Emergent Spatial Ontologies in the Early Modern Period

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Abstract: This essay will explore the history and conceptual development of emergent theories of space in the Early Modern period, that is, those hypotheses that regard space as a supervenient or emergent property or effect of a non-spatial substance or substances. While emergent space hypotheses have been become the dominate methodology in contemporary quantum gravity research, a number of natural philosophical systems developed in the seventeenth and eighteenth centuries, especially the monadologies put forward by Leibniz and the precritical Kant, proposed analogous conceptions to these modern approaches in physics. In particular, two quantum gravity hypotheses, loop quantum gravity and causal set theory, will serve as the basis for a detailed comparison with the structure of these Early Modern emergent space theories, with Kant's depiction of the emergence of matter and space from his non-spatial monads constituting the main focus.

1. Introduction

Among contemporary quantum gravity hypotheses, an "emergent" spacetime theory denotes a proposal that does not take the continuous metrical and topological structure of spacetime as fundamental. Rather, these hypotheses claim that the structure of spacetime posited by general relativity (GR) emerges from a more fundamental, non-spacetime level of reality associated with quantum mechanics, i.e., a quantum substrate. Examples of these emergent spacetime theories (or non-spacetime theories, since the foundational quantum substrate is not a spacetime theory) are causal sets, loop quantum gravity, and computational universes, to name only a few. While these non-spacetimes hypotheses have been analyzed and defended by various philosophers, other have criticized these proposals on the grounds that all physical entities require a locality in spacetime, and thus non-spacetime quantum gravity hypotheses lack "physical salience". These types of objections stem from a presumption that the non-spacetime approach is an implausible, if not outright contradictory, conception of the physical world since it is difficult to conceive an entity that is not in space. Yet, an ontology that endorses a material world that emerges from non-spatial entities has important precedents in the Early Modern period—and, as will be revealed, one can claim that Leibniz and the precritical Kant are the direct precursors of the contemporary non-spacetime approach. Hence, given a more detailed overview of the history of spatial theorizing, the non-spacetime conception is neither unusual nor an alien intrusion into the realm of scientific theorizing. Moreover, the similarities between these Early Modern (EM) and contemporary quantum gravity (QG) non-spatial hypotheses are not trivial; rather, as an in-depth analysis will demonstrate in this essay, there are an array of important parallel structures, arguments, and problems associated with these two historical approaches to constructing a spatial world from a non-spatial foundation.

Kant's struggle to construct a viable monadology, which is based on non-spatial monads from which bodies and space emerge, will be our main focus, although Leibniz' various

explanations on how his non-spatial monads bring about extended bodies will also be discussed (as will the possibility of emergent space ideas in More and Newton). The precritical Kant faced a number of objections to his conception, from Crusius and, especially, Euler, which led to revisions of his monadic system and strategies for handling these criticisms. Ultimately, Kant decided to abandon his attempts to construct a monadic system in light of these challenges, but he never rejected the essential truth of his monadic metaphysics—rather, as he entered the critical period circa 1770, his new conception of space as a subjective form of intuition ruled out any methodology that would allow for the construction of a monadology based on non-spatial entities. In short, one of the principal factors that precipitated Kant's transition to the critical period is directly analogous, if not identical, to the conceptual difficulties that face contemporary non-spacetime quantum gravity theories, as will be explained.

After a brief presentation in section 2 of some of the central features of an emergent space ontology, both as regards EM theories and contemporary non-spacetime quantum gravity hypotheses, the Neoplatonist concepts that ultimately led to an emergent theory of space will be presented in section 3, along with a brief discussion of Newton and More's versions of Neoplatonism in the late seventeenth century. Section 4 will then briefly examine Leibniz' non-spatial conception of both God's presence in the material world and his monadic system, whereas section 5 will provide an in-depth study of the evolution of Kant's equally non-spatial monadology.

2. Emergent Space Theories: Their Contemporary Importance and Metaphysics.

Before exploring EM examples of emergent space ontologies, it will be necessary to briefly examine current proposals in quantum gravity research, for comparisons between past and present versions of these emergent theories will provide valuable insights into their respective structures and goals. Likewise, how emergent space theories relate to basic metaphysical categories, i.e., substance, property, and relation, as well as substantivalist and relationist ontologies, is of crucial importance as regards their classification and assessment.

Non-spacetime QG theories are a group of approaches to unifying GR and quantum mechanics that do not posit the four-dimensional metrical and topological spacetime structure of GR as a background for the construction and operation of the basic elements of the QG theory. Rather, spacetime is itself deemed to be an emergent effect of the interconnections of these non-spatiotemporal elements. In what follows, two current and influential non-spacetime QG hypotheses will serve as the basis of comparison with EM emergent theories. The first is causal set theory (CST), which employs a causal ordering of a discrete set of elementary events that will, it is hoped, approximate the macrolevel spacetime structure of GR. Specifically, the causal ordering is a partial ordering based on a "causal precedence" relation among the basic non-spatiotemporal elements, where these elements will ultimately incorporate quantum mechanical processes. The second is loop quantum gravity (LQG), which starts by quantizing the metric of GR using a discrete quantum substructure of spin networks (which are abstract graph structures associated with quantum mechanical properties), such that the classical spacetime is then regarded as an emergent effect of the interconnections of the non-spacetime spin networks (see, e.g., Wüthrich 2019, for a brief synopsis of both theories). For both theories, the interconnections among the fundamental elements are not spatiotemporal, and thus they also pose a significant challenge for the standard substantivalist and relationist ontologies. Since space is an emergent effect of these non-spacetime elements, space fails to meet the independence criterion normally

associated with a substance, hence it does not qualify as a version of substantivalism. But relationism is not applicable either given the "many-to-one" and "many-to-none" relationships that are manifest between the structure of the non-spacetime elements in both CST and LQG and the emergent spacetime. In both theories, many different structural arrangements of the non-spacetime elements can give rise to the same emergent spacetime, hence many-to-one, but numerous structural arrangements may also fail to result in any emergent spacetime, thus many-to-none (see, Wüthrich 2019). This last scenario, many-to-none, specifically violates relationist doctrine since it holds that space is a direct relation among entities.

