A Historical Defense of Non-Spacetime Hypotheses: Non-Local Beables and Leibnizian Ubeity

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Abstract (English): Do theories of quantum mechanics and quantum gravity require spacetime to be a basic, ground level feature, or can spacetime be seen as an emergent element of these theories? While several commentators have raised serious doubts about the prospects of forgoing the standard spacetime backdrop, it will be argued that a defense of these emergent spacetime interpretations of quantum mechanics and quantum gravity hypotheses can be made, whether as an inference to the best explanation or using another strategy. Furthermore, the idea that space and time can arise from a quite different, non-spatiotemporal level of reality will be shown to have various historical precedents, especially in the seventeenth and eighteenth centuries, a realization that may help dispel some of the mystery associated with these types of hypotheses.

Abstract (French): Ne les théories de mécanique quantique et de la gravitation quantique requièrent spacetime à une fonctionnalité de niveau de base, la masse, ou peut être considérée comme une spacetime élément emergent de ces théories? Bien que plusieurs commentateurs ont soulevé de sérieux doutes sur les perspectives de renoncer à la norme spacetime toile de fond, il fera valoir que la défense de ces nouvelles interprétations spacetime de la mécanique quantique et de la gravitation quantique hypothèses peuvent être formulées, que ce soit comme une inférence pour la meilleure explication ou en utilisant une autre stratégie. En outre, l'idée que l'espace et le temps peuvent découler de manière assez différente, non-spatio-temporelle niveau de la réalité sera indiqué avoir différents des précédents historiques, en particulier dans les dix-septième et dix-huitième siècles, une réalisation qui pourrait aider à dissiper une partie du mystère associés à ces types d'hypothèses.

1. Introduction.

Although string theory, loop quantum gravity (LQG), and a host of other hypotheses that advance an alternative foundation for theoretical physics are often criticized on the (somewhat prosaic) grounds that there is little or no supporting evidence, several commentators have put forward the more ambitious claim that a certain class of these hypotheses are problematic, and potentially incoherent, both conceptually and empirically. In particular, the skeptical assessment is aimed at those quantum gravity

(QG) strategies, and interpretations of quantum mechanics (QM), that posit an underlying ontology that does not possess the 4-dimensional spacetime properties, chiefly metrical and topological, associated with twentieth century field theories, such as general relativity (GR). Rather, these QG theories claim that the spacetime structures employed by GR and other higher level field theories emerge from the non-spacetime QG entities and processes posited at a more fundamental ontological level. Hereafter, a "non-spacetime" theory denotes a QG proposal (or QM interpretation) that does not take the continuous, 4-dimensional metrical and topological structure of spacetime as fundamental. The goals of this essay are as follows. In section 2, the arguments against these non-spacetime QG hypotheses will be shown to be limited in various ways, and, with respect to structural realism, it will be argued that both the ontic and the epistemic versions are equally legitimate interpretations. Specifically, Huggett and Wüthrich have provided a defense of these non-spacetime QG hypotheses against criticisms raised by Maudlin, and this defense will be extended to rebuff similar objections developed by Esfeld and Lam, as well as challenge the latter's interpretation of the relevant form of structural realism that applies to non-spatiotemporal hypotheses. In section 3, more importantly, the allegation that a non-spacetime ontology is a radical departure from established scientific thought will be challenged through examining similar ideas and strategies from the history of natural philosophy, in particular, Leibniz' conception of ubeity and its role in his monadic conception of the material world's emergence.

2. Beables and Locality: Why Worry?

Overall, several commentators would appear to reject these non-spacetime QG proposals, insisting that "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).[1] In line with similar criticisms put forward earlier by Maudlin (2007) against configuration space interpretations of QM (but applicable to QG as well, see below), Bell's notion of a "local beable" is adopted by Lam and Esfeld to counter these non-spacetime QG proposals (see, Bell 1987, 234). A "beable" refers to, in this case, the fundamental objects of a theory's ontology, whereas a "local beable" is that object's association—locality—within a definite spacetime region. The problem, put roughly, is that non-spatiotemporal entities are not localizable, or their localization has yet to be determined, and this predicament has lead Maudlin, as well as Lam and Esfeld, to render a negative verdict on these non-spacetime hypotheses. On Maudlin's estimation, "local beables do not merely exist: they exist somewhere" (2007, 3157), so it follows that any theory which admits beables that cannot be localized does not achieve "physical salience" (3167). Likewise, Lam and Esfeld declare that "there are no beables without local beables" (Lam and Esfeld 2013, 290).

