Although there are a number of points where we disagree with Corti's paper, for the sake of simplicity we'll restrict our comments to this central argument.

The core move of the argument is that by asserting that s_1 is a candidate for representing actuality, we are thereby committed to also accepting the problematic s_5 as a candidate for representing actuality. We agree that this would be a problem, but deny that there is any such commitment.

To begin with, it is worth underlining that our account of metaphysical indeterminacy is *not* that there is indeterminacy in the world whenever a proposition is neither true nor false in a situation which is a candidate for representing actuality. This is far too broad. Even if reality were fully determinate, portions of that reality (i.e. situations) would fail to settle the truth-value of propositions about other parts of the world. Rather, metaphysical indeterminacy arises when there is a *conflict* between situations which are both candidates for representing actuality.

With this in mind, let's look at s_5 in a bit more detail. The proposition which is true in s_5 states that the system is in an x-spin superposition. Given our model, and given that superpositions are being interpreted as indeterminacy, this would have to mean that there are a pair of distinct situations which are both candidates for representing actuality such that the system is x-spin-up in one and x-spin-down in the other. The property of being superposed is therefore a meta-level property (in keeping with this meta-level account of metaphysical indeterminacy), which a system has in a situation in virtue of the properties of that system in certain other situations.

There is certainly a situation which is a candidate for actuality in which the system is x-spin-up, namely s_4. But we do not accept that there is any corresponding situation which is a candidate for actuality in which the system is x-spin-down. So, there is no situation which is a candidate for actuality in which the system is in a superposition of spin up and x-spin-down.

But Corti thinks we *must* accept that there is such a situation (namely s_5). This is because (i) there is a candidate situation (s_1) where the system has the property of being z-spin-up and (ii) the property of being z-spin-up is connected to the

property of being in an x-spin superposition in such a way that the instantiation of the former in a situation which is a candidate for reality ensures that the latter is also instantiated in a situation which is a candidate for reality.

The second step here is encoded in Corti's ECA principle. We will shortly discuss this principle. But before we do, it is worth highlighting that situation theory is specifically designed to allow fine-graining that undermines the motivation for ECA. The properties of being indeterminate for *x*-spin and being z-spin-up are clearly distinct properties. The first is a meta-level property, while the second obtains (uninformative as this is) just when the system is z-spin-up in that situation. So, a (possible) situation in which the system is superposed in *x*-spin and the situation in which the system is z-spin-up look importantly different.

Why, then, does Corti think that there is an intimate connection between the candidacy for actuality of these different situations? The answer to this revolves around Corti's ECA principle:

> Consider a situation s1 that is a candidate for representing actuality and verifies only a proposition p1 which contains a mathematical object o1. Any other situation s2 that differs from s1 only in that it makes true a proposition p2 which is obtained by simply replacing o1 with o2, where the latter is a mathematical object equivalent to the former (i.e.o1 = o2), is also a candidate for representing actuality. (p. 11)

This principle is connected to Corti's version of metaphysical naturalism. It is justified as follows:

> Such a principle seems to be intuitively reasonable. Let us see how it works by presenting a toy example. Suppose it is metaphysically indeterminate how many oranges there are in the fridge; assume further that there might just be either three or four. According to Darby and Pickup's view, there is a possible situation in which there are three oranges, and a possible situation in which there are four, but neither describes correctly nor misrepresents the actual world (and therefore the propositions 'there are three oranges in the fridge' and 'there are four oranges in the fridge' are indeterminate, being true and false in at least one situation). The principle (ECA) simply guarantees that if the possible situation in which there are three oranges is a candidate for representing actuality, then also the situations that verify respectively only the propositions 'there are two plus one oranges in the fridge' or 'there are four minus one oranges in the fridge', and so on, are candidates for representing actuality. (*ibid.*)

A number of points are worth noting about this principle and its application:

First of all, this has nothing in particular to do with indeterminacy, but is more about the workings of situations: The orange example shows that the (distinct?) situations verifying the (distinct?) propositions that there are three oranges, that there are $2 + 1$ oranges, and that there are $4 - 1$ oranges, etc, will all be candidates for representing reality if there are 3 oranges.

Second, it is not entirely obvious that the proposition that the proposition that there are three oranges in the fridge and the proposition that there are $2 + 1$ oranges in the fridge are really distinct propositions. (Are they both distinct from the proposition that there are $1 + 2$ oranges in the fridge?) If propositions are sets of worlds, then it would seem not, for example.

Third, it is also not entirely obvious, and depends on the details of the metaphysics of situations, that the situation verifying the proposition that there are three oranges in the fridge and the situation verifying the proposition that there are $2 + 1$ oranges in the fridge are really distinct situations. If situations are individuated by the propositions true in them, then this is parasitic on the previous paragraph. If, by contrast, they are individuated by the entities they contain and the properties they instantiate, then plausibly exactly the same entities and properties are in each situation (even if the propositions are distinct). Either way, it is a substantive and controversial claim that there can be distinct situations differing only in whether they verify 'there are 3 oranges in the fridge' or 'there are $2 + 1$ oranges in the fridge'.

