Priority Monism Beyond Spacetime

Baptiste Le Bihan, University of Geneva

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Abstract: *I will defend two claims. First, Schaffer's priority monism is in tension with many research programs in quantum gravity. Second, priority monism can be modified into a view more amenable to this physics. The first claim is grounded in the fact that promising approaches to quantum gravity such as loop quantum gravity or string theory deny the fundamental reality of spacetime. Since fundamental spacetime plays an important role in Schaffer's priority monism by being identified with the fundamental structure, namely the cosmos, the disappearance of spacetime in these views might undermine classical priority monism. My second claim is that priority monism can avoid this issue with two moves: first, in dropping one of its core assumption, namely that the fundamental structure is spatio-temporal, second, by identifying the connection between the non-spatio-temporal structure and the derivative spatio-temporal structure with mereological composition.*

Keywords: priority monism, quantum gravity, mereology, spacetime, fundamentality.

1. Introduction

According to "priority monism", a view defended by Schaffer (2009, 2010), the whole cosmos is more fundamental than its proper parts. The cosmos is identified with a substantivalist spacetime[1] instantiating natural properties without the mediation of objects or substrates: properties are directly pinned down on a spatio-temporal substance (a view called "monistic substantivalism" or "super-substantivalism"[2]). In Schaffer's account proper parts are derivative with respect to the whole they are parts of, and so the cosmos admits of derivative proper parts (spacetime regions instantiating properties). It means that there exists a relation of ontological priority connecting the whole to the parts: when a collection of parts *x*s composes a whole *y*, *y* is ontologically prior with respect to the *x*s.[3] Spacetime regions are identified with material objects, implying that material objects possess derivative existence. Because any proper part of the cosmos is a material object, it

1 I will always refer to "spacetime" rather than "space and time", or "space", taking for granted the lessons of

2 The name originates in Sklar (1974).

3 Whether or not this relation of ontological priority requires a modal analysis is a delicate matter. Steinberg (2015) has argued that priority monism is in conflict with the ontological dependence of any whole on any of its parts. Matteo (2017) has claimed that this argument relies on the view that priority monism is necessarily true, and argued that we should prefer the view that priority monism, if true all, is contingently true (a view also defended by Siegel 2016). My own view is that priority monism might be wholly disconnected from modal matters by being neither necessarily nor contingently true, in any interesting sense of "necessarily" and "contingently", contra a realist interpretation of metaphysical modality (cf. Sidelle 1989, Le Bihan 2015a). Therefore, I will leave aside the delicate question of the modal status of priority monism.

means that the category of material objects includes both *ordinary objects* like tables and chairs and *non-ordinary monstrous* objects such as the sum made of the Eiffel Tower and the top of your nose. Also, any proper part of the universe, seemingly empty, is a material object since any conceivable volume of spacetime *is* a spacetime region and therefore a material object. In brief, the whole cosmos (identified with spacetime) is more fundamental than its parts (identified with spacetime regions/material objects).

Schaffer's view is interesting for many reasons described at length in Schaffer (2009). For instance, priority monism recognises that many features of spacetime regions and material objects are redundant. Indeed, parts of objects do follow the same mereological pattern that spacetime regions they occupy: any part of an object occupies a region of spacetime which is itself a part of the spacetime region occupied by the object. Then, why not just identify objects with spacetime regions in line with super-substantivalism in order to account for this mereological harmony?

Priority monism also gives an explanation of why material objects are always located in spacetime: material objects are nothing other than chunks of spacetime. Therefore, by nature, no material object can escape spacetime: each object simply *is* (a hunk of) spacetime. Likewise, it explains why there is always at most one material object for each spacetime region. Since a material object is a region of spacetime, if two numerically distinct material objects were to be located at the same region of spacetime, these two numerically distinct material objects would have to be numerically identical, which is clearly a contradiction. Therefore, priority monism excludes the possibility of co-located material objects.

This ontological picture is also taken to be nicely consistent with both general relativity and quantum field theory, since the category of material object (including physical particles) does not seem to be fundamental in quantum field theory[4] and, at the very least, is not necessarily required to give an ontological interpretation of these physical theories. But, as we shall see, general relativity and quantum field theory are not the end of the story, and by looking more generally to the whole of physics, it will become clear that classical priority monism could well enter into conflict with the future theory of quantum gravity.

