European Journal for Philosophy of Science (2021) 11:74
https://doi.org/10.1007/s13194-021-00390-5

PAPER IN PHILOSOPHY OF THE NATURAL SCIENCES

An apology for conflicts between metaphysics and science in naturalized metaphysics

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Received: 26 January 2021 / Accepted: 17 June 2021

Abstract

According to naturalized metaphysics, metaphysics should be informed by our current best science and not rely on a priori reasoning. Consequently, naturalized metaphysics tends to dismiss metaphysicians' attempts to quarrel with science. This paper argues that naturalized metaphysics should instead welcome such conflicts between metaphysics and science. Naturalized metaphysics is not (and should not be) eliminative of metaphysics. So, if such conflicts are driven by the immediate absence in science of an answer to a metaphysical question, then the conflict should not be dismissed, but instead be received as an occasion to do (more) naturalized metaphysics. That conflicts between metaphysics and science might be beneficial for naturalized metaphysics is exemplified by the case of non-spatial theories of quantum gravity. These theories are criticized by metaphysicians who, often following David Lewis, argue that spatial distance is an indispensable fundamental element in any coherent metaphysics due to its role as the world-making relation. The resulting conflict, however, is found to be well-motivated since the non-spatial theories of quantum gravity offer no alternative world-making relation to spatial distance. Rather than dismissing this conflict, naturalized metaphysics should therefore receive the Lewisians' resistance as a call to search for one. How this plays out as a negotiation between the scientific theory and the metaphysical question is exemplified in the last part of the paper where entanglement is proposed as an alternative world-making relation in loop quantum gravity.

Keywords Naturalized metaphysics · Metaphysical methodology · Quantum gravity · Entanglement fundamentalism · Metaphysics vs. science · Humean supervenience

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Published online: 23 July 2021

1 Introduction

While there is no univocal definition of metaphysics, it is often characterized as the "systematic study of the most fundamental structure of reality" (Lowe, 1998, 2), as "the study of ultimate reality" (van Inwagen, 2015, 1), or as "*the exploration of the most general features of the world*" (Blackburn, 2002, 61, emphasis in original).[1] This characterization, however, might just as well be given of fundamental physics, at least adopting a realist voice. Fundamental physics is arguably also interested in the structure and features of ultimate reality. It is therefore not surprising that this (apparent) overlap in subject matter between metaphysics and fundamental physics is a seed of conflict. This paper investigates such conflicts and more generally conflicts between metaphysics and science. The paper argues that, rather than being dismissed as signs of metaphysicians' overconfidence, conflicts between metaphysics and science should be welcomed as hints of genuine and important questions to be answered by naturalized metaphysics. While metaphysics should ultimately defer to science, as naturalized metaphysics argues, metaphysicians should only yield once science – through naturalized metaphysics – provides a positive (metaphysical) answer to their metaphysical questions.

As a case study, the paper uses theories of quantum gravity – theories that attempt to reconcile quantum mechanics and general relativity – where space appears to be absent at the fundamental level of reality as described by those theories. Space, distance, and generally extension do not seem to feature in the fundamental ontology implied by quantum gravity theories such as loop quantum gravity and causal set theory (Huggett & Wüthrich, 2013). Consequently, such theories are received with suspicion by some metaphysicians and philosophers of science who have questioned the coherence of non-spatial ontologies (e.g. Esfeld, 2019; Hagar & Hemmo, 2013; Lam & Esfeld, 2013; Maudlin, 2007a). Presently, the focus will be metaphysical concerns about the non-spatial theories of quantum gravity that variously echo David Lewis' (1986a, 1986b, 1994) thesis that spatial distance is the fundamental relation in the world and in particular, the relation in virtue of which the elements of an ontology make up a world.[2] The disappearance of space in some theories of quantum gravity thus gives rise to a conflict between these scientific theories and Lewisian metaphysics (Wüthrich, 2019): Where the Lewisians[3] argue that spatial

[1] Such characterizations of metaphysics are disputed by others (e.g. Bennett, 2016; Paul, 2012) who argue that the questions addressed by metaphysics are different from those of science in general and physics in particular. This debate will be set aside here, though, since the focus will be on instances where metaphysics – as least as the term in used here – does come into direct conflict with science as exemplified by the conflict between Lewisian metaphysics and quantum gravity. Perhaps this shows that 'metaphysics' is misused in the present account, but anyone favoring this view can replace 'metaphysics' in the following by a more adequate term that they find better captures the sort of questions for instance Lewis asks about world-making.

[2] For a more detailed account of Lewis' "worldmate relation", see Darby (2009).

[3] We shall use 'Lewisians' as a collective term for those who express a preference for the fundamentality of spatial distance. While the proponents of this thesis do not in general endorse all aspects of Lewis' metaphysics, we shall use this term since especially Lewis' Humean supervenience thesis is routinely referred to in support of the ontological prioritizing of spatial distance (e.g. Esfeld & Deckert 2017; Lam, 2016).

distance – given its role as the world-making relation – is a necessary fundamental element in any coherent metaphysics, these theories of quantum gravity propose that in the actual world space is non-fundamental.

Naturalized metaphysics is known to vigorously criticize metaphysics that is not sufficiently informed by the discoveries of our best sciences. It is therefore not surprising that naturalized metaphysics finds it misguided when metaphysics quarrels with science: "If there is a contradiction between the physics and the metaphysics, then the metaphysics must give way" (Bird, 2007, 7).[4] This sentiment is even shared by metaphysicians who are not usually cast as naturalists. Jonathan Lowe, for instance, gives metaphysicians the advice of "opening oneself up to the possibility that one's claims about the metaphysical features of actuality will be undermined by developments in empirical scientific theory" (Lowe, 1998, 26). Even outside of naturalized metaphysics, few are inclined to follow Parmenides who, on a priori grounds, famously argued against the existence of change despite the empirical evidence to the contrary. The received view, in other words, seems to be that science takes priority over metaphysical theorizing in cases of direct conflict.

This promises to quickly resolve the conflict between Lewisians and the non-spatial theories of quantum gravity: Considering that their resistance – like Parmenides' – appears to be at least partly based on a priori reasoning, the Lewisians should simply yield and give up the fundamentality of spatial distance.[5] For naturalized metaphysics, this conflict is another illustration that science-independent metaphysics is not only futile but also harmful, if it aims to compete with science (e.g. Bryant, 2020).[6] This paper, however, proposes that naturalized metaphysics might benefit from preserving such conflicts, at least for a while. As Humphreys (2013) observes, "[c]ontemporary science has revealed a much more subtle and interesting world than the often simple worlds of speculative ontologists" (p. 75). Science is sometimes in conflict with metaphysics as a whole in the sense that it proves that none of our hitherto conceived metaphysical frameworks are viable. However, what new metaphysics that science replaces these with will only be revealed if we remember to probe the metaphysics of a scientific theory and not simply end our inquiry – as naturalized metaphysics sometimes seems to recommend – when science proves our held metaphysical beliefs wrong. The presence of conflicts between metaphysics and

[4] Obviously, this ruling relies on an appropriate demarcation between physics (and science in general) and wild speculation that may happen to involve some mathematical formalism; some might worry that some theories of quantum gravity are examples of the latter (see for instance Hedrich (2007) for a discussion of this and similar questions in relation to string theory). This issue will be set aside here for the reason also discussed further in footnote 17 that the present apology for conflicts between metaphysics and science does not rely on the assumption that the scientific theories in question are speculative or yet to receive proper empirical confirmation.