Viewed in historical context, the local beables quandary can be seen as a skirmish in the larger battle over the relationship between spacetime physics and matter/field theory, i.e., whether spacetime relationships are derived from, or are independent of, the dynamical processes at the microphysical level. This debate need not involve the age old

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[1] Lam and Esfeld confine their study to canonical QG theories, specifically, geometrodynamics and LQG, but we will include a host of other QG and non-QG proposals in our discussion as well.

absolute/substantival versus relationism question, and it is not restricted to QG, but it has been a major issue in the development of twentieth century physics, and in the relationship between QM and GR in particular. According to Friedman, “spacetime physics, on Einstein’s view, must precede, and then constrain, the development of microphysics” (Friedman 2013, 195), although many have drawn the opposite conclusion, e.g., Brown’s recent text that regards the “geometrical structures of Minkowski space-time as parasitic on the relativistic properties of the dynamical matter fields” (Brown 2005, 100).

2.1. Quantum Mechanics and Spacetime. A major part of Lam and Esfeld’s “no local beables” argument against non-spacetime QG theories is based on their interpretation of the role of spacetime in quantum mechanics. Put briefly, they argue that non-seperability and/or entanglement in QM, in both the non-relativistic and quantum field theory settings, depends crucially on spacetime, thus QG theories (which are QM-based) face potentially insurmountable difficulties.

These allegations raise legitimate concerns, it must be admitted, but they also involve questionable assumptions, as the work of Dieks (2001) helps to make clear. First, only some interpretations of non-relativistic QM posit spatiotemporal positions (trajectories) for quantum systems, e.g., Bohmian mechanics, whereas the more traditional interpretation first developed by Bohr does not. Under the Copenhagen interpretations, and its Hilbert space formalism, the complementarity of position and momentum entails that a quantum system can lack a spacetime position under some experimental arrangements. As Dieks notes, “[Q]uantum mechanics is not a spacetime theory. The Hilbert space formalism is self-sufficient, and does not need a spacetime manifold as a background. The quantum-mechanical states are defined directly as elements of a Hilbert space. Furthermore, it is possible to interpret these abstract mathematical states in terms of systems which do not always possess positions" (Dieks 2001, 232).[2] Turning to quantum field theory (QFT), there have been several interpretations of algebraic QFT that forsake the point manifold of Minkowski spacetime for a reconstruction based on overlapping sets of subalgebras that represent physical subsystems (see, e.g., Bannier 1994, Schroer and Wiesbrock 200, and Dieks 2000). These strategies can be seen as favouring a sophisticated relationist or property interpretation of QFT since the point manifold is replaced (or recaptured) by a particular ordering of these physical subsystems—but, more generally, these algebraic QFT constructions are akin to non-spacetime QG hypotheses in the sense that the relevant structures of the physical subsystem are encoded in a Hilbert space. That is, a Hilbert space structure, which possesses neither manifold nor metric, gives rise to QFT's Minkowski spacetime in a supervenience or emergence fashion. Accordingly, if the details can be worked out, these interpretations of QM and QFT do not necessitate spacetime at the foundational level. Likewise, the advocates of "wave-function realism", such as Albert (1996) and Ney (2010), claim that the complex-valued 3*N*-dimensional configuration space (for an *N*-particle quantum theory) is the fundamental space, with the 3-dimensional space of macrolevel processes (and common experience) either emergent or, in Albert's words,

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[2] On Diek's analysis, which rejects substantivalism for a property theory or a sophisticated relationist proposal, "one should take the Hilbert space formalism as basic. All features which are traditionally associated with attributes of space should be distilled from this Hilbert space description. Obviously, Hilbert space is here not seen as something substantial, replacing absolute space, but rather as a mathematical device with the aid of which we give a systematical account of physical properties and their evolution" (2001, 235).

