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**Citation:** Skow, Bradford. "DEEP METAPHYSICAL INDETERMINACY." *The Philosophical Quarterly* 60.241 (2010): 851-858. © 2010 The Author Journal compilation © 2010 The Editors of The Philosophical Quarterly

**As Published:** <http://dx.doi.org/10.1111/j.1467-9213.2010.672.x>

**Publisher:** Wiley

**Persistent URL:** <http://hdl.handle.net/1721.1/61728>

**Version:** Author's final manuscript: final author's manuscript post peer review, without publisher's formatting or copy editing

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# Deep Metaphysical Indeterminacy\*

Bradford Skow

## Abstract

A recent theory of metaphysical indeterminacy says that metaphysical indeterminacy is multiple actuality. That is, we have a case of metaphysical indeterminacy when there are many “complete precisifications of reality.” But it is possible for there to be metaphysical indeterminacy even when it is impossible to completely precisify reality. The orthodox interpretation of quantum mechanics illustrates this possibility. So this theory of metaphysical indeterminacy is not adequate.

## 1 Shallow and Deep Metaphysical Indeterminacy

Many questions of interest to philosophers invite the response: there is just no fact of the matter. Is the continuum hypothesis true? When someone undergoes fission, which of the resulting persons is him? Maybe the best thing to say is that it is *indeterminate* whether the continuum hypothesis is true, and that it is indeterminate which of the post-fission people is identical to the pre-fission person.

It can also be tempting to add that the source of this indeterminacy is neither semantic nor epistemic. The reason why it is indeterminate whether the continuum hypothesis is true is not that we have made too few “semantic decisions” about what the language of set theory shall mean, or that the truth-value of the continuum hypothesis is something that (for special kinds of reasons) it is impossible for us to know. Instead, this is (perhaps) a case of *metaphysical* indeterminacy.

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\*Published in *The Philosophical Quarterly* 60 (2010): 851-858.

Some presentations of the orthodox interpretation of quantum mechanics make use of the notion of metaphysical indeterminacy.<sup>1</sup> They portray reality itself as fuzzy or indefinite. Place a particle into a box with infinitely hard walls. Wait a while, and then look to see if the particle is in the left half or the right half of the box. According to the orthodox interpretation of quantum mechanics, the complete physical state of the particle before you look in the box fails to determine whether you will see it in the left half or the right half when you look. Instead, the theory assigns a probability greater than 0 but less than 1 to your finding it in the left half, and a probability greater than 0 but less than 1 to your finding it in the right half. And (the orthodox interpretation says) if the complete physical state does not assign probability 1 to the particle's being found on the left, and does not assign probability 1 to the particle's being found on the right, then (before we look) it is *indeterminate* whether the particle is on the left or on the right.

So, maybe there is such a thing as metaphysical indeterminacy, and maybe quantum mechanics provides an example of it. Still—what *is* it? Can we get any kind of a grip on what metaphysical indeterminacy is?

One picture of metaphysical indeterminacy emerges from thinking about the picture that goes along with supervaluationist treatments of semantic indeterminacy. On the supervaluationist picture, our language suffers from semantic indeterminacy because it is poised between alternative interpretations. Each interpretation fits our language use equally well (and there are no other facts about the interpretations to break the tie). We say that these interpretations are *precisifications* of our language.

Maybe a similar picture can make metaphysical indeterminacy intelligible. Say that *reality itself* is poised between alternatives. Someone is about to undergo fission. One of the post-fission people will leave by the left door; the other will leave by the right. Suppose we want to say that it is metaphysically indeterminate which post-fission person is identical to the pre-fission person. We can try to make

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<sup>1</sup> There is no canonically accepted statement of the orthodox interpretation. Some people explicitly use the language of determinacy when stating it; see, for example, [Barrett 1999: 37]. Others (see [Albert 1992: 38]) do not. I shall use “the orthodox interpretation” to mean “the orthodox interpretation, stated using the language of indeterminacy.”

this intelligible by saying that there is a *precisification of reality* in which the pre-fission person survives as the successor who leaves by the left door, and another precisification of reality in which the pre-fission persons survive as the successor who leaves by the right door.