[5] Such a priori motivated resistance against empirical science will be denoted 'Parmenidean resistance' due to the methodological analogy with Parmenides' a priori arguments against the apparent experience of change. This despite the curious coincidence that loop quantum gravity – especially with the apparent disappearance of time (e.g. Anderson, 2012; Isham, 1993) – has similarities in content with Parmenides' metaphysics.

[6] See Ladyman and Ross (2007, 19–20) for a general criticism of Lewis' metaphysics from the perspective of naturalized metaphysics.

science, I argue, is often the most vivid manner in which the metaphysical surprises of science manifest themselves, and these conflicts are therefore our best sign of when and where to begin such inquiry. This does not entail a rejection of the verdict that science generally takes priority over metaphysics. However, the paper proposes the qualification that it might be helpful if metaphysics offers a bit of (adequately motivated) Parmenidean resistance. The conflicts that result will encourage engagement with the metaphysical issue behind the conflict and thus ensure that science – through a naturalized metaphysics – not only proves our old metaphysics wrong but also provides a new *metaphysics* in its stead. The Parmenidean resistance of metaphysicians might, in other words, prove an invaluable resource for naturalized metaphysics. Furthermore, the paper argues that in merely raising unanswered metaphysical questions, this type of Parmenidean resistance should be acceptable to naturalized metaphysics even assuming all its central tenets.

To illustrate how conflicts between metaphysics and science can serve as generators for naturalized metaphysics, the paper explores the conflict between non-spatial theories of quantum gravity and Lewis-inspired metaphysics. Lewisians argue that without space in their fundamental ontology, such theories lack a candidate world-making relation and they are, as a consequence, at risk of being metaphysically incoherent. Following the present proposal, this is an occasion to inquire into the metaphysical question behind the conflict: what, if anything, might replace space as the world-making relation in non-spatial theories of quantum gravity?[7] Rather than ending with this methodological suggestion, the paper exemplifies it by reviewing the details of loop quantum gravity based on which it is argued that entanglement might serve as the world-making relation in this non-spatial theory. In a few more words, entanglement between the nodes in the spin-network of loop quantum gravity is found to be crucial for the emergence of space in this theory. This is taken to indicate that entanglement might be the relation in virtue of which the elements of the spin-network make up a world and thereby be the relation that glues together the fundamentally non-spatial worlds of loop quantum gravity; a proposal that should arguably qualify as a "subtle and interesting" alternative to the ontologies of distance, but which is nevertheless motivated by science as naturalized metaphysics requires. This account thereby concretely exemplifies how the methodological proposal of the paper can be implemented to contribute to naturalized metaphysics.

The paper proceeds as follows: Section 2 introduces the case study: the conflict between Lewisians and non-spatial theories of quantum gravity. Section 3 then discusses how philosophers who pursue such conflicts are typically derided in naturalized metaphysics but argues that they should not be if the conflict is driven by the absence of a viable metaphysical interpretation of the scientific theory. In such cases, conflicts can serve as a heuristic tool for naturalized metaphysics. Section 4 exemplifies how this plays out in the proposal that entanglement is the world-making relation in loop quantum gravity, thereby answering the question that motivated

[7] When asking this question with respects to quantum gravity, we might be seen as following Norton's (2020) suggestion that "metaphysicians ought to utilize quantum theories of gravity […] as incubators for a future metaphysics" (p. 1).

the Lewisians' conflict with the non-spatial theories of quantum gravity. Finally, a conclusion follows.

2 A conflict between metaphysics and science

The Humean supervenience thesis[8] "says that in a world like ours, the fundamental relations are exactly the spatiotemporal relations" (Lewis, 1994, 474).[9] A fundamental relation is important for Lewis' modal realism, since it explains why something belongs to one rather than to another of all the actually existing possible worlds. It explains, in other words, how two entities can be recognized as *worldmates*: "things are worldmates iff they are spatiotemporally related. A world is unified, then, by the spatiotemporal interrelation of its parts" (Lewis, 1986a, 71). Thus, both the notion of world and the worldmate relation is, according to Lewis, grounded in spatiotemporal relations.

The aim here is not Lewis exegesis, and the outset for the discussion is instead more recent proposals, inspired by Lewis, that emphasize the centrality of *spatial* distance and which are explicitly directed against the non-spatial theories of quantum gravity. An example is the ontology of distanced matter points promoted by Esfeld and Deckert (2017). They argue that spatial distance is the relation that makes the world; the "world-making relation" in the terminology of Esfeld (2019). In their view, the need for a world-making relation can be maintained independently of modal realism. Irrespective of whether the other possible worlds exist, there is a plausible sense in which we – and the entities with which we surround ourselves – belong to the same world. We are worldmates, and as such, some relation must make this fact true: "given a plurality of objects, there has to be a certain type of relations in virtue of which these objects make up a world" (Esfeld & Deckert, 2017, 3). The need for a world-making relation comes from the need of ontological glue, and this is required as soon as we commit to the existence of "a plurality of objects" in the actual world. The task of the world-making relation is to be the relation that connects the elements of the ontology into configurations and as such, it grounds whether we live in a multiverse of more detached parts or a single connected universe. Thus, 'what makes it true that we are worldmates?' suggests itself as a genuine metaphysical question independently of modal realism.[10]

The quest for a theory of quantum gravity does not, however, begin with this question. Rather, quantum gravity research is driven by an aspiration for unification of our account of nature: "The problem of quantum gravity (QG) is to find a theory that describes the phenomena at the intersection of general relativity (GR) and quantum field theory (QFT)" (Crowther & Linnemann, 2017, 2). This problem

[8] The Humean supervenience thesis has more to it than the claimed fundamentality of distance relations, see for instance Weatherson (2015) for an introduction.

[9] It is charitable to observe, as Darby (2009, 202) does, that Lewis regarded this thesis as fallible.