While a thorough investigation of the philosophical issues related to non-spacetime QG theories is beyond the scope of our investigation, one particular problem requires attention, however. In response to the criticism put forward by some philosophers that any theory that posits non-spatiotemporal fundamental entities is empirically incoherent or lacks physical salience (see, e.g., Lam and Esfeld 2013, Maudlin 2007), there have been a number of responses that strive to defuse this problem by insisting that the ontology of non-spacetime QG theories can play the functional role of spacetime, and thus empirical coherence can be regained without the need to posit a separate spacetime entity (see, Lam and Wüthrich 2018). Yet, some have argued that such strategies are deficient since any non-spatiotemporal entity/property that plays the role of spacetime is, in effect, in spacetime, and thus the alleged emergence of spacetime is undermined (Yates 2021, 147). In what follows, we will dub this predicament, which has corresponding precedents in the EM period, the "spatial presence" problem.

At this point, it will be useful to compare emergent space ontologies with the basic metaphysical categories associated with substances, properties, and external and internal relations. Twentieth century metaphysics draws a distinction between internal relations and external relations, where the former are based in part on internal or intrinsic features of an object (monadic non-relational properties), and the latter are not: e.g., "the sibling of" is an internal relation because one must have the correct internal properties (a particular genetic code) to bare that relation to another person, whereas the spatiotemporal relation "three meters to the left" is external since it only requires the existence of the relata (with no specific monadic properties required for the relation). Since philosophers deem spatiotemporal relations to be purely external (e.g., Armstrong 1989, Lewis 1986), it follows that substantivalist and relationist ontologies are based on external relations between a body, which is a substance, and either substantival space or other bodies. Emergent space ontologies, in contrast, would correlate with the property category, which also includes internal relations given their dependence on internal monadic properties. A substance is required to instantiate the, as it were, "space property", and the space property is contingent in the sense that it cannot exist apart from the substance/substances. This contingency between the underlying substance and resulting space property is reflected in the many-to-one relationship between the basic elements of contemporary non-spacetime QG theories and the emergent spacetime, as well as in the numerous cases were the emergent spacetime fails to obtain at all from the basic elements (i.e., where the basic non-spacetime elements count as the substances, and the emergent spacetime as the property). Emergence itself is a difficult concept, but Broad's old characterization is serviceable for our goals: "the characteristic properties of the whole R(A, B, C) [where R signifies the joint composition of A, B, and C] cannot, even in theory, be deduced from the most complete knowledge of the properties of A, B, and C in

isolation" (Broad 1925, 61).[1] Given the unsuitability of substantivalist and relationist ontologies, the best ontological interpretation of emergent spacetime theories, consequently, is the property theory of space: emergent spacetime as a contingent property of the foundational non-spacetime elements accounts for both the many-to-one and many-to-none scenarios in CST and LQG, and it also accords with the metaphysics of properties/internal relations.

In what follows, the fruits of our brief investigation into contemporary non-spacetime theories and their metaphysical classification will be applied to a historical and ontological examination of emergent theories of space in the EM period, with special emphasis placed on the precritical Kant's monadology. All of the ideas surveyed thus far, from the three-part metaphysical taxonomy (among substances, properties/internal relations, and external relations), spatial emergence, and the spatial presence problem, find historical analogues in these earlier theories, often with remarkable accuracy. Surveying these historical conceptions will also provide original insights and hitherto unrecognized options for the ontological evaluation of the current crop of non-spacetime QG theories.

3. The Neoplatonist Origins of Emergent Space Theories in the Early Modern Period.

In the search for historical versions or anticipations of an emergent theory of space, the late Medieval and EM periods figure prominently, since matter and space were held by some natural philosophers in those eras to have emerged from a non-spatial, immaterial level of reality. The foundational level in modern non-spacetime QG theories is, of course, quantum mechanics, which is material or physical (and not immaterial), but that fact does not negate the important structural similarities (regarding both general theoretical and geometric structure) that are manifest between the foundational and emergent levels in both QG and EM non-spacetime hypotheses. Likewise, philosophers in both the EM and contemporary QG periods faced parallel concerns, and adopted similar strategies, in striving to develop their respective non-spatiotemporal theories, thus it is imperative to investigate these similarities if the goal is to secure an adequate history of emergent spatial hypotheses.

Among the concepts that influenced EM emergent space theories, probably the most important is Neoplatonism, the ancient school founded by Plotinus (circa 3rd century). Neoplatonism, in brief, deems that all reality is an "emanation" from God, a process whereby reality "flows", or is derived, from God, but without any consequent lessening of God's own reality. In the traditional form presented by Plotinus, the order of emanation goes from the unknowable One (God), proceeding to Nous (Intellectual Principle), the World Soul, and lastly,

[1] The application of these metaphysical distinctions is warranted in the case of Early Modern spatial ontologies since Locke endorses a similar three-part division in the *Essay*, where he discusses the complex ideas pertaining to substances, modes, and relations, with "mode" defined as "Dependences on, or Affections of Substances" (Locke 1975, 166). Hence, his concept of modes would encompass internal relations when translated into the modern metaphysical schemes. Moreover, in the contemporary literature, the technical definition of emergence that is normally offered concerns an "emergent property", e.g., O'Conner (2020), Mclaughlin (2008, 93), and Gillett (2016, 176). See, also, Loux and Crisp 2017, on the various substance and property conceptions.

matter—with each lower emanation possessing less reality than the higher emanation from which it emerges (see, Gerson 2018, for an introduction to classical Neoplatonism). Although the emergence concept does not advocate a lessening of reality among levels, there is nonetheless an obvious similarity between emanation and emergence in that both posit a fundamental entity from which a derived entity arises. The other important connection with contemporary non-spacetime QG theories is that Plotinus posited that the One (God) is not in space, nor are any of the other immaterial beings implicated in the process, although the material world is spatial. Neoplatonist emanation also has a correlate in the Scholastic concept of repletive ubiety, where "ubiety" is defined as the way that a being is related to place/space. In Grant's estimation, the 13th century philosopher, Bonaventure, conceived repletive ubiety as "the special mode by which God inheres in all things, fills and contains all things, and immensely super-exceeds all things and yet remains distinct from, and unmixed with, them" (Grant 1981, 368). Given the stipulation that God is "unmixed" with the emanated entities, the conclusion that was apparently drawn by some natural philosophers is that God does not, or need not, share a location/situation with those entities under repletive ubeity.[2]