Each precisification of reality is, as it were, perfectly precise. That is, if there are many “aspects of,” or parts of, reality, A, B, ... and it is (metaphysically) indeterminate whether A is F, and it is (metaphysically) indeterminate whether B is G, ... then there is a precisification of reality at which A is F and B is G, and also a precisification of reality on which A is not F and B is G, and so on.

But is this an adequate model for metaphysical indeterminacy? Maybe metaphysical indeterminacy runs so deep (or can run so deep) that *reality cannot be completely precisified*. Call this kind of metaphysical indeterminacy “deep metaphysical indeterminacy.”

(It is consistent to accept that there is deep metaphysical indeterminacy and to continue to believe that *each aspect* of reality that is indeterminate can be precisified. It is just that not all aspects of reality that are indeterminate can be precisified “at once.” It might turn out that there is no precisification of reality at which A is F and B is G, even though there is a precisification at which A is F, and a precisification at which B is G.)

Do we have any reason to think that deep metaphysical indeterminacy is possible? I think we do. The kind of metaphysical indeterminacy that can be found in the orthodox interpretation of quantum mechanics is deep metaphysical indeterminacy. That may not show that deep metaphysical indeterminacy is *actual*. For one thing, there are presentations of the orthodox interpretation that avoid the language of indeterminacy. For another thing, the orthodox interpretation of quantum mechanics suffers from all sorts of well-known defects, and there are alternative interpretations of quantum mechanics that do not use the notion of indeterminacy at all. But looking at the orthodox interpretation of quantum mechanics shows how and why deep metaphysical indeterminacy *could* arise. Whenever the set of basic physical properties has the structure we see in orthodox quantum mechanics we can expect deep metaphysical indeterminacy to appear. Since that structure looks like a possible structure, we should think that deep metaphysical indeterminacy is at least

possible.

What is this structure that the set of basic physical properties could have, that would give rise to deep metaphysical indeterminacy? The best way to see what it is is to go through in detail why the indeterminacy in the orthodox interpretation of quantum mechanics is inconsistent with the idea that reality can be completely precisified.

## 2 The Barnes and Williams Model

Elizabeth Barnes and J. R. G. Williams have developed a model of metaphysical indeterminacy that implements the idea that (even when there is metaphysical indeterminacy) reality can be completely precisified. It will be convenient to work with their model as a standard version of a theory of shallow metaphysical indeterminacy.

Barnes and Williams model metaphysical indeterminacy by modifying a familiar model for modality.<sup>2</sup> Suppose that there are such things as possible worlds. A possible world, intuitively speaking, is a maximally specific way for reality to be. One of the possible worlds is the way reality is: that is the actual world. Other possible worlds are *merely* possible.

To fit metaphysical indeterminacy into this picture Barnes and Williams first restrict their attention to views about the nature of possible worlds other than modal realism. Instead they focus on theories according to which possible worlds are sets of sentences, or are maximally specific properties, and other theories like them. Importantly, the possible worlds in these theories are *perfectly precise*. For example, the theory that says that possible worlds are sets of sentences also says that these sentences belong to a language with respect to which all needed “semantic decisions” have been made.

Now we are ready to locate metaphysical indeterminacy. Metaphysical indeterminacy corresponds to *multiple actuality*. That is, it is metaphysically indeter-

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<sup>2</sup>The most detailed presentation of their view is in [Williams and Barnes forthcoming]. See also [Williams 2008a] and [Williams 2008b]. There are some differences between the views in these papers that will not matter for us. The version of the view I present is the one found in [Williams 2008a].

minate whether P if and only if there is an actual world at which P, and an actual world at which not-P.

This can happen only if there is more than one actual world. We usually assume that this is false. The actual world, we usually say, is *the* (unique) possible world that accurately represents reality. However, if there is metaphysical indeterminacy, if reality itself is “unsettled,” then it cannot be perfectly described using a precise language. No possible world represents reality with perfect accuracy. So we use a different definition of “actual world”: *w* is an actual world if and only if it is not the case that *w* determinately fails to correctly describe, or represent, reality. If reality itself is indeterminate, then there will be many possible worlds that do not determinately fail to represent it; those will be the actual worlds.