[10] See Jaksland (2020) for further discussion of the need for a world-making relation in the absence of modal realism.

has generated several competing research programs, the most prominent being string theory, loop quantum gravity, causal set theory, and causal dynamical triangulation (see the contributions in Oriti (2009) for an overview of these programs with focus on space and time). In their attempt to reconcile general relativity and quantum mechanics, several of these appear to do away with space at the fundamental level description.[11] Loop quantum gravity, which we shall use throughout for illustration, offers a fundamental description of the world in terms of an abstract graph structure consisting of nodes and links.[12] Both the nodes and the links carry a spin representation (SU(2)) and together these define the kinematical Hilbert space of states. States of this Hilbert space are manifestly invariant under local gauge transformations of the spin representation, and this presentation of loop quantum gravity is therefore called a spin-network. Since spin-networks are discrete, they already differ from the smooth structure of space. Indeed, most spin-network states will not even admit an approximation as a smooth spacetime just like an equilibrium thermodynamic description is only available if the macroscopic behavior of a system is sufficiently robust with respect to the individual changes among the microscopic degrees of freedom. When space is said here to be non-fundamental in loop quantum gravity, this is meant to be analogous to the sense in which temperature is non-fundamental in statistical mechanics.[13]

Even if space is absent at the fundamental level as described by non-spatial theories like loop quantum gravity, Esfeld (2019) insists that the question remains what makes it true that we are worldmates: "in this case, we need another world-making relation than the spatial or spatiotemporal one" (p. 4). The problem, as Esfeld (2020) formulates it elsewhere, is that "no one has hitherto worked out a proposal for another type of relations than distances that could […] be empirically adequate" (p. 1892). One might object to Esfeld that if space is absent at the fundamental level of description, then the same could be the case for worldmates. Indeed, people, tables, and chairs play no explicit role in for instance the fundamental description in terms of spin networks in loop quantum gravity. This, however, does not show that there are no worldmates and no need for a world-making relation. If two elements are worldmates at some level of description, then irrespective of what (complex) they correspond to at the fundamental level of description, they must arguably remain worldmates and some relation must make this fact true. Thus, just as one inquires

[11] In so far as these theories aim to recover general relativity and general relativity describes the dynamics of spacetime, the theories are naively committed to recovering spacetime as an emergent phenomenon. Whether this is sufficient to regard spacetime as real is debated (e.g. Lam & Wüthrich 2018; Le Bihan, 2018; 2019; Baron, 2019). We shall set this debate aside here and simply observe that space appears to be absent at the *fundamental* level of the ontology which is sufficient to generate the conflict with Lewisian metaphysics.

[12] This is one of several possible expositions of loop quantum gravity, see Rovelli (2008) and references therein for an overview.

[13] Since equilibrium thermodynamics requires that "all reasonable macroscopic observables have steady values" (Pitowsky, 2006, 432), no macroscopic description applies to many of the kinematically admissible microstates. The same applies to generic spin-network states: special circumstances must obtain for it to admit an approximation where anything is recognizable as space. See Wüthrich (2017) for further details and discussion of the disappearance of space in loop quantum gravity.

how a non-spatial theory of quantum gravity accounts for space, one can inquire what at its fundamental level of description makes it true that we are worldmates. As discussed in further detail in Section 4, we should remain open to the possibility that these theories prove 'worldmate' to be an inadequate category with the consequence that no question about world-making arises, but the reason would be more subtle than the absence at the fundamental level of the entities usually supposed to be worldmates. Rather, the question might be obsolete if it turns out that the categorization in terms of elements and relations is problematic. Presently, the need for a world-making relation will largely be taken for granted for purposes of illustration and it is therefore left open that the physics might in the end render this metaphysical question to be ill-posed rather than providing another world-making relation[14]; though we shall argue that loop quantum gravity does seem to suggest entanglement as alternative world-making relation.

Assuming the question about world-making is well-posed, if the distance relation is absent at the fundamental level of the ontology, then another relation must take its place, but according to Esfeld no such alternative is currently on offer.[15] Consequently, Esfeld (2019) cautions against the apparent metaphysical import of these (seemingly) non-spatial theories of quantum gravity: "as things stand, it is reasonable to recommend caution about proposing far reaching ontological consequences such as the disappearance of spacetime or fundamental spatiotemporal relations" (p. 13). These worries about fundamentally non-spatial worlds are reasons to be skeptical of these scientific theories; especially of their alleged metaphysical implications. In other words, though Esfeld offers it in a conciliatory voice, metaphysical concerns are pivoted against scientific theorizing – here in the form of specific theories of quantum gravity with metaphysically worrisome implications.

While Esfeld and the other authors mentioned in the introduction are those that voice their concern about the non-spatiality of certain theories of quantum gravity most explicitly, many of their worries are mirrored by those who prefer the Bohmian interpretation of quantum mechanics out of a concern for the absence of local beables[16] in other interpretations (e.g. Bricmont, 2017; Maudlin, 2007a); some of these even expressing an explicit sympathy for Humean supervenience (e.g. Loewer, 1996; Miller, 2014). Also the primitive ontology program (also most often pursued in the context of quantum mechanics) explicitly requires that "any satisfactory fundamental physical theory […] contains a metaphysical hypothesis about what constitutes physical objects […] which lives in three-dimensional space or space–time and constitutes the building blocks of everything else" (Allori, 2015, 107). According to (this type of) primitive ontology, space is a precondition for any satisfactory metaphysics and thus an essential component of the metaphysics of a satisfactory

[14] Likewise, we shall not enter the debate whether some views on emergence, ontological reduction, and levels of reality might allow that entities at some level of description are world-mates while entities at another level of description – such as those of the supervenience base of the former – are not.

[15] With space being emergent (in some sense) in the non-spatial theories of quantum gravity, one might propose that distance could *remain* the world-making relation. See however Wüthrich (2019, sec. 7) for a rejection of this argument.

[16] In the sense of Bell (2001).

physical theory. Consequently, proponents of primitive ontology and more generally those favoring local beables will most likely share Esfeld's sentiment that theories without space at the fundamental level of their ontology should be treated with caution, or perhaps even deem such theories metaphysically illegitimate. This, then, generates a tension with non-spatial theories of quantum gravity and offers a concrete example of a conflict between metaphysics and science.

Before we proceed to the attitude towards such conflicts in naturalized metaphysics, one may wonder how this and other conflicts like it can be sustained for long enough to be the subject of a methodological discussion. Why are these conflicts not simply resolved instead? After all, the scientific theories in question are readily available in research papers, reviews, and even often textbooks. When Esfeld worries what is the world-making relation in non-spatial theories of quantum gravity, the question could just be met with a 'like this' – presenting the theories' best account of the world. He can just have a look.[17]

Science, however, rarely explicitly answers the questions of interest to metaphysicians. As also often argued in relation to the underdetermination of metaphysics by science (see for instance Andersen and Becker Arenhart (2016), French (2011), and Jones (1991)), the metaphysics of a scientific theory is rarely manifest in its formalism. Thus, having the theory readily available will usually not immediately answer the metaphysical inquiries one might direct at it, and this is for good reason: the questions driving the scientific theories are different from those driving the metaphysical exploration of them.[18] Theories of quantum gravity and the metaphysical questions here directed at them make for a good example. As stated above, the construction of a theory of quantum gravity is driven by the problem of reconciling general relativity and quantum field theory; a problem that has proven difficult and that has therefore called for novel developments in theoretical physics. Non-spatial theories are among these developments, and their surprising character is a consequence of these difficulties. In other words, these theories were not developed to fulfill an aspiration to explore the possibility of a non-spatial physical theory. What these theories seek to make manifest is how they might recover general relativity and quantum field theory, and not what replaces distance as the world-making relation. Theories of quantum gravity are designed to answer a particular question of physics; not various metaphysical inquiries. This explains why a conflict between metaphysics and science can persevere: Science rarely, if ever, answers metaphysical

[17] As Esfeld (2019) notes, "the approaches to quantum gravity that allegedly entail that spacetime or spatiotemporal relations are not fundamental are approaches that, as things stand, do not yield any empirical predictions" (p. 11–12); they find themselves in a very speculative domain of high energy physics. This is a warranted note of caution about these theories, however, the apology made here for conflicts between metaphysics and science will not utilize this fact. Metaphysicians do not need this as an excuse when they ask metaphysical question of scientific theories.