Turning to the EM period, Neoplatonist emanation was central to the views of Patrizi (late 16th century), who inspired the Cambridge Neoplatonism of Henry More, Newton, and many others, for he argues that space emanates from God (see Brickman 1943). In *The Immortality of the Soul* (1659), for instance, More utilizes emanation to explain the spatial extension of immaterial beings, reasoning that we have a "rational apprehension of that part of a Spirit . . . [w]hose Extension aris[es] by gradual Emanation from the First and primest Essence [i.e., God]" (More 1997, 35). In more detail, he states that "an Emanative Effect is coexistent with the very Substance of that which is said to be the Cause thereof", where "Cause" is "the adequate and immediate Cause", and the "Effect" exists "so long as that Substance does exist" (33). Thus,

[2] Thomas of Strasbourg, 14th century, appealed to repletive ubiety to deny God's location in space, although that concept is distinct from non-spatiality. Repletive ubiety is also closely linked to the doctrine known as "extension of power" (or "virtual extension"), which, as the name implies, holds that only an immaterial being's powers are spatially (dimensionally) extended in a space. This conception, however, was originally intended by Aquinas to also admit a non-dimensionally extended presence in space for immaterial beings, dubbed "definitive ubiety", which by the Early Modern period was often interpreted as pertaining to the being's occupation of the (non-extended) points of space. In modern terms, this would amount to a topological (non-metric) occupation of space, and it was coupled with the additional hypothesis that the immaterial being was wholly present in each point/part of space, as well as wholly present in the whole extended region (thus the claim: "whole in the whole, and whole in each part"). Dubbed "holenmerism" by Henry More, it was the default view for many Scholastics and Early Modern thinkers. More's early work supported holenmerism, but he eventually became one of its fiercest critics, arguing that it is a contradiction for a being to be wholly present in separate locations. Overall, the extension of power doctrine is distinct from holenmerism, and many Scholastics (e.g., Scotus, Ockham) and Early Modern philosophers (e.g., Descartes, Leibniz) concluded that an extension by power need not entail a spatial presence at all, whether in extended regions or in points. On all of the topics mentioned in this footnote, including references, see Slowik 2019.

"[b]y an Emanative Cause is understood such a Cause as merely by Being, no other activity or causality interposed, produces an Effect" (32). Nevertheless, More's conception of the God-space relationship constantly shifted, and in his last work he seems to envision space as an internal property (attribute) of God, which is inconsistent with an emergence model: "The real attribute of some real subject can be found nowhere else except where in the same place there is some real subject under it. And, indeed, extension is the real attribute of a real subject [i.e., space = attribute, God = subject]" (More 1995, 56-57).

Newton's spatial ontology parallels More's views, even down to the uncertainty as to whether space is an emergent effect of God or is closer to an internal attribute. Both tendencies are evident in *De gravitatione* (c. 1680): the former in his well-known claim that "[S]pace is an emanative effect of the first existing being" (Newton 2004, 25), which suggests emergence; and the latter in the "determined quantities of extension" (DQE) hypothesis, where God's spatially extended being directly grounds the mobile bodily properties, e.g., God's "[e]xtension takes the place of the substantial [corporeal] subject in which the form of the body [i.e., the determined quantities] is conserved by the divine will" (29). In short, since there is only one spatial extension for both God and other beings under DQE, space seems more akin to an internal property of God, rather than as an emergent property.

In response, it could be maintained that the emanationist ontologies put forward by both More and Newton are not violated by their additional claims that seem to support an internal property outlook, but are merely different descriptions of that same emanationist ontology (i.e., their apparent endorsement of space as God's internal property is simply a careless use of language, as Newton does suggest in the Des Maizeaux drafts; see, Koyré and Cohen 1962, 96–97). Yet, even if true, there remains an obvious problem with their conceptions when compared with emergence in the case of non-spacetime QG theories, namely, that they run afoul of the spatial presence problem first discussed in section 2. Whereas Plotinus had rejected God's spatial presence, the Cambridge Neoplatonists (More, Newton, Raphson, etc.) embraced the concept of an extended, spatially situated God, and regarded God as the ontological foundation of space, a conjunction of ideas that, when transferred to the QG setting, would lead to the conclusion that the allegedly non-spacetime elements of CST/LQG are actually in spacetime. However, it is doubtful that the defenders of the brand of spatial Neoplatonism favored by Patrizi, More, or Newton would find this a troubling development. They would insist that space is still ontologically dependent on God, regardless of God's presence in space, for if God is annulled, then space is removed, too. In other words, although God and space come as a sort of package deal, the ontological dependency relationship is still asymmetric, flowing in only one direction and not the other.

Can the same defense be applied in the case of QG? That is, can the emergence of GR's spacetime be conceived as simply the claim that if the non-spacetime elements were to go out of existence, then so would spacetime? In essence, the emergence envisioned on this scenario is simply a commitment to a form of ontological dependence relationship, and not the more traditional definition of emergence, which usually involves positing novel features, and various causal powers, to the emergent property (see, e.g., Tahko and Lowe 2020, on ontological dependence). More's claim quoted above, that God's mere "Being, no other activity or causality interposed, produces an Effect [space]", would support this interpretation. The problem for this conception of emergence, however, is that it would only seem applicable in those cases where one entity always gives rise to one emergent property, in a one-to-one fashion, as is the case with More and Newton's God-space emanation hypothesis. Yet, as discussed in section 2, there are

numerous arrangements of the non-spacetime elements in QG theories that are not accompanied by an emergent spacetime (many-to-none). Consequently, conceiving spacetime emergence as mere ontological dependence fails to explain why some compositions of the basic elements do, and some do not, bring about spacetime. That explanatory task is easier (if still somewhat mysterious) given a one-to-one correspondence between the basic elements and the emergent property, since that correlation can be viewed as comparable to a logical consequence relationship, but that option is not available for the QG theorist given the many-to-none correlations. Indeed, the causal connections among the non-spacetime elements in CST and LQG would count, contra More, as that "other activity or causality interposed" required to bring about space, since the mere existence of those non-spacetime elements is not enough. Hence, while important for the development of later emanation strategies, the Cambridge Neoplatonist form of that doctrine seems ill-suited to serve as the basis for comparison with contemporary non-spacetime QG theories. Finally, it should be noted that Neoplatonist emanation would correspond to a properties/internal relations metaphysics, with space as a property/internal relation of God, whereas the substance and external relation conceptions are not applicable (as first noted in section 2)