"illusory" (1996, 277). To sum up, the idea that macrolevel spacetime emerges in some manner from a deeper and quite different level of reality has gained many advocates, hence the claim that QM and the related QM-based theories (QFT, QG) require the standard spacetime backdrop common to classical and relativistic physics is itself a contentious claim.

2.2. Non-Spacetime Theories and Inference to the Best Explanation. While both Lam and Esfeld (2013, 291) and Maudlin (2007, 3160) admit the possibility of constructing successful non-spacetime QG theories, Maudlin insists that these proposals lack "physical salience" relative to those approaches that retain the standard background spacetime structure. Maudlin concludes that non-spacetime interpretations of QM depend crucially on what "a derivation of something isomorphic to local structure would look like, where the derived structure deserves to be regarded as physically salient (rather then merely mathematically definable). Until we know how to identify physically serious derivative structure, it is not clear how to implement [a non-spacetime] strategy" (2007, 3161). Huggett and Wüthrich (2013, 277) interpret this passage as invoking a form of "empirical incoherence" argument, presumably, in the sense that the evidence for such a theory would be local, and thus inconsistent with non-local beables. On Huggett and Wüthrich's estimate, this kind of reasoning simply begs the question, and they offer a blueprint for how understand the scheme underlying spacetime emergence:

> [S]uppose we have a theory, $T(\tau_1,\tau_2,\ldots,\tau_n)$, 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 then, since they just

> are (in part) the things from which spacetime emerges. (Huggett and Wüthrich 2013, 284; original italics)

In short, an ontology gains physical salience if it successfully "saves the phenomena", in this case, by deriving macrolevel spacetime from a more fundamental microlevel ontology that is not spatiotemporal.

From a slightly different angle, perhaps the same point can expressed as an "inference to the best explanation": if a non-spacetime QG theory can be formulated that integrates QM and GR—a goal that remains one of the top priorities of theoretical physics—then the success of that venture provides the basis for embracing the theory's fundamental ontology, regardless of its spatiotemporal or non-spatiotemporal status. Maudlin himself interprets Newton's arguments for absolute space along the same lines, i.e., as an inference to unobservable entities that effectively explains the phenomena, just as the atomic hypothesis successfully explains the macrolevel behaviour of bodies:

> [P]hysics is evidently in the business of postulating unobservable entities in service of explaining observable behaviour. The postulation is always risky, but, as the atomic hypothesis illustrates, the risk can sometimes pay off handsomely. Newton knew that absolute space and time are not, in themselves, observable, but he also explained how postulating them could help explain the observable facts. Why is this any worse than postulating atoms? (Maudlin 2012, 46)

Well, following the same logic, why is postulating a non-spatiotemporal fundamental ontology (from which 4-dimensional spacetime emerges) any worse than postulating absolute space? Like absolute space, a non-spatiotemporal QG ontology is unobservable, but, if successful, it also "explains the observable facts" previously captured, separately, by QM and GR. Yet, by integrating QM and GR, it would gain a level of empirical support that both QM and GR lack individually.

Another analogy between a well-known scientific theory or project and the local beables argument against non-spacetime QG lies in the neurobiological account of mental phenomena, an analogy that Lam and Esfeld mention as well. Overall, Berkeley's idealism, like Descartes' dualism, stems from a deep-seated scepticism of the mind's material origins: "What connexion is there between a motion in the nerves, and the sensations of sound or colour in the mind? Or how is it possible these should be the effects of that?" (Berkeley 1979, 45). In other words, there is a close parallel between the claim that spacetime cannot emerge from a non-spatiotemporal ontology and the belief that a mind cannot emerge from a non-mental ontology. Nonetheless, there are few idealists or dualists among contemporary philosophers of mind, despite the fact that the mind-brain relationship remains fairly opaque. The available evidence, such as brain damage impairing mental function, does offer indirect support for a mind-brain connection; but, presumably, the successful correlation of brain events and mental events by some future theory will be the only way to counter the scepticism embodied in the "How can a mind come from a non-mind?" credo. Similarly, a non-spacetime QG theory that successfully combines QM and GR, following the guidelines set down by Huggett and Wüthrich above, is likely the only defence against the local beables argument. As noted above, Lam and Esfeld likewise mention the mind-body problem while entertaining a possible supervenience interpretation of non-spacetime QG theories:

