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Against 3*N*-Dimensional Space

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1 Quantum Mechanics Is False

Question 1: How many dimensions does space have? I maintain that the answer is "three." (I recognize the possibility, though, that we live in a three-dimensional hypersurface embedded in a higher-dimensional space; I'll set aside that possibility for the purposes of this chapter.) Why is the answer "three"? I have more to say about this later, but the short version of my argument is that our everyday commonsense constant experience is such that we're living in three spatial dimensions, and nothing from our experience provides powerful enough reason to give up that prima facie obvious epistemic starting point. (My foils, as you presumably know from reading this volume, are those such as David Albert [1996] who hold that actually space is 3*N*-dimensional, where *N* is the number of particles [falsely] thought to exist in [nonexistent] three-dimensional space.)

Question 2: How many dimensions does space have, according to quantum mechanics? If quantum mechanics were a true theory of the world, then the answer to Question 2 would be the same as the answer to Question 1. But quantum mechanics is not true, so the answers need not be the same.

Why is quantum mechanics false? Well, our two most fundamental worked-out physical theories, quantum mechanics and general relativity, are incompatible, and the evidence in favor of general relativity suggests that quantum mechanics is false. For example, some of the evidence for general relativity involves experiments done with precise clocks; these experiments show that clocks in stronger gravitational fields run slow compared to clocks in weaker gravitational fields (see, for example, Hafele and Keating 1972a, 1972b). According to quantum mechanics, ideal clocks run at the same rate regardless of the strength of the gravitational field affecting them. Quantum mechanics makes predictions at variance with experiment, so quantum mechanics is false. (I recognize, for the record, that this argument is not definitive; arguments in science typically aren't. It could be auxiliary hypotheses that are false, not quantum mechanics.

But I don't know of any plausible proposals for such false auxiliary hypotheses, so I assume that it's really quantum mechanics that is false.)

There are attempts by physicists to come up with a new theory that will replace both quantum mechanics and general relativity—yielding prototheories like loop quantum gravity, string theory, and M theory—but that project is very much ongoing, without clear results yet. If we are going to do physics-based metaphysics, it would be nice if we could base our metaphysics on a true fundamental physical theory, or at least on a fundamental physical theory that we had solid epistemic reason to take to be true. Sadly, we don't have such a theory. But one benefit for philosophers is that this makes the project of attempting to engage in physics-based metaphysics much more philosophically interesting. (For more of my thoughts on this, see the last section of this chapter, and for even more, see Monton 2010.)

2 Bohr, Schrödinger, and 3*N*-Dimensional Space

Let's focus on Question 2: how many dimensions does space have, according to quantum mechanics? To answer this question, it is helpful to step back and ask a more basic one: how does one determine the ontological content of a physical theory? Well, if we can (for whatever reason) presuppose that the theory is true, then the ultimate arbiter of the ontological content of the theory is reality itself. But for false physical theories, that presupposition is inappropriate. We cannot, for example, presuppose that Aristotelian physical theory is true—we wouldn't be correctly understanding the content of Aristotelian physical theory. Similarly, we can't presuppose that quantum mechanics is true. If we were to do so, we would conclude that quantum mechanics correctly predicts that clocks in stronger gravitational fields run slower, but quantum mechanics clearly makes no such prediction.

So how do we determine the content of, say, Aristotelian physics? One prima facie promising answer is: "we read Aristotle." What happens if we apply the analogous answer to the case of quantum mechanics? Quantum mechanics did not have a single developer, but Bohr and Schrödinger were two central figures, so let's look briefly at what they thought about the ontological status of quantum mechanics.

Bohr's writings on how to interpret quantum mechanics are notoriously unclear; Bohr himself is open to interpretation. One standard interpretation of what he says is that quantum mechanics cannot be used to describe the world, only the results of a given experimental arrangement. For example, he writes:

> there can be no question of any unambiguous interpretation of the symbols of quantum mechanics other than that embodied in the well-known rules which allow to predict the results to be obtained by a given

> experimental arrangement described in a totally classical way. (Bohr 1935, p. 701)

Obviously, when an experimental arrangement is described in a classical way, it's described as being in a space of just three dimensions. I conclude that Bohr would not be on board with those who hold that quantum mechanics shows that the space that actually exists is 3*N*-dimensional space. (For the record, I could provide a lot more evidence from Bohr to back this up.)