4. Leibniz: The Emergence of Space from Non-Spatial Entities.

The first truly important steps towards a theory of emergent space in the Early Modern period can be traced to Leibniz, for he conceived space along lines that fit the general profile of contemporary non-spacetime QG hypotheses: namely, in that matter and space emerge from a collection of microlevel force-constituted entities that are themselves not in space. Before investigating his theory of monads, however, it is necessary to briefly peruse Leibniz' view of the God-space relationship. Overall, Leibniz' God-based spatial ontology is an instance of repletive ubiety, and thus a form of spatial emergence, for he envisions matter as arising from God's actions, with space constituting an abstraction (ideal order of situations) derived from matter. Unlike bodies, which are extended in a place, or minds/souls, which occupy non-dimensional points of an extended place or body, God "fills the entire universe in a more perfect way than minds fill bodies, for he operates immediately on all created things, continually producing them" (Leibniz 1996, II.xxiii.21). On Leibniz' interpretation of repletive ubeity, while God's being is not situated in space (a view dubbed "nullibism" by More), God's action of preserving the world is situated in space. In the correspondence with Clarke, he contends that "God is not present to things by situation" (Leibniz and Clarke 2000, 16; L.III.12), and he rejects the notion, favored by Newton, More, and Clarke, that "God discerns what passes in the world by being present to the things"; rather, God discerns things "by the dependence on him of the continuation of their existence, which may be said to involve a continual production of them" (56; L.V.85). Clarke rebuffs this non-spatial conception of God's operations throughout the correspondence: "That God perceives and knows all things not by being present to them, but by continually producing them anew, is a mere fiction of the schoolmen, without any proof" (76; C.V.83-88). In short, both Newton and Clarke accept a locality principle for substances: namely, substances can only act where they are present (in substance/being), a view that is expressed in Newton's well-known claim in the *Principia* that "He [God] is omnipresent not only virtually but also substantially; for action requires substance" (Newton 2004, 91). Transferred to the contemporary debate, both Newton and Clarke would side with those critics who insist that non-

spacetime QG theories are "empirically incoherent" since their fundamental entities are not in spacetime.

The development of Leibniz' nullibist approach to divine omnipresence, where God's substance is not situated in space, coincides with the growth of his late monadic metaphysics, a system that posits non-spatial atom-like immaterial simple substances as the basic constituents of the material world. Unlike atoms, which compose bodies through simple aggregation or addition, the relationship between monads and extended bodies would seem to be equivalent to a supervenience or emergence process, for he states that "properly speaking, matter is not composed of constitutive unities [monads], but results from them" (Leibniz 1989, 179), and, "Certainly monads cannot be properly in absolute place, since they are not really ingredients but merely requisites of matter" (Leibniz 1969, 607). Leibniz even invokes the Neoplatonist process of emanation to describe this emergence, portraying the primitive force of monads as "a higher principle of action and resistance, from which extension and impenetrability emanate when God does not prevent it by a superior order" (Leibniz 1923, A.I.vii.249; in Adams 1994, 351). Although monads do not causally interact with one another ("monads have no windows through which something can enter or leave"; Leibniz 1989, 214), they are dependent on God, for he insists that "a monad, like a soul, is, as it were, a certain world of its own, having no relationship of dependence except with God" (Leibniz 2007, 227). Furthermore, monads, like his conception of God, are not in space: "monads in themselves do not even have situation with respect to each other" (241), and "[t]here is no spatial or absolute nearness or distance among monads. And to say that they are crowded together in a point or disseminated in space is to use certain fictions of our mind" (Leibniz 1969, 604). However, he also insists that "monads have a certain kind of situation in extension, that is, they have a certain ordered relation of coexistence to other things, namely, through the machine in which they are present" (Leibniz 1989, 178). The apparent contradiction between the non-spatiality of monads and their presence in space "through the machine that they control" is potentially resolved in a letter to Des Bosses in 1709: after reiterating his view that "I do not think it appropriate to regard souls [monads] as though in points [of space]", he adds "Perhaps someone might say that souls are not in place but through operation, speaking here according to the old system of influx; or rather, according to the new system of preestablished harmony, that they are in place through correspondence" (Leibniz 2007, 123–127). In this passage, Leibniz associates the Scholastic notion of being in place "through operation" with "the old system of influx", a process that he interprets as sanctioning a causal interaction among monads, which, as noted above, he rejects (preferring the preestablished harmony among his "windowless" monads instead). Yet, by offering a comparison between a presence by operation and his preestablished harmony system ("someone might say"), and only rebuffing the causal influx component of the older theory, Leibniz seems to be indicating that the aspect of that older system that pertains to a monad's spatial presence alone is similar to his own conception, i.e., between his non-spatial monads and extended matter. Consequently, there is a marked similarity between Leibniz' treatment of the God-world and monad-matter relationships: both God and monads are not in space, yet they partake in form of situation in matter via their "operations", respectively, by continuously preserving the world and via the bodies that "result" or emanate from monads (see, Slowik 2015).

All told, Leibniz' theory of the emergence of matter and space from non-spatial monads manifests a number of significant parallels with contemporary non-spacetime QG theories. In addition to the non-spatiality of their respective fundamental entities, from which matter and space emerge, Leibniz insists that matter and space are less real than the forces in substances:

"[F]orce is something absolutely real in substances, even in created substances, while space, time, and motion are, to a certain extent, beings of reason, and are true or real, not per se, but only to the extent that they involve either the divine attributes (immensity, eternity, and the ability to carry out works), or the force in created substances" (Leibniz 1989, 130–131). Non-spacetime QG theories depend on the forces involved in QM processes, and so there is a natural analogue with Leibniz' force based conception of reality, and one might even compare the "less real" status of matter and space in Leibniz' claim with reductive, or functionalist, interpretations of GR's emergent spacetime in the contemporary case. Furthermore, like QG theories, the relations among Leibniz' monads implicate internal relations as opposed to external relations: he states that place "seems to imply nothing but position. But in actuality, that which has a place must express place in itself; so that distance and the degree of distance involves also a degree of expressing in the thing itself a remote thing, either of affecting it or receiving an affection from it" (Leibniz 1995, 133, also, Leibniz and Clarke 200, 47; L.V.47). Much like Leibniz' preference for relations that are based on intrinsic monadic states, the interconnectedness of QM events, whether envisioned as a holistic field or as separate particles that are entangled with each other (via correlations of spin, momentum, etc.), involves dynamic properties that are internal to the field or the particles, hence external relations among substances does not capture the metaphysics of either QG or Leibniz' system. In addition, Leibniz' claim, quoted above, that God could prevent the emergence of matter and space from emerging from monads is consistent with the many-to-none scenarios in emergent space QG theories. But there are significant differences as well, most notably in that QG theories rely on the interconnections among the non-spacetime elements for the emergence of space, whereas Leibniz specifically rejects any causal influx among monads. Also problematic is that Leibniz views space as akin to an ideal abstraction from extended bodies, although the quantum excitations of the field in emergent QG theories need not involve extended material bodies (see Rickles 2005, 426-427).