> [I]f properties of type *B* (e.g. mental properties) supervene on properties of type *A* (e.g. neurobiological properties), one may in a loose and somewhat misleading sense say that the properties of type *B* emerge from properties of type *A*. . . . Supervenience implies covariation in the following sense: any variation in type *B*-properties necessarily involves a variation in type *A*-properties. However, there is no account available how a variation in spatio-temporal properties could involve a variation in the properties of a more fundamental entity that is not spatiotemporal; . . . (Lam and Esfeld 2013, 292)

But there is no “account available” how a variation in neurobiological properties could involve a variation in mental properties either. So, assuming that Lam and Esfeld accept a mind-body link, the failure to provide a successful supervenience account (or an emergence, causal, or temporal explanation, as they also discuss) must not undermine the overall plausibility of the neurobiological hypothesis. Once again, it is the indirect evidence (from, e.g., brain injuries) in conjunction with the implausibility of the remaining options (such as idealism and dualism) that is largely responsible for why the neurobiological hypothesis is the best inference (see, e.g., Churchland 1988).[3] If a particular non-spacetime QG theory were to actually incorporate QM and GR successfully along the lines set down by Huggett and Wüthrich above, the lack of a supervenience, or emergence, etc., explanation of the manner by which a non-spatiotemporal ontology brings about spacetime would similarly fail to undermine that QG theory’s status as the best inference.

2.3. Structural Realism. Besides the dispute over the salience of non-local beables, there is a question concerning which brand of structural scientific realism, epistemic (ESR) or ontic (OSR), best corresponds to non-spacetime QG hypotheses. In brief, ESR takes an epistemological stance on the mathematical structures preserved over the course

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[3] As suggested by a referee, one objection that could be aimed at the analogy between the mind-body case and the non-spacetime hypotheses is that we have direct knowledge of brain activity, but we do not have direct knowledge of non-spatiotemporal entities. However, it is not evidence of brain activity that is crucial here, but evidence of brain events “bringing about” (causing) mental events (and, it is not enough to point out that there is evidence of the correlation of brain and mental events, since a dualist will concede this correlation while simultaneously denying that it undermines dualism). Nevertheless, the fact that there is evidence of brain events reveals the limitations of using the brain-mind case as an analogue to the non-spacetime case (i.e., since there is no evidence, at least as yet, of a realm of non-spatiotemporal QG entities).

of scientific change, i.e., these mathematical structures may, or may not, provide information on the actual ontology that underlies the observed structural relationships. OSR, on the other hand, claims that these invariant mathematical structures actually represent the underlying ontology in some manner, and, in fact, may be identical the underlying ontology. There are many forms of ESR and OSR, it should be added, but the following discussion will remain within the purview of Lam and Esfeld's discussion of this complex topic.

Returning to Lam and Esfeld's investigation, they associate non-spacetime QG hypotheses with ESR, but not OSR, insisting that "the structures that OSR admits are concrete physical structures through their being embedded, implemented or instantiated in spacetime. Without the commitment to spacetime, it would simply be unknown as in ESR what the entities are that implement or instantiate the mathematical structure of the theory in question" (Lam and Esfeld 2013, 289). Yet, this assessment prompts the obvious follow-up question: What are the instantiated entities in spacetime that uphold OSR? As regards QM, which is the theory that forms the basis of their analysis, ontological interpretations have long been problematic. Leaving aside QM's measurement problem, wave-particle duality, and a host of other mysteries, the evidence is compatible with both the individuals and non-individuals interpretations of QM, as even French (2011, 219) concedes, hence the ontology of QM seems as indeterminate as QG.[4] In brief, if Lam and Esfeld hold that ESR is the proper categorization for a theory with an "unknown" ontology, then QM should also qualify as ESR, as opposed to OSR,