Within the paper, I shall defend two claims. First, in spite of its many theoretic virtues, Schaffer's priority monism is in tension with a genuine possibility described by many research programs in quantum gravity. Interestingly, it means that priority monism, in its original version, could turn out to be empirically refuted. Second, priority monism can be substantially amended in order to be turned into a view more amenable to this physics. The first claim is grounded in the fact

4 Although, it is still debated whether quantum field theory is consistent with an ontology of particles (see for instance Halvorson and Clifton 2002). At the very least, it seems that if real at all, physical particles will have to be very different from classical entities persisting through time, in such a way that it would more natural to stick to an ontology of fields by being eliminativist about physical particles (Le Bihan, 2015a).

that many approaches to quantum gravity such as loop quantum gravity or string theory are often interpreted as denying the *fundamental reality of spacetime*. Since fundamental spacetime plays an important role in Schaffer's priority monism by being identified with the fundamental structure, namely the cosmos, the disappearance of spacetime would undermine classical priority monism. My second claim is that priority monism can appeal to a two-step strategy in order to address this issue*:* First, in dropping one of its core assumptions, namely that the fundamental structure is spatio-temporal, second, in using the notion of composition to understand the connection between the non-spatio-temporal fundamental structure and the spatio-temporal derivative structure. Therefore, this article aims at using some preliminary results in physics and philosophy of physics in order to make a point in the field of contemporary metaphysics.

As I have already argued (Le Bihan, 2016), substantivalism about spacetime is not a necessary component of priority monism. Spacetime may be construed along a relationalist picture as a collection of spatiotemporal relations obtaining between matter points or natural properties. Actually, although Schaffer endorses monistic substantivalism (2009), he examines at length priority monism without considering super-substantivalism (2010). Leaving aside the exact nature of Schaffer's views about the connection between priority monism and super-substantivalism, I shall argue that priority monists should prepare themselves to let go of *both* relationism and substantivalism–at least, when these views are understood as describing the fundamental structure. (There is room for interpretations in which the fundamental structure and the derivative structure do not share the same basic ontology–relational or substantial. But let me leave aside this question in order to focus on the basic ontology of the fundamental realm.) As we shall see, contemporary physics may well establish that there is no fundamental-substantial or relational-spacetime.

2. Quantum Gravity

Quantum gravity is the name of the collection of research programs aimed at bridging the gap between general relativity and quantum field theory, two theories known to be mutually exclusive (for a general introduction aimed at philosophers, cf. Matsubara 2017). Indeed, gravity is construed as a geometrical feature of spacetime in general relativity, whereas it is not described at all by quantum field theory (although the framework of QFT *uses* spacetime, it does not give us a theory *of* spacetime). In this section, I will briefly mention two popular research programs in quantum gravity in order to show why they imply that spacetime emerges from a non-spatio-temporal ontology.

According to loop quantum gravity (LQG hereafter), the natural world is fundamentally made of a *collection of superposed non-spatio-temporal structures* called "spin foams"[5] and displaying strange features like discreteness and fuzziness (see Rovelli 2004 and Rovelli and Vidotto 2014, for a summary aimed at philosophers cf. Huggett and Wüthrich 2013). These structures can be thought of as being made of "spacetime atoms" with particular properties, and must give rise to a structure similar to general relativity in order to explain its predictive success in the domains where general relativity has been well-confirmed. Each of these structures does have its own system of locality, and they differ in general from the system of locality we observe at our macroscopic scale. As in quantum physics, it is quite difficult to understand the ontological status of quantum superpositions. But LQG triggers an additional issue, namely that the system of locality we find in our ordinary phenomenal space, or as described by general relativity, is in general not the same as the one we find in the fundamental structure (cf. Wüthrich 2017). Indeed, neither our familiar macroscopic space and time nor the spacetime of general relativity can in general be easily mapped onto these structures: the fundamental and the emergent structures are sometimes *geometrically deviant*. Huggett and Wüthrich describe the situation as follows:

> [Not] only does the quantum superposition frustrate the applicability of locality criteria, but there is a sense in which even a spin network corresponding to a single term in the superposition is not amenable to the kind of localization that may be required to ensure empirical coherence. The problem is that any natural notion of locality in LQG—one explicated in terms of the adjacency relations encoded in the fundamental structure—is at odds with locality in the emerging spacetime. In general, two fundamentally adjacent nodes will not map to the same neighbourhood of the emerging spacetime [...]. Hence the empirically relevant kind of locality cannot be had directly from the fundamental level. (2013, 279)

Therefore, if something like LQG is true, neither our familiar space and time nor the spacetime of general relativity can be fundamental. Indeed, the fundamental structures described by LQG differ in too numerous ways from them: in particular the fundamental structure is discrete and has a different organization.[6]

We may distinguish two conceptual issues with the disappearance of spacetime in LQG. First, how are we going to explain the predictive success of general relativity? We need to account for its predictive success by relating the new theory of quantum gravity, for instance LQG, to general relativity, perhaps as an approximation under particular circumstances, or perhaps as a genuinely emergent structure. In the absence of such a story, knowing why a spatio-temporal theory

5 Spin foams are the equivalent of classical GR spacetime, and spin networks are the equivalent of space. Spin works are only a first step towards the recovering of GR spacetime: an explanation of the relation obtaining between GR spacetime and spin foams.