[18] Esfeld (2019) relies on this underdetermination to question whether space is in fact absent at the fundamental level of these seemingly non-spatial theories of quantum gravity alluding to the apparent non-locality in quantum mechanics which was nevertheless reinstated in Bohmian mechanics (and thus proved to be at least consistent with the quantum formalism). However, the present argument does not rely on such underdetermination as part of its apology for conflicts between metaphysics and science, and it will therefore be assumed for purposes of argument that spacetime does disappear in these theories of quantum gravity.

questions explicitly and this, as shall be argued in the next section, is why conflicts between metaphysics and science can prove useful.

3 Naturalized metaphysics and metaphysical questions

Naturalized metaphysics features both a destructive and constructive component: The destructive component criticizes the traditional methods of metaphysics – intuitions, common sense, conceptual analysis, and a priori reasoning – while the constructive component proposes that metaphysics should instead be based on the findings of our current best sciences: "Naturalism requires that, since scientific institutions are the instruments by which we investigate objective reality, their outputs should motivate all claims about this reality, including metaphysical ones" (Ladyman & Ross, 2007, 30).

Proponents of naturalized metaphysics argue that our intuitions, concepts, and patterns of a priori reasoning are the results of biological evolution, and according to Ladyman and Ross (2007) "there is no reason to imagine that our habitual intuitions and inferential responses are well designed for science or for metaphysics" (p. 3). These evolved cognitive features furnish no faculty that can provide insights about reality, and it is therefore problematic when they have traditionally formed the methodological basis for metaphysics. This is especially so, when metaphysics take interest in those parts of reality that we do not encounter in our lifeworld, for instance the content and structure of fundamental reality. Here, any reliance on these evolved features is "ignoring the fact that science, especially physics, has shown us that the universe is very strange to our inherited conception of what it is like" (Ladyman & Ross, 2007, 10); the sentiment also expressed by Humphreys (2013, 75) above. According to Ladyman and Ross, this criticism also applies when metaphysics moves from claims of the actual world and to modal claims of possibility and necessity. In arguing what is metaphysically possible or necessary, the traditional methods of metaphysics have proven unreliable.[19] Ladyman and Ross write:

> we deny that a priori inquiry can reveal what is metaphysically possible. Philosophers have often regarded as impossible states of affairs that science has come to entertain. For example, metaphysicians confidently pronounced that non-Euclidean geometry is impossible as a model of physical space, that it is impossible that there not be deterministic causation, that non-absolute time is impossible, and so on (Ladyman & Ross, 2007, 16; see also Maudlin, 2007b, 187–88).

The traditional methods of metaphysics can neither be employed to say what is the case nor what can or cannot be the case. In particular, they cannot be employed to inform what features are indispensable for metaphysically coherent worlds.

[19] Since the aim here is an apology for conflicts between metaphysics and science *within* naturalized metaphysics, this alleged unreliability of the traditional methods of metaphysics on questions about possibility will be taken for granted here even though it, as for instance Morganti (2016, 87) argues, is questionable whether science has been any more reliable in its judgements about possibility.

By this destructive component of naturalized metaphysics, there are no resources within metaphysics that can be mobilized for a quarrel with science. Indeed, Ladyman and Ross forcefully reject this type of speculation:

> Physicists do not believe there are such things as good a priori grounds for holding beliefs about the constitution of the physical world, and we suggest that only a foolhardy philosopher should be willing to quarrel with them on the basis of his or her hunches (Ladyman & Ross, 2007, 18).

This includes "hunches" about possibility, and it should therefore be equally "foolhardy" to quarrel like this whether the science in question is empirically well-confirmed or not (though the former may be more preposterous than the latter). Even if a scientific theory is not actualized, nothing internal to metaphysics can justify the claim that a scientific theory describes an impossible state of affairs. This is also in good accordance with the constructive component of naturalized metaphysics that requires metaphysics to be motivated by the outputs of science; being in conflict with a scientific hypothesis – well-confirmed or not – looks to be the exact opposite. But how, one might ask, can we decide whether this theory is a scientific theory – such that this is a conflict between metaphysics and science – and not a piece of metaphysics itself whereby the conflict would be internal to metaphysics? Naturalized metaphysics has two independent replies: First, it can be argued that it makes no difference whether the theory being questioned by metaphysics is scientific or not. In both circumstances, there is no epistemically legitimate basis for the conflict due to the problems with the traditional methods of metaphysics. Second, Ladyman and Ross (2007) identify science "using institutional factors as proxies rather than by directly epistemological criteria" (p. 37) such that "a 'scientific hypothesis' is understood as an hypothesis that is taken seriously by institutionally bona fide science" (p. 30). Institutional factors – including being published in respectable scientific journals and funded by scientific research fonds (Ladyman & Ross, 2007, 36) – rather than empirical confirmation demarcate science from non-science. According to Ladyman and Ross, metaphysics cannot question the institutionally identified scientific hypotheses that include those of quantum mechanics and the relativity theories, but also arguably the main contenting theories of quantum gravity such as loop quantum gravity, string theory, etc. From the perspective of naturalized metaphysics, proclaiming that worlds without space are impossible seems to be no different from the claim that non-Euclidean worlds are impossible, and one might therefore speculate whether the former, like the latter, is a mere example of metaphysicians' overconfidence.

This view has recently been advanced by Lam and Wüthrich (2020). Assuming that science should inform (or "guide") metaphysics, they argue that.

> from the point of view of the QG [quantum gravity] approaches pointing to the disappearance of spacetime […] assuming a priori an ontological framework for QG relying on some standard smooth spacetime background (e.g. assuming a priori an ontology of local beables for QG) is neither physically nor metaphysically legitimate (contrary to what is sometimes claimed in the literature, see Esfeld (2019). Indeed, in this perspective, such a metaphysical assumption is illegitimate

since it directly conflicts with certain physical ingredient principles on which the considered QG approaches are based (Lam & Wüthrich, 2020, 12).