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[4] Lam and Esfeld, in fact, cite the Everett interpretation of QM in their analysis (2013, 289-290). But, one might reasonably ask: Is a branching universe (or spacetime) more ontologically palatable than a fundamental ontology that lacks the metrical and topological properties of spacetime? Many would, I suspect, demur.

regardless of its spacetime or non-spacetime setting. And, in fact, Esfeld (2013) would seem to be in league with this line of criticism, for he concludes that OSR *does* face major hurdles as regards the interpretation of QM, i.e., between the many-worlds, collapse, and hidden-variables approaches, and hence OSR is not, at least at present, "sufficient to answer the question of what the world is like if quantum mechanics is correct" (Esfeld 2013, 19).

Furthermore, since OSR's ontological interpretation seems equivalent to treating QM's standard mathematical formalism, group structure, as isomorphic to, or a description of, a physical entity (see, Slowik 2012), an argument is thus required to explain why the mathematical structures employed by other theories, including non-spacetime QG theories, cannot qualify as the hypothesized OSR entity as well. A non-spacetime ontology is still an ontology, and it possesses a mathematical structure. Put differently: How exactly does spacetime convert an "unknown" ontology into a "known" ontology? Until this question is answered, the view that spacetime renders the mathematics of QM amenable to a scientific realist interpretation would seem to beg the question against those QG theories that posit non-spatiotemporal entities (from which spacetime emerges) which also seek a scientific realist construal.

Nevertheless, there is another investigation that apparently sides with the conclusion that the strategy underlying QG theories is closer to ESR, although not for the reasons offered by Lam and Esfeld. In Wüthrich (2012), an interpretation of structural realism in the context of causal set theory, a non-spacetime QG proposal, prompts the following assessment: "for the wholesale structural realist to meet the antirealist challenge, there must be isomorphisms between substructures of the models of succeeding theories in the relevant sense in order to underwrite the necessary structural continuity across scientific revolutions", where the structural continuity "must manifest itself in the form of partial isomorphisms between their models, i.e., of isomorphisms between [the QM-based] causal sets and substructures of the general-relativistic spacetimes" (Wüthrich 2012, 239). Overall, many advocates of OSR do not take the anti-realist challenge of the pessimistic meta-induction to be their primary goal (see, Esfeld and Lam 2008, 29), nor do they seem particularly concerned about structural continuity across scientific revolutions; instead, their main concern is to provide an ontology that denies the individuality of, say, quantum particles or spacetime points. Accordingly, despite the fact that Wüthrich raises concerns for both OSR and ESR (2012, 226-229), the quotation above seems much better suited to ESR than OSR—i.e., ESR's main goal is to defeat the pessimistic meta-induction via structural continuity across scientific change, just as Wüthrich counsels.

3. Historical Precedents: Ubeity and Local Beables.

3.1. Leibniz and Ubeity. Part of the rationale underlying the "no local beables" accusation against non-spacetime QG hypotheses almost certainly stems from the assumption that these types of hypotheses are entirely new and unorthodox contributions to the debate on spatial ontology. However, the history of speculation on the ontology of space (spacetime) belies that supposition, for there were a host of similarly structured hypotheses in the late seventeenth, eighteenth, and nineteenth centuries that were advanced by the most prominent natural philosophers of the day, such as Leibniz and the pre-critical Kant. In what follows, we will focus on Leibniz, since his wide-ranging conception of force (dubbed “proto-energetics” in Bernstein 1984, 101) laid the groundwork for a school of thought that, ultimately, inspired the development of the energy concept and the laws of thermodynamics. Indeed, Leibniz’ view that force was the basis of matter and spatial extension can be seen, in retrospect, as the forerunner of the type of modern field theories that includes QG hypotheses; and, to demonstrate this point, a leading QG proponent, Lee Smolin, has even gone so far as to draw ideas for potential QG hypotheses directly from Leibniz’ theory of non-spatiotemporal, soul-like entities, i.e., monads (see, Barbour and Smolin 1992).