5. How Kant's Precritical Monadology Foreshadows Casual Set Theory.

5.1. The Development of Kant's System. Among the candidates for an Early Modern version of an emergent space ontology, Kant's early precritical monadology takes pride of place. Not only did he improve upon the monadological systems of the Leibniz-Wolff school by developing a version that is more indebted to natural philosophy than most previous exemplars, but he retained Leibniz' preference for a non-spatial monadic foundation from which space and matter emerge. The metaphysics of immaterial beings stills plays a prominent role, but Kant's main concern, evident over the course of several works, is to expound and refine the physical processes that are involved in spatial emergence. Equally important is that Kant fully embraces a causal influx among his monads, and the end result is a system that bears an uncanny resemblance with the basic structure of contemporary causal set theory, often down to specific details or consequences.

The Leibniz-Wolff school had followed Leibniz by associating their simple substances with force, and by conceiving the material world as an emergent effect of force, although most members of the tradition, unlike Leibniz, situated their monads in the points of space (see, e.g., De Risi 2007, 309 n. 8). The fundamental ontology of these alternative monadologies thus does not meet the requirements of an emergent space theory, nor would Boscovich's, but Kant's first work from 1749 (*Living Forces*) would offer a true system of non-spatial elements from which space emerges. In contrast to Leibniz, the force that comprises his simple substances/monads can

interact with one another, and by these interactions they give rise to space: "There would be no space and no extension if substances had no force to act external to themselves. For without this force there is no connection, without connection, no order, and, finally, without order, no space" (Kant 2012, 26; 1:23). Hence, just as in contemporary CST, it is the causal relations among the basic elements that provide the ontological grounds for space, and there is a further similarity between CST and Kant's theory in that both allow for the possibility that their respective fundamental elements may lack a causal connection with other elements, and thereby lack a presence in space:

> A substance is either connected with and related to other substances external to it, or it is not. Because every independent entity contains within itself the complete source of all its determinations, it is not necessary for its existence that it should stand in any connection with other things. That is why substances can exist and nonetheless have no external relation to other substances, or have no real connection with them. Now since there can be no location without external connections, positions, and relations, it is quite possible that a thing actually exists, yet is not present anywhere in the entire world. (25-26; 1:22-23).

As noted, a similar potential scenario has been discussed as regards CST: "By virtue of what would this single event [a single CST basal element] be a single point of spacetime? Spacetime, according to causal set theory, is an emergent, not a fundamental entity" (Wüthrich 2020, 244). CST would, accordingly, seem consistent with Kant's additional proviso that there may exist "many millions of worlds" (Kant 2012, 6; 1:22), presumably, by interconnecting different sets of elements to form different worlds along with their different spaces. Whereas the causal connections in CST will incorporate dynamic quantum processes, Kant appeals to a correlation between his inter-monadic connections and the well-known inverse-square relation of distance from Newtonian gravity, an interconnection that he also thinks accounts for space's three-dimensionality, although he adds that it is only one of the possible connections (and hence dimensions of space) that God could have established (25-27; 1:23–25). In the *New Elucidations* (1755), Kant further stipulates that the inverse-square law of "Newtonian attraction" that holds among bodies is derived from the force connection among simple substances: "[i]t is...probable that this attraction [Newtonian attraction] is brought about by the same connection of substances, by virtue of which they determine space" (Kant 1992, 43; 1:415).

As explored earlier (section 2), various interpretations of non-spacetime QG theories, especially the functionalist accounts, have been criticized on the grounds that any non-spatial entity that plays the role of spacetime must, on the contrary, be in spacetime, and thus the alleged emergence of spacetime in such theories as CST or LQG is simply false. An analogous form of this "spatial presence" problem, as we have dubbed it, can also be discerned in the development of Kant's monadology, and these worries would ultimately lead him to abandon a detailed construction of his system at the dawn of his late critical period. In particular, since Kant claims in *Living Forces* "there can be no location without external connections" (quoted above), it would seem to follow that his non-spatial monads are located in space once these external connections are established. Kant's estimation of this problem, however, is more centered on the threat that a spatial presence poses for the simplicity of his monads given the divisibility of space. In the *Physical Monadology* (1756), accordingly, he strives to defuse this problem by introducing a difference between a monad's "internal determination", which is not in space and thus not divisible, and its "external determination" (or "sphere of activity"), which is responsible

for spatial emergence via its force connections with other monads: "Though any monad, when posited on its own, fills a space", yet "the filled space is not to be sought in the mere positing of a substance but in its relation with respect to substances external to it. . . . It must, therefore, be granted that the monad fills the space by the sphere of its activity" (57; 1:481). In more detail:

> Space itself is the orbit of the external presence of its element. Accordingly, if one divides space, one divides the extensive quantity of its presence. But . . . there are other, internal determinations; if the latter did not exist, the former would have no subject in which to inhere. But the internal determinations are not in space . . . Accordingly, they are not themselves divided by the division of the external determinations. . . . It is as if one were to say that God was internally present to all created things by the act of preservation; and that thus someone who divides the mass of created things divides God, since that person divides the orbit of His presence—and than this there is nothing more absurd which could be said" (58; 1:481).