But Bohr was not the only developer of quantum mechanics; Schrödinger played a key role as well. Schrödinger does explicitly consider the possibility that the ontology for quantum mechanics involves a 3*N*-dimensional space. In fact, one might think that he is endorsing that ontology when he writes: "The true mechanical process is realised or represented in a fitting way by the wave processes in *q*-space [where '*q*-space' is Schrödinger's terminology for 'configuration space']" (Schrödinger 1926, p. 25). But he makes this claim in the context of a discussion of one-particle systems, where configuration space is just three-dimensional space. So what would he say about a multiparticle system? Schrödinger considers a two-particle system late in the same paper, but he offers only one sentence about the physical representation of the six-dimensional wave function: "The direct interpretation of this wave function of six variables in three-dimensional space meets, at any rate initially, with difficulties of an abstract nature" (Schrödinger 1926, p. 39). Schrödinger does not elaborate on what these difficulties are, but it's clear he is not endorsing the hypothesis that space is 3*N*-dimensional.

Lorentz picks up on this problem with multiparticle systems. In 1926, he wrote a letter to Schrödinger, in which he says:

> If I had to choose now between your wave mechanics and the matrix mechanics, I would give the preference to the former, because of its greater intuitive clarity, so long as one only has to deal with the three coordinates *x*, *y*, *z*. If, however, there are more degrees of freedom, then I cannot interpret the waves and vibrations physically, and I must therefore decide in favor of matrix mechanics. (Lorentz in Przibram 1967, p. 44)

Schrödinger kept trying to develop an ontology for the wave function—there's a long and interesting story here, but to present it all would be outside the scope of this paper. The short version of the story is that Schrödinger was looking for a way of having the wave function be a mathematical representation of physical processes in three-dimensional space. For example, he wrote a letter in response to Lorentz, and the first point he addresses is the issue of the multiparticle wave function. He writes: "I have been very sensitive to this difficulty for a long time but believe that I have now overcome it" (Schrödinger in Przibram 1967, p. 55). One way to overcome the difficulty would be to decide that it's not a difficulty at all and embrace the thought that physical reality really consists of a wave function evolving in 3*N*-dimensional space. This is definitely not what Schrödinger did. Instead, he gave a (somewhat complicated) proposal for how the wave function can be understood as providing a representation of processes in three-dimensional space. I don't completely understand the proposal, and Schrödinger ultimately decided it was unsuccessful, but here is the proposal he gave in the letter to Lorentz:

> $|\psi|^2$ (just as ψ itself) is a function of 3*N* variables or, as I want to say, of *N* three dimensional spaces, $R_1, R_2, \ldots, R_N$. Now first let R_1 be identified with the real space and integrate $|\psi|_2$ over $R_2, \ldots, R_N$; second, identify R_2 with the real space and integrate over $R_1, R_3, \ldots, R_N$; and so on. The *N* individual results are to be added after they have been multiplied by certain constants which characterize the particles, (their charges, according to the former theory). I consider the result to be the electric charge density in real space. (Schrödinger in Przibram 1967, pp. 55–56)

Schrödinger gives a partial ontology for the wave function, showing how electric charge density in three-dimensional space can be determined via the wave function. Though it would be interesting to explore in more detail how this proposal is meant to work, the key point for our purposes is that Schrödinger is looking for a way to understand the wave function as representing what's going on in "real," three-dimensional space.

Schrödinger kept working on this project for a while, but by 1935 he had given up. He wrote: "I am long past the stage where I thought that one can consider the ψ-function as somehow a direct description of reality" (Schrödinger in Fine 1996, p. 82). For the record, it is unclear to me to what extent he gave up on the project of considering the wave function as a direct description of reality because of the measurement problem, and to what extent he gave up on the project because of the issues of interpreting the 3*N*-dimensional wave function as representing something existing in real, three-dimensional space. Clearly, though, Schrödinger was not willing to endorse the view that the space of reality is 3*N*-dimensional.