While Leibniz’ monads can be envisioned as immaterial, soul-like things, it is also clear from his writings that they play a dual role in his metaphysics as the ontological foundation of the material world. First, following a conception popular in his time as regards immaterial entities, monads are not in space: he declares that “there is no spatial or absolute nearness or distance among monads” (1969, 604), and that each monad is “a certain world of its own, having no connections of dependency except with God” (1989, 199). Second, matter and space emerge from a non-spatiotemporal monadic realm that, like QM and QG theories, is more aptly described in terms of force: a monad is “endowed with primitive power” so that the “derivative forces [of bodies] are only modifications and resultants of the primitive forces” (176). Derivative force, as a value of the primitive force, is also tied to material extension, which is described as “diffusion”: “the derivative force of being acted upon later shows itself to different degrees in secondary [i.e., extended] matter” (120); “the nature which is supposed to be diffused, repeated, continued, is that which constitutes the physical body; it cannot be found in anything but the principle of acting and being acted upon” (179). In other words, Leibniz’ monads (like his conception of God, see below) are not in space *per se*, but they "bring about" matter and, hence, space: "[c]ertainly monads cannot be properly in absolute place, since they are not really ingredients but merely requisites of matter" (1969, 607); and, "properly speaking, matter is not composed of constitutive unities [monads], but results from them" (1989, 179; see, e.g., Rutherford 1995, for an extended analysis; and, Garber 2009, 383-384, who briefly mentions a similar, particle physics-inspired interpretation).

For all of its connotations with respect to modern physics, the motivation behind Leibniz' monadic conception stems from a more general dispute in the late Medieval and Early Modern periods regarding the relationship between God and space. Overall, the predominate view in the late seventeenth century held that space is an emergent effect of a deeper ontological entity, God, who lacks the spatiotemporal properties manifest at the material level of bodies. For instance, Gassendi, who linked space directly to God, nonetheless rejected the idea that God was spatially extended in the normal, metrical sense: "[W]e conceive an infinity as if of extension, which we call [God's] immensity, by which we hold that he is everywhere. But, I say *as if* of extension, lest we imagine that the divine substance were extended through space like bodies are" (1976, 94). Rather, "the divine substance is supremely indivisible and whole at any time and any place" (1976, 94), an hypotheses that posits a sort of topological conception of divine presence (since God is only in the points of space, but not extended across them; see Slowik 2013). Leibniz, in contrast, rejects the view that God is situated in space in either the metrical or topological sense, although, like Gassendi, God's immensity grounds space: "He is the source of possibilities and of existents alike, the one by his essence and the other by his will. So that space like time derives its reality only from him, and he can fill up the void whenever he pleases. It is in this way that he is omnipresent" (1996, II.xv.2). Therefore, Leibniz' non-spatiotemporal monadic hypothesis is akin to his non-spatiotemporal notion of immaterial beings, like God.

More specifically, the issues that pertain to the locality of QG entities would seem to naturally invoke a set of historical parallels with the seventeenth century's version of the same dilemma, namely, ubeity, as Leibniz explains in the *New Essays*:

> The Scholastics have three sorts of *ubeity,* or ways of being somewhere. The first is called *circumscriptive.* It is attributed to bodies in space which are in it point for point, so that measuring them depends on being able to specify points in the located thing corresponding to points in space. The second is the *definitive.* In this case, one can "define"—i.e. determine—that the located thing lies within a given space without being able to specify exact points or places which it occupies exclusively. That is how some people have thought that the soul is in the body, because they have not thought it possible to specify an exact point such that the soul or something pertaining to it is there and at no other point. . . . The third kind of ubeity is *repletive.* God is said to have it, because he fills the entire universe in a more perfect way than minds fill bodies, for he operates immediately on all created things, continually producing them . . . . (1996, II.xxiii.21)

Leaving aside God's unique ontological role, Leibniz inquiry is additionally concerned with the ubeity of lesser finite entities, such as angels and souls that—unlike God, but like monads—are not congruent with the whole of space. It is partially with respect to these finite immaterial entities that specific comparisons can be made to recent suggestions on how to conceive the locality of QG's non-spatiotemporal "beables" (entities), as will be demonstrated in section 3.2.