6 The status to be played by time in LQG is still ill understood, but it is very likely that the strangeness affecting space will also impact time. It will certainly impact the features of time that are common to space (they are both dimensions made of relations) since, after all, we will need to recover GR *spacetime*. The recovering of specific features of time (like flow, or direction) will also be a difficult task and is called "the problem of time".

adequately describes the world when, fundamentally, there is no spacetime, turns out to be a mysterious fact. Second, how are we going to make sense of the possibility of measurement somewhere and somewhen (problem of empirical coherence)? If there is no space, observations and measurements are not occurring in space. And if there is no time, these observations and measurements are not occurring in time. The challenge is thereby to understand how a view, which is grounded in empirical evidences, could entail that these empirical evidences are not occurring in space and time. Can we just modify our view about the nature of empirical justification in order to preserve an empirical coherence between the physical view and its empirical justification? Do we need some ersatz of space and time in order to ground these empirical justifications?[7] The two problems of GR success and empirical coherence rest on a very same issue: the *ontological problem of spacetime*. What is the ontological status of this emergent spacetime? Should we take it to be real, although derivatively real, less fundamental than the non-spatio-temporal structure described by LQG?

The problem is acute since the two structures are drastically different in having distinct systems of locality. Locality is always *relative to a particular structure* and there is no absolute locality *per se*. Moving from this idea, we may build the two notions of *fundamental locality* and *emergent locality*. Each spin network has its own system of fundamental locality, and likewise, the emergent structure displays its own brand of emergent locality. Locality means here that it is possible to situate an entity in the structure, at least partially. Locality, in this general sense, does not say anything about the nature of the structure that gives rise to locality. Perhaps fundamental locality is compatible with the view that there is no fundamental space because the existence of space requires more than locality in the narrow sense (for instance a metric).[8] Or, alternatively, perhaps fundamental locality requires that there *is* a fundamental space. The choice is purely

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7 On this problem of empirical coherence in the context of configuration space realism, which is a particular interpretation of quantum mechanics, cf. Ney (2015). This issue of recovering space was raised by Monton (2006) and Maudlin (2007) in the context of configuration space realism. In this view, what is real is not the ordinary 3D space, but a 3*N* configuration space, namely a space made of 3N dimensions, *N* corresponding to the number of fundamental particles to be found in the world. Classically, a configuration space is a mathematical tool used to describe the possible states of a system. This approach posits the existence of a physical counterpart of this mathematical space, an exotic physical space that is not the ordinary three-dimensional space. In the context of quantum gravity, the issue has the same structure. But the goal is to recover GR spacetime (from various research programs in quantum gravity) instead of ordinary 3D space (from this particular interpretation of quantum mechanics).

8 The situation is the same in causal set theory. This program draws upon Malament's theorem (1977), which shows that up to a conformal factor, it is possible to derive the geometry described by general relativity models from purely causal structures. It suggests the possibility of recovering general relativistic spacetimes from an ontology of spacetime atoms and “pure causal relations” between these points. This ontology is metric free, since the causal relations between the points are very specific: they do not carry any information about the distance between the points. Cf. Dowker (2014) for a general presentation and Wüthrich (2012) for a philosophical presentation. I mention this approach because it illustrates the idea of a system of locality metric free. You may situate any spacetime atom by describing the network of relations between all the spacetime atoms, without any reference to the derivative geometry. In particular, there is no need to refer to *continuous distances* between entities in order to localise these entities.

terminological for it depends on how we want to define the notion of space, and what we take its essential properties to be, namely the properties that space should instantiate in order to be real.

Although both structures (the fundamental structure and the derivative spacetime) are four-dimensional, there is no isomorphic *mapping* of the fundamental structure upon the derivative spacetime: relations of vicinity in the derivative structure do not systematically correspond to relations of vicinity in the fundamental structure. Let me put it more intuitively. Consider a small arbitrary region of (the derivative) space *R* in front of you. The proper parts of *R*, namely its subregions, are not always organised in the same way in the fundamental structure and in the derivative space. The structural organization of the fundamental structure and the derivative structure are not the same. In a nutshell, insofar as the fundamental space is radically different from the classical space, LQG requires positing two numerically distinct spaces. Now, how are we going to conceive of the relationship between these two structures? This is what is called the "problem of spacetime emergence".

Obviously, loop quantum gravity's ontology is still tentative and it is one research program among others. However, the same worries about the existence of spacetime appear in many other approaches to quantum gravity. In *string theory*, the other most popular attempt at unifying general relativity and quantum physics into a unified theory of quantum gravity, the natural world is conceived of as being made of a collection of strings having ten dimensions in such a way that the issue of getting back our "emergent" ordinary space, or the four-dimensional spacetime of general relativity, is a delicate matter. One might object that most of these dimensions are compactified (closed as circles) in such a way that spacetime emergence is not particularly problematic: the exotic dimensions only play a role at the fundamental scale, and as soon as we zoom out, these dimensions disappear.