3 Interpreting Quantum Mechanics

Let's step back. We started this discussion of Bohr and Schrödinger because we were asking about how many dimensions space has, according to the false theory of quantum mechanics. Just as we look to Aristotle to determine the content of Aristotelian physics, it seems reasonable to look to Bohr and Schrödinger to determine the content of quantum mechanics. If we do that, though, we can readily conclude that people like Albert are wrong to hold that quantum mechanics says that space is really 3*N*-dimensional—that's not the view that Bohr and Schrödinger endorsed.

It's open to people like Albert, though, to hold that the originators of quantum mechanics are not the final arbiters of the content of quantum mechanics. This point could be made generally about scientific theories—like political constitutions, scientific theories are living documents, and how to understand them evolves as history progresses. Though I would not be inclined to endorse this view about scientific theories (or constitutions) in general, quantum mechanics is a special case. The reason is that quantum mechanics as originally formulated has been deemed unacceptable by many physicists and philosophers of physics—it faces the measurement problem, and the originators of quantum mechanics did not come up with any acceptable solution to that problem. As a result, new versions of quantum mechanics have been put on the table. Three prominent versions, which I focus on in turn later, are Bohm's theory, modal interpretations, and spontaneous localization theories like the GRW theory. But when we look to the originators of these versions of quantum mechanics to obtain guidance as to how to understand the ontologies of these versions, we again do not get support for the hypothesis that quantum mechanics should be understood as saying that space is 3*N*-dimensional.

Let's start with Bohm. According to Bohm's theory, particles always have definite positions and evolve deterministically in accordance with a dynamic equation of motion that involves the wave function. The wave function is sometimes referred to as a "pilot wave," pushing the particles around. This understanding of the wave function ignores the fact that the wave function is defined over 3*N*-dimensional space, while the Bohmian particles evolve in three-dimensional space. Bohm recognized this problem. In this 1957 book, he first presents his theory for one electron, where the wave function for the electron would evolve in three-dimensional space (since $N = 1$). He then writes:

> a serious problem confronts us when we extend the theory … to the treatment of more than one electron. This difficulty arises in the circumstance that, for this case, Schrödinger's equation (and also Dirac's equation) do not describe a wave in ordinary three-dimensional space, but instead they describe a wave in an abstract 3*N*-dimensional space, when *N* is the number of particles. While our theory can be extended formally in a logically consistent way by introducing the concept of a wave in a *3N*-dimensional space, it is evident that this procedure is not really acceptable in a physical theory, and should at least be regarded as an artifice that one uses provisionally until one obtains a better theory in which everything is expressed once more in ordinary three-dimensional space. (Bohm 1957, p. 117)

Bohm doesn't elaborate on why using 3*N*-dimensional space is not really acceptable in a physical theory, but I take it that his reasoning is that a physical theory is supposed to be about physical reality, and in our world physical reality consists of ordinary three-dimensional space.

As Jeffrey Bub (1997) spells out, Bohm's interpretation is just one version of a modal interpretation. Modal interpretations specify when and which properties of particles are definite—but unlike Bohm's theory, these definite properties could be properties other than position. The key point though of modal interpretations is that they specify the properties that particles have in three-dimensional space. I don't see how one could provide a version of modal interpretations that made sense in the context of 3*N*-dimensional space. Perhaps it could be done, but this certainly is not a project in which proponents of modal interpretations have engaged.

The GRW theory is more promising from the standpoint of a proponent of the 3*N*-dimensional space ontology. In the GRW theory, the wave function evolves according to a modified version of Schrödinger's equation, where sometimes the wave function indeterministically spontaneously collapses. If this is all there is to the ontology of the GRW theory, then it indeed endorses the hypothesis that the universe is really 3*N*-dimensional. But in fact, Ghirardi himself (the *G* of GRW, and the leading proponent of the theory) wants to add more to his theory, as he makes clear in for example Ghirardi, Grassi, and Benatti (1995). Ghirardi is often interpreted as endorsing the "accessible mass density" link, which specifies how the mass of objects in *three*-dimensional space is distributed, given the structure of the wave function. I have argued (Monton 2004) that this is not the best ontology for the GRW theory, and instead have endorsed the "mass density simpliciter" link, which specifies a somewhat different distribution of the mass of objects in three-dimensional space. The key point is that this debate is happening in the context of understanding what the GRW theory says about what's going on in three-dimensional space; the 3*N*-dimensional ontology is not being endorsed (at least not by Ghirardi).