To recap Leibniz' discussion, which is based on his own unique interpretation of the Medieval ubeity concept, circumscriptive ubeity maps an entity to space directly, point by point, so that "measuring them depends on being able to specify points in the located thing corresponding to points in space". In definitive ubeity, "the located thing lies within a given space without being able to specify exact points or places which it occupies exclusively", i.e., it is not "possible to specify an exact point such that the soul or something pertaining to it is there and at no other point". Lastly, as regards repletive ubeity, Leibniz explains that God "operates immediately on all created things, continually producing them". Immediate operation is also linked to the entity's absence of spatiotemporal situation: "God is not present to things by situation but by essence; his presence is manifested by his immediate operation" (2000, 16-17; L.III.12). As noted above, there are strong parallels between Leibniz' concept of God and his concept of monads—both are posited as non-spatiotemporal foundations of the spatiotemporal material world—hence one might possibly infer lessons on the ubeity problem as it pertains to monads from the analysis in the *New Essays* quoted above.

3.2. Ubeity and Non-Spacetime Theories. In an attempt to address the local beables issue for those QG hypotheses that embrace spacetime emergence, Huggett and Wüthrich (2013) put forward a detailed analysis of locality that, quite intriguingly, mirror Leibniz' interpretation of the three forms of ubeity (and, in what follows, Leibniz' understanding of ubeity, rather than earlier Medieval precedents, will inform our analysis). Starting with circumscriptive ubeity, Huggett and Wüthrich comment that, on a simple reading of string theory, "it looks exactly as if strings are local beables, bits of stuff describing worldsheets in a classical spacetime", but they go on to add that the duality structure of the later versions of string theory undermines that conclusion (2013, 280). Nonetheless, Huggett and Wüthrich's discussion would seem to concede that the earliest string theories (first phase, roughly pre-1995), as well as any other QG strategy with a classical background space (spacetime), such as the naive covariant quantization techniques and geometrodynamics, would not violate the demand for local beables either, and hence meet Leibniz' circumscriptive category.

Turning to definitive ubeity, there is close parallel between the problems associated with the locality of LQG's beables, the discrete QM-based spin networks from which spacetime emerges, and Leibniz' analysis of the locality (situation) of finite immaterial beings. A critical obstacle in the development of LQG has centered on its inability to preserve some notion of adjacency ("next to" relationship) among spin networks at the emergent level of spacetime. As described by Huggett and Wüthrich, "[t]he problem is that any natural notion of locality in LQG—one explicated in terms of the adjacency relationship encoded in the fundamental structure—is at odds with locality in the emerging spacetime. In general, two fundamentally adjacent nodes [i.e., of two spin networks] will not map to the same neighborhood of the emerging spacetime" (279). Since locality and adjacency in spacetime are topological notions, LQG's local beables quandary correlates with Gassendi's topological conception of God's presence—but, focusing strictly on the locality of finite immaterial beings as mentioned in the *New Essays* passage, the inability to localize these immaterial beings in space is analogous to the inability to localize LQG's spin networks, e.g., "the located thing [angel, soul] lies within a given space without being able to specify exact points or places which it occupies exclusively" (1996, II.xxiii.21). In both cases, finite immaterial beings and LQG's spin networks, the difficulty is topological in nature and specifically concerns the adjacency relationship: under Leibniz' definitive ubeity concept, there is no determinate adjacency relationship among the "parts" of a soul or angel in space under; whereas in the case of LQG, adjacent spin networks fail to remain adjacent in the emergent spacetime.