However, this objection would be missing part of the story. Indeed, the phenomenon of dualities renders such a derivation problematic. The five string theories were found to be related by a network of duality relations. The theories are empirically equivalent, in a strange way. The mainstream interpretation among philosophers of physics is that this fact tells us something interesting about a more fundamental theory, the M-theory. Take for instance *T-duality* which obtains between the type 2A and the type 2B string theories, and between the two heterotic string theories. T-duality describes the correspondence between two apparently different physical situations: when one of the extra dimensions posited by string theory is compactified in a big circle or in very small circle. A solution with a compactification radius R in one dual is *equivalent* to a solution with radius L^2/R in the other dual, where L is the string length (see for instance Matsubara 2013, 481 and Huggett, 2017). As Matsubara puts it:

> When one of the extra dimensions used in string theory is compactified as a circle something surprising happens. It turns out that physically there is no real difference between a very small circle and a bigger one. If the radius in one solution is R this cannot be distinguished from a solution with radius l_s^2/R where l_s is the so-called string length. (Matsubara, 2013, 481)

What is surprising is that these two seemingly different structures (since they posit different compactification radius for the exotic dimensions) are physically equivalent. According to the mainstream interpretation, the two structures are dual descriptions of the same physical system. From this, it is natural to conclude that what is genuinely physical (in contrast of being only a part of the mathematical description) is what is shared by the two dual descriptions. The idea is then what is common to universes with apparently different sizes is a deeper structure, hard to picture, which may be described in different models attributing different sizes to space. Therefore, the fundamental structure would not be a spacetime (although each dual theory is formally described as a relativistic spacetime). If this is true, then the fundamental structure would be so different from the relativistic spacetime described by general relativity that we may not identify the two structures.

As Huggett writes:

> [The fundamental structure] is not a space in the familiar sense at all, but a "space" with only the structures on which the duals agree. (Quite possibly then, a structure that appears as a formal representation of some more fundamental, as yet unknown, non-spatial object.) [Duals] do agree on the radius of phenomenal space, so that is determinate. But nothing can be both determinate and indeterminate with respect to radius, and so [the fundamental structure] is not phenomenal space. Therefore phenomenal space, specifically as a geometric space of determinate radius, is not a fundamental object of string theory, but an appearance, arising from physical processes [...]. (2017, section 3)

As Huggett argues, if the fundamental structure has no determinate radius, contrary to the phenomenal space that does have a definite radius, it is hard to see how these two structures could be identical. Therefore, relativistic spacetime cannot be identical with the space or, more accurately, with the space*s* described in string theory. Of course, there is a way out: positing the existence of an underlying space, for which the dual representations are only mathematical redundancies. But note that this structure, if it is a space at all, is very different from the relativistic spacetime. Here again, we will need a story about the relationship between the fundamental space, and the derivative relativistic spacetime, namely an explanation of spacetime emergence.[9]

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[9] This more fundamental structure could be described by an M-theory but it could also be something else, a first step towards the formulation of M-theory. My presentation was oversimplified for the sake of clarity. For the reader familiar with string theory, the point could be expressed differently as the view that, independently of the exact

So, at the present time, we do not have a clear story about how to recover relativistic spacetime from the string space(s) but what we do know is that, if string theory were to be born out, the fundamental structure will not be identical with relativistic spacetime. What is more, this emergence will not be explained through a simple story of compactification of the problematic dimensions.

These examples show why spacetime might be emergent from a non-spatial, more fundamental, structure, and is not a relativistic spacetime consistent with general relativity. Independently of which research program will turn out to be the most accurate description of the natural world, it is very likely that general relativity qualifies as what physicists call an "effective theory"–namely one which describes correctly the world only for a particular domain of description (say, for a particular range of energy, see Crowther 2016). Unfortunately, the theory breaks down at other domains: when we zoom in closely to look at very small regions involving a high energy, the notion of spacetime ceases to adequately describe the natural world. For this reason, priority monism, with its commitment to a fundamental spacetime, is at risk of being empirically refuted by the forthcoming physics. However, because of its commitment to the view that reality is stratified in layers, with one layer being more fundamental than the other, we may expect to find interesting resources in priority monism that might help us to interpret spacetime emergence. In brief, priority monism might lead to an interesting interpretation of spacetime emergence but it also requires substantial alterations if we want to put the view at work in this context.