Since Esfeld and others, on Lam and Wüthrich's construal, defend the need for space(time) at the fundamental level of the ontology on a priori grounds, it is *illegitimate* for them to hold onto this metaphysical assumption when the considered approaches to quantum gravity point to the non-fundamentality of space(time). The scientific theory takes priority over metaphysical reasoning in cases of conflict. Insisting on an a priori metaphysical assumption in the interpretation of the scientific theory, i.e. "[p]ostulating ontologies on some fixed background spacetime for these QG approaches", Lam and Wüthrich conclude, "stands in direct tension with the naturalism we have adopted and in particular with a naturalistic approach to metaphysics" (Lam & Wüthrich, 2020, 13). In stressing their focus on specific "QG approaches" and in recognizing that these are still lacking in empirical support, Lam and Wüthrich are open to the possibility that the theory of quantum gravity that is eventually vindicated is one where space remains fundamental. However, they nevertheless insist, and thus echoes the view above, that this is no excuse for metaphysical objections to these non-spatial approaches. Lam and Wüthrich appeal to a naturalistic approach to metaphysics to argue that Esfeld and others must end their illegitimate metaphysically motivated criticism of the non-spatial theories of quantum gravity.[20]

But exactly why is naturalized metaphysics critical of (a priori) metaphysical conflicts with science? The general aim of naturalized metaphysics is not, and should not be, to end metaphysics. Naturalized metaphysics involves a criticism of the methods but not the subject matter of traditional metaphysics. In contrast to eliminative programs advocating metaphysical anti-realism (e.g. Carnap, 1950; Chalmers, 2009; Yablo, 1998), Ladyman (2017) insists that "metaphysics should not be abolished but reformed" (p. 143).[21] The constructive component of naturalized metaphysics involves the introduction of new science-informed approaches to metaphysics that can replace those illicit methods traditionally employed in metaphysics while preserving the subject matter and thus ambitions of metaphysics.[22] Where metaphysical anti-realists are critical of metaphysical questions – for instance describing them as "devoid of cognitive content" (Carnap, 1950, 28) – naturalized

[20] Notice that this does not entail that the non-spatial theories of quantum gravity considered by Lam and Wüthrich take priority over other theories of quantum gravity that are more hospitable to fundamental spatial relations (e.g. Goldstein & Teufel 2001; Dürr et al., 2018). Thus, while metaphysicians, on their view, should end their criticism of the non-spatial theories, metaphysicians are of course welcome to spend their time on the metaphysical implications of other theories of quantum gravity. However, according to naturalized metaphysics, science will decide which of these that will be vindicated and not some a priori argument to the effect that one or the other theory is metaphysically impossible.

[21] The elimination of metaphysicians is not a characterizing feature of naturalized metaphysics either. Naturalized metaphysics does not recommend that metaphysicians should become scientists and adopt the methods of science in metaphysics; it is not characterized by this type of methodological naturalism despite some authors claim to the contrary (e.g. Esfeld, 2018; Hudson, 2016).

[22] Ney (2012), for instance, sees the task of naturalized metaphysics to be "to establish conclusions about ultimate reality" (p. 76) and Ladyman and Ross (2007) argue that "no other sort of metaphysics counts as inquiry into the objective nature of the world" (p. 9). In this respect, naturalized metaphysics differs from other recent attempts to salvage metaphysics that instead adopt more modest ambitions on behalf of the content of metaphysics (e.g. Hofweber, 2016; Kraut, 2016; Thomasson, 2014).

metaphysics is critical of how we go about answering metaphysical questions. For naturalized metaphysics, the questions themselves are not the problem. However, as Ladyman (2017) qualifies, "[t]hat is not to say that [naturalized metaphysicians] advocate answering all the same questions that are asked by analytic metaphysicians by different means" since some of them are "making insufficient contact with reality to be worth entertaining" (p. 143). Some – perhaps even many – metaphysical questions are (currently) epistemically unsafe to answer since the process of answering them will not be sufficiently inspired and constrained by science to satisfy the standards of naturalized metaphysics. However, it is still such *epistemic* concerns that are, or at least should be, behind the dismissive attitude towards metaphysicians quarrelling with science.

This must also apply when Lewisians ask about the world-making relation, propose distance as an answer, and then caution against non-spatial theories of quantum gravity in the absence of an alternative to distance. Recognizing that the aim of naturalized *metaphysics* is metaphysics, the problem with this conflict is *not* the metaphysical question behind it: what is the world-making relation? Rather, the issue concerns the methods that are employed to promote the conflict, i.e. the intuitions and a priori reasoning – the metaphysicians' "hunches" – that enter the argument to the effect that distance is indispensable. There is certainly some merit (at least from a naturalistic perspective) to the view that it is ill-advised to attach too much significance to our apparent inability to imagine a world without space; especially considering the poor track record of success for proclamations about metaphysical possibility. However, a priori arguments for the indispensability of distance are not the decisive elements in for instance Esfeld's caution against the non-spatial theories of quantum gravity. As discussed in Section 2, Esfeld's caution is motivated by the absence of an alternative to distance as a world-making relation and he explicitly recognizes that the "[t]he claim that there are no fundamental spatiotemporal relations could be true" (Esfeld, 2019, 2). This conflict is, in other words, not (only) the result of an a priori preference for distance as the world-making relation, as Lam and Wuthrich seem to suggest, but rather mostly driven by the apparent lack of any other answer to the metaphysical question. While the absence of space at the fundamental level in for instance loop quantum gravity entails that distance cannot be the world-making relation, it is not manifest in the usual presentation of the theory what other relation makes it true that the elements of the ontology are worldmates. Consequently, the Lewisians, in their conflict with these non-spatial theories of quantum gravity, are not simply stubborn, but rather they stand their ground since these theories only provide a negative answer to their metaphysical inquiry.

In this respect, the conflict, and the Lewisians' Parmenidean resistance, is different from conflicts where a metaphysical interpretation of the scientific theory is available but simply disliked by some metaphysicians. An (admittedly contentious) example for the latter is when relativity theory apparently sides with eternalism and the B-theory of time against the A-theory of time in the form of either presentism or the growing block universe. The potential conflict between presentists and relativity theory is of a different kind than that discussed presently and exemplified by the conflict between Lewisians and non-spatial theories of quantum gravity. With respect to the question of how to conceive of time, relativity theory has an

apparently consistent metaphysical interpretation in eternalism, whereas non-spatial theories of quantum gravity have no such interpretation with respect to the question of world-making. We might say that science in cases like that of relativity theory is not actually in conflict with metaphysics, but rather in conflict with one side in a metaphysical debate. By the standards of naturalized metaphysics, metaphysicians quarreling with scientific theories because they dislike the metaphysical view favored by the theory should probably just yield (though this issue is of course much less clean once we recognize that the metaphysical implications might be contentious and possibly underdetermined).