4 The Wave Function Is Represented by a Property

People like Albert, who endorse the hypothesis that space is really 3*N*-dimensional, could just say that people like Bohr, Schrödinger, Bohm, and Ghirardi are wrong to understand quantum mechanics in the way that they do. But that sounds a bit like saying that Aristotle was wrong to understand Aristotelian physics in the way that he did. (Aristotle was wrong about the truths about physics, but he wasn't wrong about the content of Aristotelian physics.) Perhaps people like Albert should instead be viewed as presenting a new version of quantum mechanics, modifying whatever version they want to start with. For example, starting with Bohm's theory, they could argue that Bohm is wrong to hold that the concept of a wave in 3*N*-dimensional space is not really acceptable in a physical theory, and they can offer a new version of Bohm's theory with the 3*N*-dimensional ontology. Starting from the GRW theory, they can set aside the debate about the correct version of the mass density link and hold that in fact all that exists according to the GRW theory is the wave function evolving in 3*N*-dimensional space. People like Albert can then argue that their new version of quantum mechanics, with the 3*N*-dimensional ontology, is better than all the previous versions of quantum mechanics that have been proposed.

This brings us to the key problem with the 3*N*-dimensional ontology: there is no good reason to endorse it. All the work that the physically existing wave function does can instead be done by a property of the system of all the particles in three-dimensional space (as I first pointed out in Monton 2006). As I discuss in more detail in the next section, given the choice between a radically revisionary 3*N*-dimensional ontology and a normal three-dimensional ontology where the *N* particles in the universe collectively have a certain property, we have no good reason to endorse the radically revisionary ontology.

What is this property I am postulating? Is this some special property that's never been discussed in the literature before, that I'm just making up? On the contrary, this property exists according to a standard way of understanding quantum mechanics. Specifically, it's standard to interpret quantum mechanics in such a way that the *eigenstate-to-eigenvalue link* is true, and according to that link, the *N*-particle system has a property that carries all the information represented by the wave function.

Here's how this works. Consider the wave function for an *N*-particle system; I grant that the mathematical description of the wave function is as of a field evolving in 3*N*-dimensional space. But the wave function is a representation of the quantum state of that *N*-particle system. This quantum state is the eigenstate of some observable. Now, what the eigenstate-to-eigenvalue link holds is that if the *N*-particle system is in an eigenstate of some observable, then the *N*-particle system actually has the property corresponding to that eigenstate. The observable can take various possible values, and the idea is that the property the system has is that it has the value—the "eigenvalue"—corresponding to that eigenstate. In other words, we do not need the wave function as a physical field evolving in a physically existing 3*N*-dimensional space—all the information about the system that the wave function carries can be carried by a single property of the *N*-particle system in physically existing three-dimensional space.

Moreover, moving from the wave function to a property isn't some special move I made up—it's just a fact about quantum mechanics that the wave function is a representation of the quantum state, and a standard way of understanding the quantum state of a system is that it corresponds to a property that a system has. My ontology uses this standard (yet, in this context, unappreciated) way of thinking. To sum up: on my ontology, the wave function doesn't exist as a physical field in physically existing 3*N*-dimensional space; it is represented by property possessed by the physically existing *N*-particle system in physically existing three-dimensional space.