In this spirit, I propose to sketch out a novel kind of priority monism consistent with the claim that spacetime emerges from a fundamental non-spatio-temporal structure. Indeed, in the same way substantivalist spacetime is not a necessary component of priority monism, the view that spacetime is fundamental is not required in order to get priority monism off the ground. Let me call the new kind of priority monism that states that spacetime is not fundamentally real the "*non-*

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relation obtaining between the non-perturbative more fundamental string theory and the less fundamental perturbative string theories, it remains that there the target spaces described by the perturbative string theories may not be identified with the even less fundamental phenomenological spacetime described by general relativity (see Huggett, 2017).

spatiotemporal priority monist view". The view inherits the monist spirit by claiming that there is *only one fundamental entity*: the whole cosmos itself. But it states that this fundamental entity is not spatio-temporal. In classical priority monism, spacetime regions are derivative entities, unlike the whole spacetime. With the non-spatio-temporal priority monist view, I suggest that the priority monist should accept that the *whole spacetime itself*, like spacetime regions, is *derivative*. Both spacetime regions *and* the whole spacetime are less fundamental than the structure that will be described by the future theory of quantum gravity. Interestingly, this picture saves the explanatory power of classical priority monism since it preserves the relation of identity obtaining between material objects and spacetime regions. Indeed, the view displays all the advantages of the super-substantivalist version of priority monism described at length by Schaffer (2009). For instance, it explains why, for any considered material object, this object occupies exactly *one* spacetime region and may not be multi-located: it is simply because material objects are *identical with* spacetime regions. There is no need to posit two different kinds of fundamental entities: spacetime regions *and* objects.

Now, the most pressing issue with the development of a non-spatio-temporal priority monist view is the connection between the fundamental non-spatio-temporal structure and the derivative spacetime.

3. Composing Spacetime

A promising strategy, I suggest, consists in identifying the relation which relates spacetime and the non-spatio-temporal structure on the one hand with the very same relation which relates spacetime and spacetime regions on the other hand: the *relation of parthood*. In the classical picture of priority monism, the fact that spacetime regions are less fundamental that the whole spacetime follows from two claims: 1) spacetime regions are proper parts of the whole spacetime, 2) proper parts are less fundamental than the whole they compose. The relation of proper parthood is acting as a *fundamentality device*. Any whole is more fundamental than the parts it is made of. Therefore, if we decide to extend mereology to cover spacetime emergence, and if we are willing to assume that the non-spatio-temporal structure is more fundamental than spacetime, a natural move is to claim that the whole spacetime is itself a *proper part* of the maximal structure. Indeed, if the whole spacetime is a proper part of the maximal structure (namely, the cosmos) and if proper parts are less fundamental than the whole they compose, then it follows analytically that spacetime is less fundamental than the whole cosmos, and we can cash out the derivativeness of spacetime from the fact that it is a proper part of the fundamental structure.

However, one could object that composition requires, at least intuitively, a *spatial* framework: composition, or decomposition, is taken to obtain *within* space, by taking entities located in space as inputs, and giving other entities located in space and time as outputs. If spacetime is not fundamental, how can we even make sense of the claim that spacetime itself is a *proper part* of something else? Drawing inspiration from logical mereology as developed by L.A. Paul (2002, 2012), and taking note that mereology is sometimes applied to abstract entities, one may deny that mereology require space to get off the ground. The view was developed (Paul, 2002) to solve issues about material composition, identity across time and properties (tropes versus universals) and extended to a discussion of configuration space realism (2012) but it gives us an interesting picture to understand spacetime emergence in general as a compositional phenomenon (as suggested by Paul 2012).

The parts of material objects can be construed in two very different ways: *spatio-temporally* and *logically*. The spatio-temporal parts (or say, to simplify, the spatial parts) of, say, a chair, are the molecules, atoms and other entities all the way down to the mereological bottom of reality, if there is such a thing as a mereological ground level. Alternatively, if the world is gunky, there is no mereological ground level, and material objects admit of an infinite number of smaller and smaller spatial or material proper parts. In contrast, the logical parts of a chair are its properties. The chair is made of a shape, a colour, and many other properties. According to Paul, all these properties of the chair are taken to be its logical parts and to be glued together by a *relation of restricted composition*. She identifies thereby the bundling device that turns some properties into an object with a relation of logical composition. Interestingly for our purpose, this relation of logical composition displays a *trans-categorical feature*, by taking properties as inputs, and giving rise to a material object: its inputs belong to one ontological category, its outputs to another. The mereological parts are *properties*; the mereological whole is an *object*.

There is no need to present at length Paul's view. It is enough to explain roughly how it is supposed to solve classical philosophical puzzles. An example is the problem of co-location. Take for instance a statue and the clay it is made of. The two entities are co-located and, for this very reason, the monist will argue that co-location entails identity: the statue is identical to the piece of clay. In contrast, the pluralist will argue that the statue and the clay own distinct modal properties and that, by an instance of Leibniz law, if the two objects exhibit distinct properties, then they are numerically distinct. Of course, there are many ways to approach this puzzle, but what is of interest here is that logical mereology construes objects as bundles of properties offering thereby a particular solution to the problem of co-location. Properties themselves are not co-located, only material objects (collections of properties) are located by relating to location properties. Locations themselves *are* properties. The statue and the piece of clay, in this account, are two bundles of properties. The two bundles are numerically distinct but they both have, as a logical part, the same *absolute location* corresponding to where the statue and the piece of clay are.