This model is not advanced as an analysis of metaphysical indeterminacy. As an analysis it would be circular, because “It is (metaphysically) indeterminate that...” appears in the definition of “actual world.” But even though this model cannot be used to analyze the notion of metaphysical indeterminacy, it can still be useful. Metaphysical indeterminacy is an obscure notion; the model helps makes metaphysical indeterminacy intelligible. The model can also provide a guide to discovering the logical properties of the “It is metaphysically indeterminate that...” operator. And the model can help us think clearly about arguments that make use of (or directly concern) metaphysical indeterminacy.

Because their possible worlds are perfectly precise, and those possible worlds play the role of precisifications of reality in their theory, Barnes and Williams have given us a model of shallow metaphysical indeterminacy. So it is incompatible with the deep metaphysical indeterminacy in the orthodox interpretation of quantum mechanics.

### **3 The Incompatibility with Quantum Mechanics**

Assume (for now) that the orthodox interpretation of quantum mechanics is true. When it is indeterminate whether the particle is on the left side of the box or on the right side of the box, Barnes and Williams want to say that there is an actual world at which the particle is on the left, and one at which the particle is on the right. This

generalizes to features of things other than their positions. For many determinable properties of a quantum system (momentum, spin in a given spatial direction,...), there is a possible physical state of that system such that, when the system is in that state, the orthodox interpretation says that it is indeterminate which value it has for at least one of those determinables. So in the Barnes and Williams model each actual world will attribute to each quantum system a value for each determinable property. And all actual worlds will agree on the values assigned to properties which have determinate values.

But there is a well-known theorem, the Kochen-Specker Theorem, that says that these attributions cannot be made. My goal here is to outline the set-up and proof of this theorem in a way that is accessible to metaphysicians who have had little exposure to the mathematical formalism of quantum mechanics. (I mostly follow [Hughes 1989].) Seeing why the theorem is true will let us grasp the circumstances in which there will be deep metaphysical indeterminacy.

Some of the quantum physics of spin-1/2 particles, like electrons, is familiar to philosophers with little background in the philosophy of physics. We may set up an experiment to measure the spin of an electron along any spatial direction. Such a measurement will have one of two possible outcomes: “up” (which we represent, mathematically, by +1) or “down” (represented by  $-1$ ). So for each direction in space  $r$  there are two values the electron may have for the property spin-in-direction- $r$ : +1 or  $-1$ .

For a spin-1 particle, by contrast, there are three values it may have for the property spin-in-direction- $r$  (I will use “ $S_r$ ” as a name for this property): +1, 0, and  $-1$ . (Photons have spin-1.)

Now for each  $r$  consider the property: the-square-of-spin-in-direction- $r$ , or  $S_r^2$ . One way to measure a particle’s value for  $S_r^2$ , obviously, is to measure its value for  $S_r$ , and then square the result. So there are just two possible values for  $S_r^2$ : 1 and 0. Any (perfectly precise) possible world will attribute to a spin-1 particle exactly one of these two values for each determinable property  $S_r^2$ .

Let  $I$  be the property (of spin-1 particles) of having some value or other for spin in some direction or other. This is a “trivial” property, with only one possible value (+1). The orthodox interpretation says that every spin-1 particle determi-

nately has value +1 for  $I$ .

Now comes a crucial part of the set-up of the Kochen-Specker Theorem. If  $x, y$ , and  $z$  are three mutually perpendicular directions in space, then it is possible to simultaneously measure a spin-1 particle's values for each of the properties  $S_x^2, S_y^2$ , and  $S_z^2$ . When there is a collection of properties of a system that are simultaneously measurable, the quantum mechanical formalism says that there is a property of the system corresponding to every algebraic combination of those properties. So there is a property,  $S_x^2 + S_y^2 + S_z^2$ , which a spin-1 may also have values for; and in any circumstance in which the particle definitely has values (say)  $a, b$ , and  $c$  for  $S_x^2, S_y^2$ , and  $S_z^2$ , it (by definition) definitely has value  $a + b + c$  for  $S_x^2 + S_y^2 + S_z^2$ .

According to orthodox quantum mechanics, the spin properties of a spin-1 particle are not independent. Here is one constraint they satisfy:  $S_x^2 + S_y^2 + S_z^2 = 2I$ . (Proving this is straightforward but beyond the scope of this paper.) Now focus your attention on one particular spin-1 particle. For each determinable property  $P$  let us write  $v(P)$  for the value this particle has for  $P$ . It follows from what I have said that

- (1) In every actual world,  $v(S_x^2) + v(S_y^2) + v(S_z^2) = v(2I) = 2$ , where  $x, y$ , and  $z$  are any three mutually perpendicular directions in space. (That is, it is determinately the case that  $v(S_x^2) + v(S_y^2) + v(S_z^2) = 2$ .)