For a more precise formulation of my view, it helps to think of the theory of quantum mechanics using the semantic view of scientific theories. In the semantic view, a theory consists of two parts: a set of mathematical models, and a theoretical hypothesis that says how those mathematical models are taken to represent the world. There are different ways to mathematically model quantum mechanics. For example, using the Hilbert space representation, the state of a system is given by a vector in Hilbert space, whereas using the Schrödinger representation, the state of a system is given by a wave function in 3*N*-dimensional space. How does this correspond to the world? One could put forth a theoretical hypothesis saying that Hilbert space is physically real, and there really is a line of a particular length pointed in a particular direction in that space. Similarly, one could put forth a theoretical hypothesis saying that 3*N*-dimensional space is physically real, and there really is a wave function field evolving in that space. I do not endorse either of these theoretical hypotheses. The theoretical hypothesis I endorse says that there is an *N*-particle system evolving in three-dimensional space; this *N*-particle system has a certain property, and that property can be mathematically represented by a field in 3*N*-dimensional space or by a vector in Hilbert space. What is physically real, though, is the property, not the field or the vector. (Those who are mathematical Platonists are welcome to believe that the field or the vector exists as an abstract object; I myself am a nominalist so will set Platonism aside.)

An analogy might help in this context. Consider the color observable, and consider an ordinary object that has a particular color property. This color property can be mathematically represented by a point in a multidimensional color space. But I do not believe that multidimensional color space exists; what I believe exists is the ordinary object and the color property. (The metaphysics of properties gets tricky here, but I have said all I need to say to present my perhaps helpful analogy.)

So let's go back to quantum mechanics—what role does this property that I'm attributing to *N*-particle systems play? The dynamical evolution of a system in quantum mechanics is given by Schrödinger's equation, and Schrödinger's equation uses the quantum state of a system. Where is this information about the quantum state represented in the world? According to proponents of the 3*N*-dimensional ontology, this information is represented by the wave function field in 3*N*-dimensional space. I maintain, in contrast, that this information is represented by this property that the *N*-particle system has. (Just as the wave function evolves through time, the property that the *N*-particle system has changes.)

In his original paper promulgating the 3*N*-dimensional ontology, Albert (1996, p. 283) writes: "insofar as we are committed to *realism*, there was simply never anything other than physical objects that wave functions *could* have been."

I maintain that that's mistaken—we can be committed to realism but hold that the wave function is represented in reality not by a physical *object* but by a *property*. Specifically, the wave function corresponds to a property of the *N*-particle system, and all the information carried by the wave function is instantiated in reality by that property of the *N*-particle system. We do not need 3*N*-dimensional space to be real to interpret quantum mechanics realistically.

A passage from J. S. Bell backs me up on this. Bell is sometimes presented as supporting the 3*N*-dimensional ontology, but in this passage, at least, he supports my view regarding the wave function: "we can regard it simply as a convenient but inessential mathematical device for formulating correlations between experimental procedures and experimental results, i.e., between one set of beables and another" (Bell 1987, p. 53). The wave function, according to Bell, is an inessential mathematical device; the beables, existing in three-dimensional space, are what's real. What I make explicit is the physical way the information carried by the wave function is represented in the world—the information is represented by a property had by the system of beables in three-dimensional space.

5 Comparing Ontologies

We have two ontologies on the table—the three-dimensional ontology and the 3*N*-dimensional ontology. Why should we favor one over the other? Well, suppose that these two ontologies make the same empirical predictions. That is, suppose that all the experiences we have will be the same regardless of which ontology is true. That is, suppose that the correct relationship between consciousness and the physical world is such that a wave function evolving in 3*N*-dimensional space can give rise to normal conscious experience. (I take issue with these suppositions in Monton 2002, but for the purposes of this chapter I set those arguments aside.) How, then, can we adjudicate between the ontologies? One mode of adjudication is how a choice of ontology will influence the development of future theories; I talk about that in the next section. Another mode is which ontology better fits the pragmatic virtues that scientists use, such as simplicity, elegance, ease of use, and consilience with other theories. I discuss these pragmatic virtues here.

Let's start with simplicity, elegance, and ease of use. For all these pragmatic virtues, I think that the choice between the standard three-dimensional ontology and the 3*N*-dimensional ontology is a draw. I don't see much difference in simplicity or elegance between a three-dimensional space with *N* particles and a 3*N*-dimensional space with a wave function field. Postulating that the wave function is represented by a property of the *N*-dimensional system is not an ad hoc move, because the eigenstate-to-eigenvalue link is a commonly accepted part of quantum theory. Regarding ease of use, both ontologies are ontologies for quantum mechanics, so mathematically, Schrödinger's equation and the wave function can still be used to make predictions for measurement outcomes regardless of which ontology holds.