Another interesting feature of her view, in order to approach spacetime emergence, is the treatment of properties with respect to the problem of universals. Philosophers involved in this debate aim at ascertain whether qualitatively identical properties are numerically identical entities multi-located (i.e. genuine universals) or numerically distinct entities holding in a relation of exact resemblance (tropes, i.e. particular properties). However, according to Paul's view, properties are not universals, and in some sense, they are not tropes. Indeed, properties do not have locations. Only objects do by having "*location properties*" as logical proper parts. Properties cannot be multi-located since multi-location is defined as the existence of multiple bundles, which have the same *absolute location* (a property) as a logical proper part. Furthermore, there is no need to posit a relation of exact resemblance between these particular properties (as in the classical trope view) because the qualitative identity of apparently numerical distinct properties is explained by the numerical identity of one and only one property. This property is involved in many bundles of properties and, in particular, is connected to many different *absolute locations*.

It seems as if Paul's view evolved, since in her article from 2002 she defends the view that absolute locations play a central role in solving metaphysical puzzles, while in her article from 2012 she suggests that it could turn out that fundamental mereological atoms are not spatio-temporal. However, conceiving of the mereological atoms as being non-spatio-temporal entails abandoning the notion of absolute locations (which are, by definition, spatio-temporal mereological atoms). If space and time are not fundamentally real, then absolute locations should not be included amid the fundamental elements of the world. Also, Paul explicitly contrasts her view from Schaffer's priority monism by claiming that she subscribes to the view that parts are metaphysically prior to the whole they compose, in contrast to Schaffer's view that wholes are more fundamental than their parts (2012, 221, footnote 1). However, there is no necessary connection between logical mereology and the view that parts are metaphysically prior to the whole they compose. There is no bar to extract logical mereology from Paul's view and priority monism from Schaffer's system, in order to combine them.

Therefore, I propose to endorse both logical composition and the view that wholes are more fundamental than the parts composing these wholes, in order to build a non-spatio-temporal priority monist view. In this new version of priority monism, the whole cosmos is more fundamental than any of its parts. But this whole is not spatio-temporal. The non-spatio-temporal cosmos decomposes into spatio-temporal entities, which are the *logical proper parts* of the fundamental non spatio-temporal structure. Since the whole is more fundamental than its parts, it follows that: 1) spacetime, 2) spacetime regions, and 3) material objects, are less fundamental than the non-spatio-temporal structure. The view remains a form a priority monism: it conceives of the cosmos as being fundamentally *one*. It only departs itself from classical priority monism by approaching the fundamental structure as not being fundamentally spatial and temporal. If spacetime is a proper part of the cosmos, one may ask about its other proper parts. Here it will depend on each program in quantum gravity will turn out to be true. But one should not picture these other parts are ingredients of the phenomenal spacetime like material objects of fields, but rather as ingredients of the fundamental structure. All the other proper parts of the cosmos will be the structures that do not give rise to spacetime (including the manifold, the metric field and the matter field), or to something close to GR.

It is worth emphasising that this new form of priority monism is as virtuous as the classical version. Material objects are still identified with proper parts of spacetime. And these material objects (identical with spacetime regions) are themselves less fundamental than spacetime itself. The only difference with classical priority monism has to do with the additional layer of more-fundamental-than relations obtaining between spacetime itself and the more fundamental structure. Therefore, we can make priority monism consistent with spacetime emergence and benefit from its advantages. Once again, I am not arguing for priority monism on independent grounds. But it is important to realise that priority monism, granted minor modifications, may be turned into a view more amenable to spacetime emergence.

Now, an intriguing question is: to what sort of categories belong the entities that logically compose spacetime? Are they properties, like in Paul's view, or something else? And should we try to think of the mereological atoms as belonging to a particular metaphysical category (like relations, properties) or to a physical category more specific to a particular research program (spin foams, strings, etc.)? I shall leave this difficult question open. Arguably, we may have to wait for a final theory of quantum gravity in order to get a clearer picture of its underlying ontology. What matters here, independently of the fundamental ontology which makes up the actual world, is that logical mereology and priority monism offer an interesting understanding of spacetime emergence.

Finally, one may ask in what sense the cosmos remains *physical* if it is *not spatio-temporal*. Indeed, in the spirit of Armstrong (1978, 261), one may believe that spatio-temporality is a necessary condition or even a definition of what it is to be physical (or natural). According to Armstrong, something is physical iff it is in spacetime or it is spacetime itself. The emergence of spacetime entails that this assumption is false: something can be physical although it is neither spacetime nor in spacetime. Therefore, it might be an empirical discovery that physicality should not be defined in term of spatio-temporality and that spatio-temporality is not a necessary condition of physicality.