The argument for (1) is straightforward. Since it is determinately the case that the particle has value 1 for property  $I$ ,  $v(I) = 1$  in every actual world. And so  $v(2I)$  should be 2 in every actual world, since a particle's value for  $2I$  is just defined to be 2 times its value for  $I$ . But why should  $v(S_x^2 + S_y^2 + S_z^2)$  be equal to  $v(S_x^2) + v(S_y^2) + v(S_z^2)$  in every actual world? Well, it is (physically) necessary that if the particle has determinate values for  $S_x^2, S_y^2$ , and  $S_z^2$ , then it has a determinate value for  $S_x^2 + S_y^2 + S_z^2$ , and its value for the sum is just the sum of the individual values. (The converse is not true, but we do not need it for the proof.) But what is physically necessary is determinately true. So for any actual world  $w$ , if  $S_x^2, S_y^2$ , and  $S_z^2$  have definite values in  $w$ , then  $v(S_x^2 + S_y^2 + S_z^2) = v(S_x^2) + v(S_y^2) + v(S_z^2)$  in  $w$ . But  $S_x^2, S_y^2$ , and  $S_z^2$  do have definite values in every actual world.

The Kochen-Specker Theorem says that there is no possible world at which



the equation in (1) is true. It follows that there are no actual worlds. Here is an outline of the proof:

The directions in space can be put in one-to-one correspondence with the points on a sphere (a direction corresponds to a point  $p$  if it is the direction from the center of the sphere to  $p$ ). So an attribution of exactly one of two values to  $S_r^2$  for each direction in space  $r$  corresponds to an assignment of either 0 or 1 to each point on a sphere. Each possible world determines such an assignment.

Any three mutually perpendicular directions in space determine three points on the sphere. Call such a triple of points an *orthogonal triple*. So every actual world determines an assignment of either 0 or 1 to each point on a sphere, subject to the constraint that exactly one point in each orthogonal triple is assigned 0.

It can be proved, using relatively simple geometry, that there are no assignments of 1s and 0s to points on a sphere that meet this constraint. And that is what was to be shown.

So: assuming that the orthodox interpretation of quantum mechanics is correct (and the assumptions that went into the proof of the Kochen-Specker theorem are correct), there are no actual worlds. That, of course, is an absurd conclusion. What has happened is that the Barnes-Williams model of metaphysical indeterminacy has broken down. It is not adequate for representing the kind of indeterminacy we find in the orthodox interpretation of quantum mechanics.

Let me emphasize that it is not part of my argument that the orthodox interpretation of quantum mechanics is, in fact, correct. There are many other interpretations of quantum mechanics (Bohmian mechanics, for example, and the many Everettian interpretations) that make no use of the notion of metaphysical indeterminacy. If we reject the orthodox interpretation and accept one of them instead then we will not have to say that there is *actually* any deep metaphysical indeterminacy. But it will still be true that the metaphysical indeterminacy in the orthodox interpretation of quantum mechanics is a *possible* kind of metaphysical indeterminacy. My conclusion is that the Barnes and Williams model fails to model all possible kinds of metaphysical indeterminacy.

(In a recent paper George Darby [2010] also discusses what the Kochen-Specker theorem can teach us about metaphysical indeterminacy in quantum me-

chanics. He does not reach a definitive conclusion, but he does suggest that it can be used to show that the Barnes-Williams model is incorrect. However, his argument assumes that quantum mechanical indeterminacy is actual. So Barnes and Williams can avoid his conclusion by embracing interpretations of quantum mechanics that do not invoke indeterminacy. For reasons I give in the text they cannot avoid my conclusion in this way.)