With regard to consilience with other theories, here I maintain that the three-dimensional ontology is a clear winner. Theories in chemistry and biology and other parts of physics all talk about the world as if it has three dimensions of space. General relativity, for example, provides models of manifolds that have three spatial dimensions and one time dimension.

Related to the pragmatic virtue of consilience with other theories is the pragmatic virtue of consilience with common sense. As I suggested elsewhere (Monton 2006), a pragmatic virtue that scientists use is that one should not accept theories that radically revise people's everyday understanding of the world when there are other, at least equally acceptable theories that do not entail such extreme revision. The 3*N*-dimensional ontology is radically revisionary: we think that the world around us has objects extended in exactly three spatial dimensions, but in fact there is no such three-dimensional space and no such three-dimensional objects. As Albert (1996, p. 277) writes, "whatever impression we have, say, of living in a three-dimensional space … is somehow flatly illusory."

Some disagree with my claim that the 3*N*-dimensional ontology is radically revisionary. Wallace and Timpson write:

> While the wave-function realist will deny that 3-dimensional objects and spatial structures find a place in the fundamental ontology, this is not to say that the 3-dimensional objects surrounding us, with which we constantly interact, and which we perceive, think and talk about, do not exist, that there are not truths about them. It is just to maintain that they are emergent objects, rather than fundamental ones. But an emergent object is no less real for being emergent. (2010, pp. 705–6)

Despite Wallace and Timpson's confident assertion to the contrary, a wave function in 3*N*-dimensional space does not give rise to three-dimensional emergent objects. To argue for my view, it would help to see why Wallace and Timpson think otherwise. But it's not clear from their discussion what is meant to ground the claim that three-dimensional objects exist emergently. As I see it, they have two options.

The first way is to appeal to the fact that there are observers who *experience* three-dimensional objects, and given that that experience takes place, there are (emergently) three-dimensional objects. The second way rejects this and holds that emergence has nothing to do with experience. The second way holds that even in a 3*N*-dimensional universe with no experience at all, there could (emergently) exist three-dimensional objects. (Moreover, just to make clear, we are not talking about objects existing within a three-dimensional hypersurface of this higher-dimensional space; we are talking about a more complicated form of emergence, in which particular sets of three dimensions of the 3*N*-dimensional space correspond to particular positions of particles in the emergent objects. For more on this point, see Ney 2010.)

If the claim of emergence is meant to be grounded in experience, then I offer the following argument by analogy against their position. Imagine that Wallace and Timpson try to appeal to emergence in the context of skepticism. Imagine that they maintain that we are brains in vats, and we don't have hands according to the fundamental ontology, but nevertheless we do have hands—hands are emergent objects. A view along these lines has been presented before, by David Chalmers (2005), but the vast majority of philosophers definitively reject this purported solution to skepticism. The reason this purported solution to skepticism should be rejected is that, given the brain-in-the-vat ontology, it's a fact about reality that the observers who are brains in vats don't have hands, despite the fact that they have the experience of having hands. The same claim can be made in the context of the 3*N*-dimensional ontology—it's a fact about reality that there aren't three-dimensional objects, despite the fact that observers have the experience of interacting with three-dimensional objects.

Let's turn to the second way of understanding the claim that three-dimensional objects exist emergently. Maybe Wallace and Timpson hold that there's something special about the structure of the wave function in 3*N*-dimensional space that gives rise to three-dimensional objects, even in a world in which there's no experience at all. I have two responses. First, I would need to see the argument. Second, I do not think one could provide a sound argument for this, because reality doesn't work that way. It's simply not the case that one can have a 3*N*-dimensional space with a field evolving in it, such that when the field has a certain configuration, three-dimensional objects come into existence. Granted, this is not logically impossible—there could be laws of physics that specify the conditions under which three-dimensional objects come into existence—but for them to come into existence emergently, without this happening in accordance with certain novel laws of physics, is not the way a world where quantum mechanics is true works.