In comparison, Lewisians' resistance to non-spatial theories is not merely an expression of preference for space-based ontologies (though this might, of course, still have a place as Lam and Wüthrich suggest). If a presentist were to give up her conviction in the sole existence of the present and only preserve her question about the nature of time, the conflict with relativity theory would immediately dissipate by the question being answered with eternalism.[23] The same would not be the case for Lewisians. If not the conflict itself, then much of the tension between metaphysics and science would persist even if the contentious positive proposal that distance is the world-making relation were left behind. Moderate Lewisians – which might very well include Esfeld – could simply be cast as asking, 'what makes it true that we are worldmates in non-spatial theories of quantum gravity?', but only receiving the answer 'not spatial distance'. Since naturalized metaphysics does not in general renounce the meaningfulness or acceptability of metaphysical questions, Lewisians can certainly *hope* for an answer to their question and insist that we continue searching for one.

To remain true to the spirit of naturalized metaphysics, however, this search should be sensitive to signals from the scientific theory that the question is not epistemically safe to answer or that it is posed in such a way that the scientific theory must be appropriated or "domesticated", as Ladyman and Ross call it, to the metaphysical purposes of our question:

> An aspect of leaving science undomesticated is recognizing that it itself may tell us that there are questions we absolutely cannot answer because any attempted answer is as probable as any other. This does not imply that we should look to an institution other than science to answer such questions; we should in these cases forget about the questions (Ladyman & Ross, 2007, 30).

We should accept that some metaphysical questions are not answerable and as at least implicit from this remark, some metaphysical questions may in their very formulation presume metaphysical assumptions that could render the questions inapplicable to the considered scientific theory.

[23] Arguably, A-theorists might simply insist that relativity theory with eternalism does not provide a satisfactory answer to their metaphysical question and that there consequently is no alternative answer to that question. It is admittedly unclear who shall serve as arbiter in such cases. There is therefore a risk that allowing for conflicts between science and metaphysics as a whole will prove to sanction any conflict between metaphysics and science contrary to what is the intention of this proposal.

Circumstances may, in other words, be such that a metaphysical question must ultimately be left unanswered, but pressing the question initially promises to be a good way of finding this out. As such, the Lewisians' stubbornness enforces a tension – an echo of a conflict – which ensures that a positive answer to the question about world-making is pursued. Though the Lewisians might not be entitled in their preference for distance as the world-making relation due to its origin in the problematic traditional methods of metaphysics, their Parmenidean resistance ensures the reassertion of the metaphysical question: what replaces distance as the world-making relation in the non-spatial theories of quantum gravity? More generally, they are partaking in an overarching aspiration that scientific theories need a coherent metaphysical interpretation that goes beyond merely negative replies to metaphysical inquiries; an aspiration that should be acceptable to and shared by naturalized metaphysics as long as it keeps away from the contested methods of traditional metaphysics and is careful to avoid domestication of the scientific theories. Unless we allow for some Parmenidean resistance, we might overlook when scientific theories have disclosed hitherto inconceivable metaphysics.[24]

Metaphysicians' outspoken conflicts with scientific theories serve to remind us to seek positive answers to our metaphysical questions and not be content with negative ones. As such, conflicts between science and *metaphysics as a whole* (and not just one side of a metaphysical debate) are signals of when science leaves metaphysical questions unanswered. In so far as naturalized metaphysics aspires to answer metaphysical questions, conflicts between metaphysics and science should therefore be welcomed as occasions to do (more) naturalized metaphysics. This apology for *conflicts* between metaphysics and science does as such not offer any vindication for prioritizing the views of a priori metaphysics over those science (or science-based metaphysics). But a priori metaphysics – through its conflicts with science – is nevertheless argued to be important and useful when naturalized metaphysics tries to develop a metaphysics informed by our best scientific theories. In this sense, the present proposal could be regarded as adding another function of a priori metaphysics to French and McKenzie's (2012) toolbox-approach to metaphysics, where the methods and frameworks developed within traditional a priori metaphysics are appreciated for their usefulness as tools that the naturalized metaphysicians can employ for various purposes in their scientifically informed and constrained metaphysics (for further discussion, see French & McKenzie (2016), Ross (2016), Le Bihan & Barton (2018), and French (2018)).

[24] Though presenting it somewhat differently, Norton (2020, 1966–71) offers four historical examples where science came into conflict with firmly held metaphysical beliefs and how these conflicts lead to what he describes as "conceptual revolutions". In our terms, these conflicts, as documented by Norton, were used as heuristics for the development of new naturalized metaphysics. Norton (2020, 1971–80) also accounts how non-spatial theories of quantum gravity suggest a reconfiguration of the distinction between concrete and abstract objects which might be seen as yet another example where a conflict between metaphysics and quantum gravity drives important developments in metaphysics.

4 The world-making relation in quantum gravity

The Lewisians can be cast as inquiring what replaces distance as the world-making relation in non-spatial theories of quantum gravity; a legitimate question – even by the standards of naturalized metaphysics – with no immediate answer. In general terms, Lewisians' worry about the metaphysical coherence of a scientific theory and the resulting conflict – like other conflicts between metaphysics and science – can be received as indicating a possible open problem relating to the metaphysical foundation the theory in question. This section will show in more detail – by the example of the conflict between Lewisians and non-spatial theories of quantum gravity – how such metaphysical worries can be utilized as a heuristic in naturalized metaphysics. More precisely, it shows how the Lewisians – and Esfeld in particular – with their Parmenidean resistance bring attention to the interesting metaphysical question: what replaces distance as that which connects the elements of the ontology in non-spatial theories of quantum gravity? Based (primarily) on reasoning coming from string theory, I have elsewhere given the details of how entanglement can serve as an alternative world-making relation (Jaksland, 2020). The present account echoes this answer in terms of entanglement, but it does so based on loop quantum gravity which has been the primary example of a non-spatial theory of quantum gravity in the debate between Esfeld (2019) and Lam and Wüthrich (2020). While this perspective from loop quantum gravity nicely supplements the other arguments in favor of entanglement as the world-making relation, the aim here is first and foremost to show how this work plays out as a naturalized metaphysics driven by the Lewisians' conflict with non-spatial theories of quantum gravity such as loop quantum gravity. In particular, the present account will indicate how answering the Lewisians' question about world-making – to abide by the standards of naturalized metaphysics – requires the negotiation between constraints coming from the scientific theory and the presuppositions that are implicit in this metaphysical question.

For an ontology of objects in space, distance is an exemplary world-making relation: Every object is at a distance from any other object such that the distance relation can make it true that the two objects are worldmates. In addition, a coherent world-making relation should, according to Esfeld (2020), "(a) do the trick of individuating simple objects and (b) be empirically adequate" (p. 1892). This already exposes a dilemma for our investigation: how much and what aspects of the metaphysical question should be preserved? When asking a metaphysical question of a scientific theory, it is always a possibility that the question is explained away as misconstrued rather than answered. The scientific theory might simply expose that the question is asked on false premises or relies on inappropriate metaphors. In so far as the interesting new metaphysics is due to the answers, it is important that the metaphysical question is well-posed. In the formulation of the question, Esfeld presupposes a metaphysics of individual objects; this is part of what the world-making relation should make sense of. While empirical adequacy seems to be a relevant minimal requirement, individuating simple objects – especially since Esfeld (2020,

1893) requires absolute discernibility[25] – comes with the type of metaphysical prejudices that risk rendering our questions ill-posed. More generally, if we attempt to preserve too many of our metaphysical intuitions when answering the metaphysical question driving the conflict, then this might preclude the metaphysical novelties of the theory and in addition move us towards the domestication of science that naturalized metaphysics warns against. The ambition must not be to satisfy stubborn metaphysicians, but to use the conflicts between metaphysics and science as an occasion for open-minded exploration.