Now, I believe we should not worry too much about the disconnection of physicality from spatio-temporality. One may simply claim that the physical *is* just what *triggers* the derivative spacetime.[10] In non-spatio-temporal priority monism, physicality is defined as what *grounds* the derivative spacetime. But note that this explanation of physicality depends on the particular priority monist interpretation of spacetime emergence, which is a particular answer of what I call "the hard problem of spacetime emergence". Indeed, one may distinguish between two questions in the metaphysics of spacetime emergence in analogy with the philosophy of mind. In the same way that, following Chalmers (1995), we may distinguish between the *easy problem of consciousness* and the *hard problem of consciousness*, we may distinguish between the *easy problem of spacetime* and the *hard problem of spacetime*. When asking about the relation obtaining between the physical and the mental, one may aim at finding systematic correlations between mental and physical entities (such as brains or states). This is the easy problem of consciousness. On the other hand, one may ask about the intimate relation between the mental and the physical, at a more abstract level. Are these entities identical (the identity theory)? Or rather, are mental and physical entities distinct (dualism)? Or again, are mental entities purely illusory, entailing that the world is purely physical, without mental entities? In the same way, one might try to find a concrete theoretical reduction of the spatio-temporal theory (general relativity) to the non-spatio-temporal theory (quantum gravity). This is the easy problem of spacetime. Of course this problem is not easy at all, but at least we may expect physicists and philosophers of physics to solve the problem. On the other hand, the hard problem of spacetime is about the abstract relation obtaining between entities posited by the spatio-temporal and the non-spatio-temporal theories. Are these entities identical, distinct, or are only the entities posited by the fundamental non-spatio-temporal theory real?

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[10] I would like to thank Christian Wüthrich for suggesting this idea to redefine the physical as what gives rise somehow to the derivative spatio-temporal (private discussion during the Discussion group on the Metaphysics of Quantum Gravity at the International *Summer School in Philosophy of Physics on the Philosophy of Quantum Gravity*, William Bay, 2016; cf. also Wüthrich 2017, section 2 for a discussion of this point).

Non-spatio-temporal priority monism entails a form of dualism, since the derivative spatio-temporal world, although real, is not identical with the fundamental non-spatio-temporal structure. The monist can use the notion of derivative spacetime as a tool to single out spatio-temporality and, thereby, physicality. On the other hand, an eliminativist approach, stating that spacetime is not fundamentally real, and thereby not real at all, has to propose a different answer: physicality would be defined as what gives rise to the *illusion* of spacetime. Therefore, non-spatio-temporal monism has an interesting proposal regarding what it is to be physical, although it need not be thought of as a reason to favor it over rival interpretations of spacetime emergence: *the physical world is the fundamental structure that grounds the derivative spacetime*.

Does it entail that a physical world could exist without being spatio-temporal? This is a delicate question, and any plausible answer will rely on particular modal conception of the grounding relation connecting the spatio-temporal to the non-spatio-temporal. And the modal status of this relation will depend on the answer given to the hard problem of spacetime. For a priority monist, if the relation of grounding is necessary, as it is often assumed, then there is no way the physical could exist without the spatio-temporal. But if grounded entities are contingently entailed by the grounding entities, then the physical could (in the sense of metaphysical modality) exist in absence of the spatio-temporal. But these issues are specific to priority monism and to the analysis of grounding and I do not aim at settling the issue here.

Conclusion

Priority monism is compatible with *both* the view that spacetime is fundamentally real (classical priority monism) *and* the view that it is not (non spatio-temporal priority monism). The fate of priority monism is not tied to the fundamental reality of spacetime. Arguably, this is good news for priority monists: the fundamental reality of spacetime, or at least of some of its central aspects, comes under attack in most plausible approaches to quantum gravity. Priority monists should be prepared to reject the claim that spacetime is fundamental, and endorse the view that mereological composition should not be tied to spatio-temporality. Perhaps one will remain untouched by this line of thought, though: insofar as the disappearance of fundamental spacetime appears only in physical theories still in development, one might claim that we should not bother too much about their metaphysical consequences. And indeed, we cannot be sure of the exact ontological message the forthcoming physics will deliver. However, claims that spacetime does not exist fundamentally appear in most approaches to quantum gravity and it is very likely that some core properties of spacetime will be erased from the physical description of the world. This essay is a first attempt at relating priority monism with spacetime emergence as we find it in quantum gravity. Although I have not presented a fully developed proposal, I hope at least to have brought the possible non-fundamentality of spacetime and its implication for priority monism to the attention of metaphysicians. In brief, from the perspective of physics and philosophy of physics, non-spatio-temporal priority monism is a serious candidate to interpret spacetime emergence. From the perspective of metaphysics, it is an interesting new conception of priority monism that deserves to be studied further by metaphysicians; at least those who want to keep their metaphysical picture consistent with what we learn from contemporary physics.