#### **4 Morals**

The Kochen-Specker theorem was originally stated and proved out of an interest in hidden variables theories. According to the orthodox interpretation of quantum mechanics, the entire physical state of a quantum system is encoded in its wavefunction. But the wavefunction does not determine a value for all of the system's determinable physical properties. In a hidden variables theory, by contrast, a quantum system does have determinate values for each determinable physical property. But we are (necessarily) ignorant of the exact value a system has for each physical property. So when using the hidden variables theory to make predictions we have to "average over our ignorance." Since we cannot know the exact initial state of any given experimental set-up, we will only be able to use our hidden variables theory to assign probabilities to outcomes of experiments, even if the theory's underlying dynamics is deterministic. The hope was that a hidden variables theory could be constructed that assigns the very same probabilities to outcomes of experiments that quantum mechanics assigns. The Kochen-Specker theorem was originally proved to show that no such hidden variables can be constructed.

But there is a close connection between these two applications of the Kochen-Specker theorem. A hidden variables theory says that a quantum system is under-described by its wavefunction, and that a complete description will specify values for all of its physical properties. An attempt to model quantum indeterminacy using the Barnes-Williams model says that a quantum system is completely described by its wavefunction, so its values for some physical properties are unsettled; but there are many actual worlds, each of which specifies (possibly different) values for all of the system's physical properties. The state of a quantum system in a

hidden variables theory assigns values that (it says) are unknown to us, and an actual world in the Barnes-Williams model assigns values that are left indeterminate. The Kochen-Specker theorem shows that neither enterprise can succeed.

(The Kochen-Specker Theorem notwithstanding, there are successful hidden variables theories. But to get around the Kochen-Specker theorem such theories must disagree with the orthodox interpretation about what the basic physical properties of quantum systems are. For just this reason these hidden variables theories are of little interest to us in this context.<sup>3</sup>)

The key fact that makes the Kochen-Specker theorem work is that the properties of a quantum system are not independent. ( $S_x^2, S_y^2$ , and  $S_z^2$  must be assigned values that sum to 2.) This sort of thing is familiar from discussions of semantic vagueness and indeterminacy. Failures of property independence resemble the existence of “penumbral connections.” Kit Fine introduced the notion of penumbral connections when arguing for a supervaluationist treatment of vagueness [1975]. He said that any precisification of our language must respect penumbral connections. A color chip may be a borderline case of “blue” and also a borderline case of “green” while definitely being either blue or green. If a color chip is a borderline case of both “blue” and of “green” then some precisifications place it in the extension of “blue” and some do not, and similarly for “green”; but there is also the additional constraint that every precisification place the color chip in the extension of exactly one of the predicates. The failure of the properties of a quantum mechanical system to be independent is something like a penumbral connection between them.

Fine assumed that there were precisifications of our language that respected

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<sup>3</sup>Bohmian mechanics, for example, says that there are no such properties of spin-1 particles as the properties  $S_r$ . In Bohmian mechanics, spin becomes a feature of the wavefunction, rather than of particles. More generally, the Kochen-Specker theorem does not show that *contextualist* hidden variables theories are impossible. A contextualist hidden variables theory does not assign a value to each of the  $S_r^2$  properties. Instead, for each orthogonal triple  $x, y$ , and  $z$ , it assigns a value to  $S_x^2$  only *relative to*  $S_y^2$  and  $S_z^2$  (and there are infinitely many orthogonal triples containing  $x$ ). So in these theories the fundamental features of spin-1 particles are relational in a complicated way.

the penumbral connections in our language. The Kochen-Specker theorem shows that there are not complete precisifications of reality that respect the dependencies among properties in orthodox quantum mechanics. (I doubt, though, that the possibility of complete precisification marks a difference between semantic and metaphysical indeterminacy. Jaime Tappenden [1993: 567], for one, argues that it is not possible to completely precisify our language while respecting penumbral connections, and develops a version of supervenience that uses partial precisifications.)

The orthodox interpretation of quantum mechanics is compatible with the existence of partial precisifications of reality. But the prospects of using this notion to put together a model of metaphysical indeterminacy similar to Barnes and Williams' are dim. For suppose we keep their framework but replace perfectly precise possible worlds with imprecise possible worlds (sets of sentences from a language that suffers from semantic indeterminacy). Even when there is no metaphysical indeterminacy we can expect it to happen that several imprecise possible worlds do not determinately fail to correctly represent reality. So using imprecise worlds would give us multiple actuality even when there is no metaphysical indeterminacy. How to model deep metaphysical indeterminacy remains an open question.<sup>4</sup>

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<sup>4</sup>Thanks to Elizabeth Barnes, Robbie Williams, Steve Yablo, Agustin Rayo, and an anonymous referee.

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