It seems to me that there is never a guarantee that a metaphysical question is well-posed, since it can never be completely detached from any metaphysical background assumptions. Even asking for a world-making relation without any assumption about the nature of the relata relies on there being a relation in some recognizable sense. The result of the exploration of the non-spatial theories of quantum gravity might therefore be that also this question is misguided. Still, this absence of relations would be a metaphysical discovery, especially if accompanied by indications of how to construe worlds without relations, and the pursuit of the metaphysical question behind the conflict between metaphysics and science would have yielded interesting insights. I do, however, think that Esfeld and the Lewisians' question about the world-making relation in quantum gravity can be answered, at least if it is stripped of its object ontology prejudices.

The proposal of distance as the world-making relation provides us with two hints on what to look for. First, we are looking for a relation that relates every pair of elements of the world (though these may not be recognizable as objects in any strict sense). Second, distance is a likely world-making relation which suggests that whatever distance derives from in these non-spatial theories is a likely candidate as well. Following this second hint, we shall look at how space is supposed to[26] emerge from the spin-networks of loop quantum gravity.[27] As stated in Section 2, the spin-networks are at the outset an abstract graph structure with a spin (SU(2)) representation for the nodes of the graph and one for the links. From this, one can construct a Hilbert space that defines the states of loop quantum gravity. The route towards space goes via Penrose's (1971) spin-geometry theorem which implies that each node can be associated with a polyhedron; a geometrical object with polygonal faces that is uniquely described by the areas and angles between its faces. More precisely, one can for each link construct a scalar from spin operators. Each node is thus associated with as many such scalars as it has links and with the additional requirement of gauge invariance of the spin representation, these scalars of each node uniquely determine a polyhedron where the scalars are identified with the areas of the faces. The angles between the faces can, together with the areas, then be used to define a three-dimensional metric and the volume of the polyhedron. The angles, along with the other properties, are still quantum and thus associated with non-commuting operators: "the shape of a quantum polyhedron is fuzzy"

[25] See Saunders (2006) a discussion of types of individuation in the context of quantum mechanics.

[26] None of these approaches are yet rigorous and they can therefore not say with absolute certainty how space emerges.

[27] This exposition is partly based on Rovelli (2011).

(Bianchi, 2017, 112). However, under additional coherence conditions (for details see Bianchi et al. (2011)), the areas take precise values and the expectation value of the angle operators approximates the classical angles. The polyhedra thus become semi-classical and each node together with its links can in this way receive a geometric interpretation as a chunk of space whose volume and metric is determined by the spin-network: "the algebraic structure [of the spin representation] determines the existence of a metric at each node and therefore equips each quantum of space with a geometry" (Rovelli, 2011, 4). Each node is linked to other nodes, and on the geometrical viewpoint this can be conceived as polyhedra adjacent to one another. In this way, a cellular space of many polyhedra can emerge from the spin-network. It is intriguing to imagine how this, despite its granularity, may approximate a smooth space, just like a regular dodecahedron – the Platonic solid consisting of twelve pentagons – may look round from afar. However, even from afar – and thus disregarding the granularity due to the polyhedra – the metric of this space is discontinuous. In the spin-network, any two linked nodes have a geometrical interpretation as two polyhedra facing each other. Since they share the same link, the faces have the same area, but since generic nodes have a different number of links to other nodes, the shape of and angle between the faces will be different even though they have the same area; they are not shape-matched. As a consequence, the metric is generally discontinuous (Bianchi et al., 2011, 11).

In a paper with Antonio Vassallo, Esfeld speculates how such networks of polyhedra or – "atoms of space" as they call them – might be connected up to form a continuous space. However, they also implicitly recognizes that spatial distance – or generally "metrical properties" – are absent at this fundamental level of networks of polyhedra: "grouping the atoms of space together in a suitable manner as represented by nodes and edges on a graph makes it possible for the configuration to instantiate metrical properties, while the individual atoms of space are connected only by a contiguity relation" (Vassallo & Esfeld, 2014, 10).[28] Thus, also Esfeld seems to agree that distance cannot be the world-making relation in loop quantum gravity. The referred to "contiguity relation" amounts to little else than noting that the polyhedra in the spin network representation are connected by links in the graph. And while this may be visually intriguing, it is just another way of representing the formalism. Proposing this contiguity relation as the world-making relation – which Vassallo and Esfeld do not do either – seems equivalent to simply stating the loop quantum gravity formalism as an answer.[29] As already advertised, I think we can do better than that by considering how space emerges from the initially disconnected metric of contiguous polyhedra.

Continuous (though still cellular) spaces, known as Regge geometries, correspond to special spin-network states where faces are shape-matched and aligned.

[28] Vassallo and Esfeld's ontology comprising of these atoms of space might be an interesting candidate for the elements in an ontology with entanglement as the world-making relation, but working out this proposal will be postponed to future work.

[29] Arguably, more can and should be said about this issue, but this will be postponed for future work.

Recent research suggests that entanglement between the nodes of the spin-network plays an important role for this effect.[30] One can understand the role of entanglement by remembering that we are dealing with quantum polyhedra: just like an electron can be in a superposition state of spin up and down, a quantum polyhedron can be in a superposition of various shapes. Two adjacent polyhedra, i.e. polyhedra sharing a link in the graph, both in such a superposition state might have the same spectrum of shapes, but upon collapsing the superposition they can collapse on different shapes: "their geometry has uncorrelated fluctuations. At the classical level this behavior corresponds to a twisted geometry—the geometry of a collection of polyhedra with uncorrelated shapes" (Baytaş et al., 2018, 15). Considering electrons again, the collapse of the superposition state of two electrons can be correlated by entanglement, i.e. they are correlated if they are prepared in an inseparable state such as the Bell state. The same goes for spin-networks. Entangling neighboring nodes produce correlations between the polyhedra and therefore looks to be a necessary condition for the alignment and shape-matching of the faces. Baytaş et al. (2018) conclude: "The results presented show clearly the role of entanglement in the gluing of quantum regions of space" (p. 16). It seems, in other words, that in loop quantum gravity entanglement is responsible for the emergence of the continuous cellular space that "from afar" will look like a (semi-)classical space.