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References

Armstrong, David M. 1978. "Naturalism, Materialism and First Philosophy." *Philosophia* 8 (2-3): 261–276.

Chalmers, David J. 1995. "Facing Up to the Problem of Consciousness." *Journal of Consciousness Studies* 2 (3): 200–19.

Crowther, Karen J. 2016. *Effective Spacetime: Understanding Emergence in Effective Field Theory and Quantum Gravity*. New York, NY: Springer.

Dowker, Fay. 2014. "The Birth of Spacetime Atoms as the Passage of Time." *Annals of the New York Academy of Sciences* 1326: 18–25.

Halvorson, Hans, and Clifton, Rob. 2002. "No Place for Particles in Relativistic Quantum Theories?" *Philosophy of Science* 69 (1): 1–28.

Huggett, Nick. 2017. "Target Space ≠ Space." *Studies in History and Philosophy of Science Part B: Studies in History and Philosophy of Modern Physics*. doi:10.1016/j.shpsb.2015.08.007.

Huggett, Nick, and Wüthrich, Christian. 2013. "Emergent Spacetime and Empirical (In)Coherence." *Studies in History and Philosophy of Science Part B: Studies in History and Philosophy of Modern Physics* 44 (3): 276–285.

Le Bihan, Baptiste. 2015a. "Un espace-temps de contingences." *Ph.D. dissertation*, University of Rennes 1.

———. 2015b. "No Physical Particles For a Dispositional Monist?" *Philosophical Papers* 44 (2): 207-232.

———. 2016. "Super-Relationism: Combining Eliminativism about Objects and Relationism about Spacetime." *Philosophical Studies* 173 (8): 2152-2178.

Malament, David. B. 1977. "The Class of Continuous Timelike Curves Determines the Topology of Spacetime." *Journal of Mathematical Physics* 18 (7): 1399–1404. doi:10.1063/1.523436.

Matsubara, Keizo. 2013. "Realism, Underdetermination and String Theory Dualities." *Synthese* 190 (3): 471–489.

———. 2017. "Quantum Gravity and the Nature of Space and Time." *Philosophy Compass* 12 (3).

Matteo, Benocci. 2017 "Priority Monism and Essentiality of Fundamentality: A Reply to Steinberg." *Philosophical Studies* 174 (8): 1983-1990.

Maudlin, Tim W. E. 2007. "Completeness, Supervenience and Ontology." *Journal of Physics A: Mathematical and Theoretical* 40 (12): 3151.

Monton, Bradley. 2006. "Quantum Mechanics and 3NDimensional Space." *Philosophy of Science* 73 (5): 778–789.

Ney, Alyssa. 2015. "Fundamental Physical Ontologies and the Constraint of Empirical Coherence: A Defense of Wave Function Realism." *Synthese* 192 (10): 3105–3124.

Paul, L. A. 2002. "Logical Parts." Noûs 36 (4): 578–596.

———. 2012. "Building the World From Its Fundamental Constituents." Philosophical Studies 158 (2): 221–256.

Rovelli, Carlo. 2004. *Quantum Gravity*. Cambridge University Press.

Rovelli, Carlo and Vidotto, Francesca. 2014. *Covariant Loop Quantum Gravity: An Elementary Introduction to Quantum Gravity and Spinfoam Theory*. Cambridge University Press.

Schaffer, Jonathan. 2009. "Spacetime the One Substance." *Philosophical Studies* 145 (1): 131–148.

———. 2010. "Monism: The Priority of the Whole." *Philosophical Review* 119 (1): 31–76.

Sidelle, Alan. 1989. *Necessity, Essence, and Individuation: A Defense of Conventionalism*. Cornell University Press.

Siegel, Max. 2016. "Priority Monism is Contingent." *Thought: A Journal of Philosophy* 5 (1): 23–32.

Sklar, Lawrence. 1974. *Space, Time and Spacetime*. Vol. 25. 101. University of California Press.

Steinberg, Alex. 2015. "Priority Monism and Part/Whole Dependence." *Philosophical Studies* 172 (8): 2025–2031.

Wüthrich, Christian. 2012. "The Structure of Causal Sets." *Journal for General Philosophy of Science* 43 (2): 223–41.

———. 2017. “Raiders of the Lost Spacetime.” In *Towards a Theory of Spacetime Theories*, Lehmkuhl, Dennis, Schiemann, Gregor, Scholz, Erhard (eds.). Springer.

———. 2017. “Philosophie der Physik.” In *Grundriss Wissenschaftsphilosophie: Die Philosophien der Einzelwissenschaften,* Lohse, Simon and Reydson, Thomas (eds.), Hamburg: Meiner, 201-228.

Wüthrich, Christian, and Callender, Craig. 2017. “What Becomes of a Causal Set?” *The British Journal for the Philosophy of Science* 68 (3): 907–925.