What is notable in this quotation is that Kant explicitly sanctions the type of virtual presence conception (nullibism, repletive ubiety, etc.) that one finds in Leibniz, for Kant supports his conclusion by drawing an analogy between a monad's sphere of activity and God's presence "to all created things by the act of preservation"— a description that is equivalent to Leibniz' account (see section 4) where God's spatiality is manifest through operation (the continual production of the world) without a substantial presence in space. That is, just as Leibniz accepts a non-spatial God that only acts in space to conserve the world, so Kant posits a type of monadic operation responsible for the emergence of space and matter, but which similarly denies the presence in space of the entity responsible for that emergence, i.e., the monad's substance (internal determination). Unlike Leibniz, however, Kant openly supports a causal influx among his monads, which are physical and not merely immaterial interactions, for he claims that his form of inter-monadic connection incorporates a "reciprocal dependency", a dependency that he deems to be more robust than the mere "agreement among substances" that one finds in Leibniz' pre-established harmony doctrine (44; 1:415). Therefore, the *Physical Monadology* represents one of the most elaborate attempts to defend the non-spatially situated component of Leibniz' original monadological hypothesis alongside a full-fledged notion of physical inter-monadic activity and matter/space emergence.[3]

Finally, although the sphere of activity involves external connections among monads, it is clear that these causal connections are intrinsic relations grounded on internal features of the monads, since he insists (in the quote above) that if the internal determinations did not exist, the external determinations "would have no subject in which to inhere"; and later describes external determinations as "accidents" that "do not exist independently of their substances [i.e., intrinsic determinations]" (59; 1:482). This raises an intriguing question. Is the property theory of space, which fits the details of both Kant's and Leibniz' respective monadic systems, consistent with

[3] It should be noted that, like Leibniz, an important part in Kant's story relies on a (non-spatial) divine source as the basis of the inter-monadic connections, which he dubs the "schema of the divine understanding", and which he compares, once again, with God's act of preservation (40-43; 1:413-414).

the relational account of space and motion that Kant also espoused in the pre-critical period as regards bodily phenomena (see, *New Doctrine of Motion and Rest*, for Kant's body-based relationism; 2:16-17)? The answer, surprisingly, is yes. Since the property theory of space in the context of emergent space only pertains to the relationship between the non-spatial monads and emergent space/matter, the relationship among bodies, or between bodies and the emergent space property, is entirely open to different possibilities. Those relationships at the emergent level, which are external relations, might favor relationism among bodies alone, or substantivalism between bodies and the emergent space property (with Leibniz' brief flirtation with his "substantial chain" potentially representing the latter; Leibniz 1989, 198-203), but those possibilities at the emergent level do not compromise the property/internal relations metaphysics that holds between the non-spatial monadic level and the emergent space/matter level, and thus they do not undermine the property theory of space's status as the more basic ontology (i.e., between the foundational and the emergent levels). Similar conclusions can, and should, be drawn as regards contemporary non-spacetime QG theories.

5.2. The Downfall of Kant's Precritical Monadology. The criticisms raised against the Leibniz-Wolff school's monadology by the great German mathematician, Leonhard Euler, would play an important role in Kant's eventual turn against his monadology. Although a full treatment of Euler's arguments is beyond the bounds of this essay, his skeptical take on monadic systems is coupled, ironically, with a full endorsement of Leibniz' conception of non-spatial beings, God and souls, that only act in space: "My soul, then, does not exist in a particular place, but it acts there, and as God possesses the power of acting upon all bodies, it is, in this respect, we say, He is every where, though his existence is attached to no place" (Euler 1761, 355). This interpretation of a virtual presence (i.e., a presence by action but not by substance), along with Euler's contention that the relationship between immaterial and material beings is "a mystery which we shall never be able to unfold" (309), would seem to have had lasting impact on Kant's evolving approach to these issues, for he cites Euler and endorses his skepticism in the 1770 *Inaugural Dissertation*:

> But the presence of immaterial things in the corporeal world is a virtual not a local presence. . . . But space contains the conditions of possible reciprocal actions only in respect of matter. But as to what constitutes the external relations of force in the case of immaterial substances, whether those relations be between the immaterial substances themselves or between immaterial substances and bodies: that is quite beyond the human understanding, as the extremely perspicacious Euler, for the rest a great investigator and judge of phenomena, penetratingly noted. (Kant 1992, 410; 2:414)

Rather than employ the virtual presence hypotheses to describes the exact relationship between monads and emergent matter/space, as he had done in the *Physical Monadology*, Kant now employs Euler's understanding of virtual presence to separate God and immaterial monads from the material world that we experience (i.e., phenomenal world). In short, the monadic emergence model is now to be taken as metaphorically true, and not literally true, and part of the justification, besides the unknowability of immaterial processes, is that "space contains the conditions of possible reciprocal actions only in respect of matter", a view that would constitute one of the cornerstones of the forthcoming critical period.

Nevertheless, Kant still accepts that matter and space emerge from monads, and he posits a form divine omnipresence that pertains to the phenomenal world alone.

> [S]pace, which is the sensitively cognized universal and necessary condition of the co-presence of all things, can be called PHENOMENAL OMNIPRESENCE (For the cause of the universe is not present to each and every thing simply in virtue of the fact that that cause is in the places in which they are. It is rather the case that places exist, that is to say, that relations of substances are possible, because the cause of the universe is inwardly present to all things.) (405; 2:410)

As noted, a "phenomenal omnipresence" heralds the beginning of Kant's critical turn, since space is confined to the phenomenal world of matter, with immaterial entities excluded. As he explains in the *Metaphysical Foundations of Natural Science* (1786), "space is in no way a property that attaches in itself to any thing at all outside our senses. It is, rather, only the subjective form of our sensibility, under which objects of the outer senses, with whose constitution in itself we are not acquainted, appear to us, and we then call this appearance matter (Kant 2004, 45; 4:507). But a phenomenal presence of immaterial entities suggests a corresponding noumenal presence of immaterial entities, and Kant accepts this implication—and, equally important, he never abandons this belief:

> The ground for this aberration lies in a poorly understood *monadology*, [a theory] which has nothing at all to do with the explanation of natural appearances, but is rather an intrinsically correct *platonic* concept of the world devised by *Leibniz*, insofar as it is considered, not at all as object of the senses, but as thing in itself, and is merely an object of the understanding, which, however, does indeed underlie the appearances of the senses. . . . Therefore, Leibniz's idea, so far as I comprehend it, was not to explicate space through the order of simple beings next to one another, but was rather to set this order alongside space as corresponding to it, but as belonging to a merely intelligible world (unknown to us). (45, 4:507-508)

Kant's insistence in this critical period work that the monadic system is a "correct *platonic* concept of the world", and that monads do "indeed underlie the appearances of the senses", demonstrates, consequently, that he has only forsaken the attempt to construct a realistic, or natural philosophical, monadic system—but he still holds that the monadic system is true "as an object of the understanding", i.e., as a truth that pertains to the noumenal world, but not the phenomenal world obviously. Indeed, in commenting on Leibniz' monadology in the *Critique*, the non-spatiality of the inner determinations put forward in the *Physical Monadology* seems to be reaffirmed in his claim that "[s]ubstances in general must have something inner", whereby "that which is inner in their state cannot consist in place, shape, contact, or motion (which determinations are all outer relations), and we can therefore attribute to the substances no other inner state than that through which we internally determine our sense itself, namely state of representations" (Kant 1998, 374; A274/B330).[4]

[4] See, also, Friedman (2009, 44, n.14) on Kant's evolving conception of his earlier monadology between the *Inaugural Dissertation* and the later critical period works. Ultimately, it seems, the *Critique*'s stance is that the noumenal truth of his monadic system can only be justified on the grounds of faith.