Entanglement appears to connect the "quantum regions of space" in the form of polyhedra. Even though these polyhedra or their related nodes bear little resemblance to objects as we know them, entanglement thus fills a role similar to that of distance in connecting the elements of the ontology. Entanglement is interesting in this regard, since it shares some of the features that made distance a likely world-making relation (Jaksland, 2020).[31] First, entanglement is an extrinsic property; something is entangled with something *else*. Second, entanglement shares the universality of distance: distance can relate everything in space to everything else and likewise, entanglement can obtain between any quantum degrees of freedom. Presuming that all degrees of freedom are quantum in *quantum* gravity, this entails that all degrees of freedom can be entangled in such theories. Furthermore, results coming out of algebraic relativistic quantum field theory indicate that all degrees of freedom not only can be but actually are entangled which testifies to the pervasiveness of entanglement. More precisely, Redhead (1995) shows that in the vacuum state all spacelike separated subsystems – all the subsystem that are also connected by a distance – are highly entangled and this result is generalized to generic states by Clifton and Halvorson (2001) who also show that no local operation can disentangle spacelike separated subsystems (see Lam (2013) and Swanson (2020) for further details). Third, entanglement is, via entanglement entropy and mutual information,

[30] More precisely, it can be shown that the twistor geometry of generic spin-network states becomes a vector geometry (of which Regge geometries are a subset) by entangling the nodes of the network with their nearest neighbors (Baytaş et al., 2018).

[31] Lewis specifically argues that if space is to be replaced, it must be replaced by a relation that is analogous (in a specified sense) to a spatiotemporal relation. A more detailed discussion of the extent to which entanglement satisfies Lewis' condition for an analogous spatiotemporal relation will be postponed to future work. See, however, Wüthrich (2019) for some preliminary remarks about analogously spatiotemporal relations in quantum gravity.

quantifiable as a non-negative scalar just like distance. Given these features and its role in loop quantum gravity, entanglement is a promising replacement for distance as the world-making relation. Entanglement might be the relation in virtue of which the elements of the spin-network make up a world and that thereby is the relation that glues together the fundamentally non-spatial worlds of loop quantum gravity. While the non-spatial theories of quantum gravity had so far only provided the negative answer that distance is not the world-making relation, the Parmenidean resistance of Lewisians has motivated the (preliminary) development of new metaphysics in the form of an entanglement fundamentalism hitherto unseen in the metaphysics literature.

The proposal that entanglement might be the world-making relation in loop quantum gravity is claimed to qualify as naturalized metaphysics. It is a proposal that answers a metaphysical question but whose answer is motivated by a scientific theory. In being relative to loop quantum gravity, the proposal does not say anything of what is and certainly not what must be the case in actual reality. Following the deference to science in naturalized metaphysics, it is science that determinates what is and what is not the case. The claim is therefore that if loop quantum gravity is eventually vindicated, then entanglement *might* be the answer to the question 'what makes it true that we are worldmates'. Again, following the spirit of naturalized metaphysics, 'might' is emphasized since the thesis should be considered fallible and furthermore, more research might reveal that this question about world-making is after all epistemically unsafe to answer in loop quantum gravity by the standards of naturalized metaphysics or that the question may be prone to domestication.

In connection with the latter, two warnings are in place: (1) Even though entanglement is offered as an answer to a metaphysical question, this answer originates in the serious engagement with a physical theory and for this reason, entanglement does not carry any significance beyond its role in gluing polyhedra in loop quantum gravity. Even though it is brought to bear on this metaphysical question, it does so as an element of the theory under scrutiny that is picked as a candidate answer to our metaphysical inquiry and its use in metaphysics must remain true to this origin to abide by the standard of naturalized metaphysics. (2) Esfeld might insist that entanglement is not a satisfactory world-making relation since it does not appear to individuate simple objects and it cannot provide for separable subsystems. Now, it may of course be that we have not found the right world-making relation in loop quantum gravity, but it seems more likely that the metaphysical question, and especially our expectation for the answer, must be adapted to what the theory provides. In this sense, answering metaphysical questions posed at scientific theories must take the form of a negotiation between our metaphysical aspirations and the details of the theory. The theory might ultimately indicate that parts of the metaphysical question were ill-posed, such that these aspects are explained away rather than answered. However, metaphysical lessons are learned under both circumstances whereby the conflict driving the investigation has proving useful to naturalized metaphysics.

5 Conclusion

The introduction claimed that few today would side with Parmenides and metaphysical doctrines against the senses and, by extension, science. This is probably for the best, but maybe a Parmenidean resistance of the right sort can still be beneficial. The history of science has been full of metaphysical surprises. Often, science has explicitly proven our metaphysical preconceptions wrong, quantum mechanics being an example. Science, however, is rarely similarly explicit about what metaphysical theory should take the place of our preconceptions; the industry of interpreting quantum mechanics nicely illustrates this difference. If we follow the tenet of naturalized metaphysics, metaphysicians should not start quarrelling with science over these lost preconceptions: metaphysics should yield to science. However, if we simply dismiss the metaphysicians like this, we lose one side of science's contribution to metaphysics: whereas science will still prove our metaphysical preconceptions wrong, we risk continuing without putting any new metaphysics in their stead if we silence the metaphysical questions behind the conflicts between metaphysics and science. A Parmenidean resistance should be maintained until science has an alternative *positive* metaphysical story to tell.

Such a resistance was specifically advised in circumstances where there is no known metaphysical framework that is consistent with the scientific theory. While some scientific theories simply side with one side of a metaphysical debate, other conflicts – such as that of Lewisians against non-spatial theories of quantum gravity – can be construed as a conflict between science and metaphysics as a whole. It is these conflicts that are valuable as indicators where science has only provided a negative answer and where there is consequently more work to do for naturalized metaphysics. Only by asking the metaphysical questions will we disclose the hitherto inconceivable metaphysics with which science replaces our metaphysical preconceptions. A bit of Parmenidean resistance ensures that we do so, and naturalized metaphysics should therefore welcome conflicts between metaphysics and science as a resource for metaphysical development. Section 4 showed how to carry this out in the context of loop quantum gravity – a non-spatial theory of quantum gravity – with an emphasis on what replaces distance in that theory as the world-making relation. The suggestion was entanglement; an answer arrived at as an equilibrium between the details of the scientific theory and the metaphysical aspirations of the question.

Acknowledgements I would like to thank Jonathan Knowles, Frida Trotter, Javier Cumpa, Astrid Rasch, Andreas Achen, Kian Salimkhani, and Niels Linnemann for valuable feedback on earlier draft of this paper. I also send my thanks for constructive comments to the audiences in Aarhus, Bristol, Bonn, Cologne, and Trondheim where earlier versions of this paper were presented.

Authors' contributions Single authored.

Funding Open access funding provided by NTNU Norwegian University of Science and Technology (incl St. Olavs Hospital - Trondheim University Hospital).

Data availability Not applicable.

Code availability Not applicable.

Declarations

Ethical approval Not applicable.

Informed consent Not applicable.

Conflicts of interest None.

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