On the other hand, one could no doubt construe things in such a way that the required distinctions can be made – perhaps we are dealing with one proposition concerning the oranges and the number 3, and another proposition concerning the oranges and the numbers 1 and 2. Then perhaps there would be a non-trivial sense in which there are two situations that are both candidates for representing actuality. Of course one could also do that without involving the oranges at all: The situation that verifies the proposition that $1 + 2 = 3$ and the situation that verifies the proposition that $4 - 1 = 3$ would also both be candidates for representing actuality.

In the terms used in the definition of ECA, the first situation differs from the second "only in that it makes true a proposition [the proposition that $4 - 1 = 3$] which is obtained by simply replacing $[1 + 2]$ with $[4 - 1]$, where the latter is a mathematical object equivalent to the former".

Again, the exact meaning of ECA depends on what it is for a proposition to *contain* a mathematical object, which in turn depends on what propositions are, and what mathematical objects are, and on what is meant by "equivalent". One might mean that the *terms* are equivalent, i.e. co-referential, but presumably not, because here Corti is talking about objects, not terms. The mathematical objects might be identical (as is suggested by "$o_1 = o_2$"), or isomorphic; or one sequence of operators might be equivalent to another sequence of operators by having the same effect. Or, of course, the mathematical objects themselves might be representationally equivalent, perhaps because they represent the same physical state, for example, but that depends on the details of the interpretation.

Our point in labouring this is that principles like ECA, and the "naturalistic" approach to metaphysics that underlies them, mask a number of crucial assumptions.

In essence, Corti's argument goes like this:

Consider a particle in an x-spin eigenstate. Then we would think of it (assuming, as usual, that quantum mechanics is being interpreted as involving worldly indeterminacy) like this:

(1) It is indeterminate whether the particle is z-spin-up or z-spin-down.

And, on the situations way of thinking, that entails:

(2) the situation of the particle's being z-spin-up is a candidate for actuality.

And presumably we should also accept:

(3) The particle is not indeterminate for x-spin.

So, again on our way of thinking:

(4) The situation of the particle's being indeterminate for x-spin is not a candidate for actuality.

But suppose we also had:

(5) To be z-spin-up *is* to be indeterminate for x-spin.

Then (2) and (5) would entail:

(6) The situation of the particle's being indeterminate for x-spin is a candidate for actuality.

Which contradicts (4).

But that assumption (5) just seems to be false – why should *what it is to be* z-spin-up be the same as *what it is to be* indeterminate for x-spin?

This gap is supposed to be closed by the ECA, but of course the ECA can't apply to any of the statements above, because none of them describes, at least obviously, a situation that verifies a proposition that "contains a mathematical object".

You can get mathematical objects into the picture like this (still using the example of a particle with determinate x-spin):

(1′) It is indeterminate whether the particle is in state |+z> or |-z>.
So (2′) the situation of the particle's being in state |+z> is a candidate for actuality

And then argue that, since the particle is supposed to be in an x-spin eigenstate, and since |+z> is *not* an x-spin eigenstate, there is a candidate for actuality that determinately misrepresents it, which would be a bad result. But this time, as far as we can see, (1′) is straightforwardly false. It is not indeterminate whether the particle is in state |+z> or |–z> but rather determinate that it is in the state $1/\sqrt{2}$ |+z> + |–z>, which is straightforwardly neither |+z> nor |–Z>. What is indeterminate is whether the particle is z-spin-up. Equating being z-spin-up with being in state |+z> is to make some deep assumptions about the connection between mathematical formalism representing the states of quantum systems and the properties of those quantum systems.

So, the point is that the argument only gets going if couched in terms of properties rather than state vectors – but then the ECA, which revolves around "mathematical objects" like state vectors, just doesn't apply.

24.5 Conclusion

Have we established that quantum indeterminacy is worldly indecision? Of course not – that would involve adopting a realist position in the philosophy of science, and advocating for a particular interpretation of quantum mechanics (i.e. solution to the measurement problem, e.g. some collapse interpretation), *and* putting a particular

metaphysical spin on it so that the indeterminacy involved is "worldly", and then spelling out the metaphysical theory about how that worldly indecision is to be understood.

The challenges and obstacles for that approach may be insurmountable – in particular, it may be that Calosi and Wilson (2019) have shown that metaphysical supervaluationist approaches are poorly motivated for a wide range of interpretations. Partly for this reason, and partly because we are at least somewhat drawn to the idea that there is no such thing as worldly indeterminacy at all, we took the supposed indeterminacy in QM, and the fact that it appears prima facie to be "deep", in Skow's terms, as simply a suggestive motivation for something that it ought to be possible to account for.

We do think that the machinery offered by situation theory – already used in various areas of metaphysics – offers a way of doing so that, unlike "standard" meta-level accounts of metaphysical indeterminacy, does justice to the general features of quantum mechanics that motivate the idea of worldly indeterminacy in the first place. For the same reason, we think it worth noting that those general features of the formalism don't translate into straightforward difficulties for the account in the way that Corti argues. More broadly, what we take this to show is that care is needed, especially in this domain, to disentangle internal criticisms of metaphysical models from external criticisms arising from naturalistic metametaphysical assumptions. Our situations-based account of quantum metaphysical indeterminacy is explicitly provisional on the controversial moves needed to get the game started. But closing up the gap in which the theory would sit requires controversial assumptions of its own.

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