Also disclosed in the above passage is the claim that Leibniz did not try "to explicate space through the order of simple beings next to one another", which is likely a reference to Crusius' circularity allegation from 1745 against both relational space and Leibniz' pre-established harmony theses, i.e., that "next to one another" already presumes space, and so one cannot use that analysis to define space. After stating "that the true concept of space already lies in the word 'next to each other'", Crusius adds that "music or meditation or a definition would otherwise be a space, because many things are next to each other in them. Pre-established harmony would likewise be a space, because it is the mode of coexistence between the body and the soul (Crusius 2009, 147). Crusius criticism, that "next to each other" presupposes space—and hence entails that allegedly non-spatial items, such as music or monads, are really in space—is another manifestation of the "spatial presence" problem, in this case applied to topological notions (e.g., next to, adjacent, neighborhood). It appears that Kant was persuaded by these types of criticisms, for he reasons that Leibniz had merely tried to "set this [monadic] order alongside space as corresponding to it, but as belonging to a merely intelligible world (unknown to us)", a defense of Leibniz' monadology that, needless to say, equally applies to the attempt to salvage his own pre-critical system through an appeal to its, as it were, "noumenal truth".

As first discussed in section 2, there have been objections raised to contemporary non-spacetime QG hypotheses that claim, roughly, that an entity that does not exist in spacetime is a problematic, or even incoherent, notion. For example: "it is unclear how to make sense of concrete physical entities that are not in spacetime and of the notion of ontological emergence that is involved" (Lam and Esfeld 2013, 287). These types of allegations are closely related to the spatial presence problem since they would seem to constitute the conclusion that the critics believe should be drawn from that problem. That is, if all attempts to give a non-spatial foundation for space fail, either by presupposing or playing the role of space, then the very existence of a non-spatial entity is incoherent or contradictory. Many of the arguments raised against non-spatial conceptions of God or monads in the Early Modern period are similar in content, e.g., Newton's insistence in *De gravitatione* that "whatever is neither everywhere nor anywhere does not exist" (Newton 2004, 25). Likewise, Kant's defense of his "noumenal monadology" is evocative of some of the defenses offered on behalf of non-spacetime QG hypotheses:

> [S]uppose we have a theory . . . of some non-spatiotemporal entities, $\tau 1, \tau 2, \ldots, \tau n$, and a demonstration that, given suitable idealizations, some formal structure can be derived in which certain variables are functionally related just as phenomenal—'old'—spacetime quantities....[T]he τs are defined to be the unique collection of things satisfying the theory, such that *the structure in question veridically represents the spatiotemporal quantities.* So, by definition, if the τs exist, there is no further question of whether spacetime emerges from them. (Huggett and Wüthrich 2013, 284)

Kant's assertion that the monadological system is "an intrinsically correct *platonic* concept of the world", and that Leibniz' idea was "to set this order [of monads] alongside space as corresponding to it", is the Early Modern equivalent of Huggett and Wüthrich's claim that the structure of the non-spatiotemporal entities is "functionally related just as phenomenal—'old'—spacetime quantities", and is "such that the structure in question veridically represents the spatiotemporal quantities" (notice: "intrinsically correct", "corresponding to", "functionally related", "veridically represents"). Of course, contemporary attempts to defend non-spacetime

QG hypotheses are not hobbled by Kant's commitment to an a priori form of spatial intuition, a fixed Euclidean geometry, and the existence of immaterial entities—and they can additionally appeal to the well established scientific knowledge that has accrued over the past two centuries concerning the often drastic differences in material properties manifest between the micro and macro levels. Consequently, a possible further difference between Early Modern and contemporary debates on emergent space ontologies is that the latter appear to have a wealth of resources to counter the incoherence and spatial presence problems than were available to the former.

6. Conclusion.

There are many reasons that can be cited for Kant's decision to restrict the subjective forms of the intuition of space and time to material bodies alone, and thus expel his monadological system to the unknowable noumenal domain, e.g., as a means of preserving the a priori status of geometry (Kant 1992, 397; 2:404), as well as Euler's arguments against the monadic center of force conception (see, Friedman 2010, 606-608). Yet, the spatial presence problem, as revealed in the reference to Crusius' argument in the *Metaphysical Foundations*, also played a crucial role. To recap our analysis, not only did spatial emergence comprise a central theme in Early Modern philosophy in general, but it likewise constituted one of the specific reasons for Kant's critical turn. The development of contemporary non-spacetime QG theories, along with their associated philosophical puzzles, is thus not a unique conceptual development. It is but one part of a long tradition of philosophical speculation regarding, along with the attempts to construct, systems that posit a non-spatial realm from which the spatial world emerges.

Bibliography

Adams, R. 1994. *Leibniz: Determinist, Theist, Idealist*. Oxford: Oxford University Press.

Armstrong, D. M. 1989. *Universals: An Opinionated Introduction.* New York: Routledge.

Brickman, B. 1943. "On physical space, Francesco Patrizi". *Journal of the History of Ideas* 4: 224–225.

Broad, C.D. 1925. *The Mind and Its Place in Nature*. London: Routledge.

Crusius, A. 2009. *Sketch of the Necessary Truths of Reason*, in Kant's *Critique of Pure Reason: Background Source Materials*, ed. and trans. by E. Watkins, 137-179. Cambridge: Cambridge University Press.

De Risi, V. 2007. *Geometry and Monadology: Leibniz's Analysis Situs and Philosophy of Space*. Basel: Birkhäuser.

Euler, L. 1761. *Letters to a German Princess*, trans. by H. Hunter. London: Murray and Highley.

Friedman, M. 2009. "Newton and Kant on Absolute Space: From Theology

to Transcendental Philosophy", in *Constituting Objectivity: Transcendental Perspectives on Modern Physics*, ed. by M. Bitbol, P. Kerszberg, J. Petitot, 35-50. Dordrecht: Springer.