Similarly, for a three-dimensional Newtonian world with *N* point particles, it is unreasonable to hold that a single point particle in 3*N*-dimensional space emergently exists, even though there is a sense in which the 3*N*-dimensional configuration space with the single particle has a straightforward mathematical correspondence with the *N* point particles in three-dimensional space. (Also, given this three-dimensional Newtonian world with *N* point particles, it is unreasonable to hold that there emergently exist two point particles in a 3*N*/2-dimensional space [assuming 3*N* is even], or four point particles in a 3*N*/4-dimensional space [assuming 3*N* is a multiple of 4], and so on.)

So far I have been engaging in speculation—but what is Wallace and Timpson's actual argument for the claim that three-dimensional objects exist emergently, given the 3*N*-dimensional ontology? Unfortunately, they don't provide much of one. Just after the passage I already quoted, they continue with the following:

> It is also worth keeping in mind that many workers in quantum gravity have long taken seriously the possibility that our 4-dimensional spacetime will turn out to be emergent from some underlying reality that is either higher-dimensional (as in the case of string theory) or not spatio-temporal at all (as in the case of loop quantum gravity). In neither case is it suggested that ordinary spacetime is *non-existent*, just that it is *emergent*. (Wallace and Timpson 2010, p. 706)

In the string theory case, I believe that four-dimensional space-time exists, but I wouldn't say it's emergent. Instead, the three spatial dimensions we are familiar with exist as a kind of hypersurface in a higher-dimensional space—the other spatial dimensions are such that we don't perceive ourselves as moving through them. The loop quantum gravity case is different, because on that theory fundamental reality is not spatiotemporal at all. The passive voice construction of Wallace and Timpson's last sentence hides the fact that a theory like loop quantum gravity is open to philosophical interpretation and that some philosophers—I, for example—would strongly argue that for a nonspatiotemporal theory like loop quantum gravity, then indeed ordinary space-time is nonexistent.

Thus, I conclude that the 3*N*-dimensional ontology does not include the existence of real yet emergent three-dimensional objects. It follows that the 3*N*-dimensional ontology really does provide a radically revisionary account of the world, and this is a pragmatic mark against it.

6 Looking Ahead

I maintain that my wave-function-represented-by-a-property-of-an-*N*-particle-system ontology is better than the wave-function-field-evolving-in-3*N*-dimensional-space ontology. But I do not want to argue that my ontology is right and the other ontology is wrong—quantum mechanics is a false theory, so it is natural to conclude that any ontology for quantum mechanics is a false ontology.

Although these ontologies may be false in all their details, one may be more on the right track than the other. It may be that quantum mechanics is false, but we really are living in a space with a large number of dimensions, such that if we were presented with the true theory of physics we would see a natural connection between the quantummechanical ontology of 3*N*-dimensional space and the ontology of the true theory. I think that this is ultimately the viable and prima facie promising claim that the proponents of the 3*N*-dimensional ontology should be understood as making.

It's part of the history of physics that physicists will identify certain claims in a theory as being definitively true, even when they recognize that the theory itself is false. Some false theories are taken to provide certain insights that will carry over into the development of any future theories. For example, Copernican cosmology endorsed the view that the Earth is not at the center of the universe, and that view is universally taken to be an insight of this false theory that carries over into any future development of physics. Somewhat more controversially, most physicists hold that the idea that simultaneity is relative is a core idea of the false theory of special relativity, an idea that will get carried over into any future development of physics. Similarly, the proponent of the 3*N*-dimensional ontology could hold that the idea that the space in which things fundamentally exist is configuration space is an insight that will get carried over into any future development of physics.

It's too early to say whether this idea will catch on the way the antigeocentrism and relativity of simultaneity ideas did, but in principle that could happen. But even if the 3*N*-dimensional idea doesn't catch on in that way, it could still be fruitful. Specifically, proponents of the 3*N*-dimensional ontology can be taken to be providing an expansion of possibilities. Before the development of their view, we had not even recognized that this was a possibility for how to interpret a physical theory. Now that we do, this is a possibility that can be kept in mind as new physical theories are developed in the future. The debate we engage in regarding whether the 3*N*-dimensional ontology is the best ontology for quantum mechanics can be construed as an implicit debate regarding how seriously this possibility should be kept in mind for future theories of physics.

Thanks to David Albert, Alyssa Ney, and Ted Sider for helpful comments.

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