Friedman, M. 2010. "Synthetic History Reconsidered" in *Discourse on A New Method*, ed. by M. Domski and M. Dickson, 574-813. Chicago: Open Press.

Gerson, L. 2018. "Plotinus", in *The Stanford Encyclopedia of Philosophy*, ed. E. Zalta, https://plato.stanford.edu/archives/fall2018/entries/plotinus/.

Gillett, C. 2016. *Reduction and Emergence in Science and Philosophy.* Cambridge: Cambridge U. Press.

Grant, E. 1981. *Much Ado about Nothing: Theories of Space and Vacuum from the Middle Ages to the Scientific Revolution*. Cambridge: Cambridge University Press.

Huggett, N., and C. Wüthrich. 2013. "Emergent spacetime and empirical (in)coherence". *Studies in History and Philosophy of Modern Physics* 44: 276–285.

Kant, I. 1992. *Theoretical Philosophy: 1755–1770*, trans. and ed. by D. Walford and M. Meerbote. Cambridge: Cambridge University Press. [Referenced with volume, page number, from the standard Academy edition of Kant's works]

Kant, I. 1998. *Critique of Pure Reason*, trans. and ed. by P. Guyer and A. Wood. Cambridge: Cambridge University Press.

Kant, I. 2004. *Metaphysical Foundations of Natural Science*, trans. and ed. by M. Friedman. Cambridge: Cambridge University Press. [Referenced with volume, page number, from the standard Academy edition of Kant's works]

Kant, I. 2012. *Natural Science*, ed. by E. Watkins, trans. by L.W. Beck, J.B. Edwards, O. Reinhardt, M. Schönfeld, and E. Watkins. Cambridge: Cambridge University Press. [Referenced with volume, page number, from the standard Academy edition of Kant's works]

Koyré, A., and I.B. Cohen. 1962. Newton and the Leibniz-Clarke correspondence. *Archives Internationales d'Histoire des Sciences* 15: 63–126.

Lam, V., and M. Esfeld. 2013. "A Dilemma for the Emergence of Spacetime in Canonical Quantum Gravity". *Studies in History and Philosophy of Modern Physics* 44: 286–293.

Lam, V., and C. Wüthrich. 2018. "Spacetime is as Spacetime does". *Studies in History and Philosophy of Modern Physics* 64, 39-51.

Leibniz, G.W. 1923. *Sämtliche Schriften und Briefe*, ed. by Akademie der Wissenschaften der DDR. Darmstadt/Berlin: Akademie-Verlag. [referenced with series, volume, page]

Leibniz, G.W. 1969. *Leibniz: Philosophical Letters and Papers*, 2nd ed., ed. and trans.

by L. E. Loemker. Dordrecht: Kluwer.

Leibniz, G.W. 1989. *Leibniz: Philosophical Essays*, ed. and trans. by R. Ariew and D. Garber. Indianapolis: Hackett.

Leibniz, G.W. 1995. *Leibniz: Philosophical Writings*, ed. and trans. by M. Morris and G. H. R. Parkinson. Rutland, Vermont: C. Tuttle.

Leibniz, G.W. 1996. *New Essay on Human Understanding*, ed. and trans. by P. Remnant and J. Bennett. Cambridge: Cambridge University Press. [referenced with book, chapter, section]

Leibniz, G.W. and S. Clarke. 2000. *Leibniz and Clarke Correspondence*, ed. and trans. by R. Ariew. Indianapolis: Hackett. [referenced with author, L or C, letter, section]

Leibniz, G.W. 2007. *The Leibniz-Des Bosses Correspondence*, ed. and trans. by B. Look and D. Rutherford. New Haven: Yale University Press.

Lewis, D. 1986. *On the Plurality of Worlds*. Oxford: Blackwell.

Locke, J. 1975. *An Essay Concerning Human Understanding*, ed. by P. Nidditch. Oxford: Clarendon Press.

Loux, M. J., and T. M. Crisp. 2017. *Metaphysics: A Contemporary Introduction*, 4th ed. New York: Routledge.

Maudlin, T. 2007. "Completeness, Supervenience, and Ontology", *Journal of Physics A: Mathematical and Theoretical* 40: 3151–3171.

McLaughlin, B. 2008. "Emergence and Supervenience", in *Emergence*, ed. by A. Bedau and P. Humphreys, 81–98. Cambridge: MIT Press.

More, H. 1995 [1679]. *Henry More's Manual of Metaphysics: A Translation of the Enchiridium Metaphysicum, Parts I and II*, trans. by A. Jacob. Hildesheim: Olms.

More, H. 1997 [1659]. *The Immortality of the Soul*. Bristol: Thommes Press.

Newton, I. 2004. *Philosophical Writings*, trans. and ed. by A. Janiak and C. Johnson. Cambridge: Cambridge University Press.

O'Connor, T. 2021. "Emergent Properties", The Stanford Encyclopedia of Philosophy, ed. by E. Zalta, https://plato.stanford.edu/archives/win2021/entries/properties-emergent/.

Rickles, D. 2005. "A New Spin on the Hole Argument". *Studies in History and Philosophy of Modern Physics* 36: 415–434.

Slowik, E. 2015. “Space and the Extension of Power in Leibniz’ Monadic Metaphysics”, *History of Philosophy Quarterly*, 32: 253-270.

Slowik, E. 2019. “Cartesian Holenmerism and its Discontents: Or, On the ‘Dislocated’ Relationship of Descartes’s God to the Material World”, *Journal of the History of Philosophy* 57: 235-254.

Tahko, T. E., and E. J. Lowe. 2020. “Ontological Dependence”, in *The Stanford Encyclopedia of Philosophy*, ed. by E. Zalta, https://plato.stanford.edu/archives/fall2020/entries/dependence-ontological/.

Wüthrich, C. 2019. “The Emergence of Space and Time”, in *The Routledge Handbook of Emergence*, ed. by S. Gibb, R. Findlay Hendry, T. Lancaster, 315-326. New York: Routledge.

Wüthrich, C. 2020. “When the Actual World is Not Even Possible”, in *The Foundation of Reality*, ed. by D. Glick, G. Darby, A. Marmodoro, 233-254. Oxford: Oxford University Press.

Yates, D. 2021. “Thinking about Spacetime”, in *Philosophy Beyond Spacetime: Implications from Quantum Gravity*, ed. by C. Wüthrich, B. Le Bihan, N. Huggett, 129-153. Oxford: Oxford University Press.