The third form of ubeity is repletive, where only an entity's actions or effects can be situated in space, but not the entity itself. Repletive ubeity, therefore, is the seventeenth century equivalent of the absence of local beables. Given all of the parallels disclosed thus far between ubeity and local beables, it probably should not be surprising that Huggett and Wüthrich's proposal for a surrogate notion of locality for those QG theories with the most thoroughgoing non-spatiotemporal ontology, such as causal set theory, bears an uncanny similarity with Leibniz' repletive ubeity: "take localization in causal terms, and argue that it is causal nexus [among the non-spatiotemporal basal elements], rather than spatiotemporally understood locality, which supplies the condition relevant for empirical coherence [of the theory]" (2013, 278). Just as Leibniz' God and monads are not situated in space, but God's actions and the monad's "results" (i.e., matter) are situated, so it would seem that the non-spatiotemporal elements of causal set theory are not spatially located, but one can obtain a proxy notion of locality via their causal structure. It is important to point out that the term "causal" as used in this context pertains to a structural relationship among the basal elements, and not to the more familiar philosophical notion of causality that is a subject within metaphysics. In particular, causal structure does not include metric structure ("[t]here simply is nothing on the fundamental level corresponding to lengths and durations"), and it cannot "identify 'space', in the sense of a spacelike hypersurface", or, "[i]n other words, nothing but a difference analogous to that between spacelike and timelike remains at the fundamental level" (278). At a minimum, maintaining a difference of this sort would guarantee that, at the foundational level, two basal elements are distinct and do not overlap, and this restricted form of structural relationship finds a parallel in the structural relationship among God's conservation of the world's material occupants and the structural relationship among monads. That is, since God's effort to maintain each material object would naturally impose a discrete order among these actions (i.e., for each object), and the monadic forces that "bring about" matter (and thus space) emanate from individual monads, the only type of quasi-spatial relationship that can be attributed at the foundational level to God's conservation actions and the monads themselves would likely amount to a non-overlapping or discreteness criterion analogous to the quasi-spacelike separation requirement mentioned by Huggett and Wüthrich with respect to causal set theory's structure.

In summary, Huggett and Wüthrich's analysis of the local beables issue not only correlates with the ubeity system, but their proposals as regards particular QG theories, e.g., string theory, LQG, and causal sets, also fall under the specific categories of ubeity, and with respect to the same geometrical structures, as referenced by Leibniz: circumscriptive/metric with (early) string theory or naive covariant quantization; definitive/topological with LQG; and repletive with those QG hypotheses that have more non-spatiotemporal aspects than LQG, such as causal set theory.

4. Conclusion.

In Smart's popular anthology, *Problems of Space and Time*, a work that coincided with the rise of the contemporary movement in the philosophy of space and time, one finds an early reference to the possibility that the world's underlying ontology may be non-spatiotemporal:

> It is just possible that we shall come to regard space and time as statistical properties on the macroscopic level only—just as, for example, temperature is statistical property on the macrolevel, which has no meaning in micro-physics. In this case, the particles of microphysics will be related only by relations which are not spatio-temporal, and so these particles will bear a remarkable likeness to Kant's "things-in-themselves". (1964, 16-17)

Whether a successful QG theory would envision emergent space as a "statistical" property of the underlying ontology is debatable, as is the reference to Kant's noumenal world, but the analysis is, nonetheless, prophetic. That is, at the very start of the modern approach to the philosophy of space and time, a well-known introductory text suggests a non-spatiotemporal ontology as a potential candidate, once again demonstrating that these types of physical theories have always retained a degree of relevance and plausibility.

There are other historical examples of non-spatiotemporal physical ontologies that might be cited, of course, such as the unextended point-forces of the Leibniz-Wolff school (from which space and the material macrolevel arise), but one of the results of our investigation into ubeity in section 3 should stand out quite clearly by this point—namely, that the emergence of space, time, and matter from a deeper non-spatiotemporal level of ontology has played an important role in the history of natural philosophy. These non-spatiotemporal QG hypotheses will need to be fully developed and their various problems worked out, of course, and they may very well fail in this regard, but the criticisms directed at their lack of a spacetime backdrop finds no support if it is based on the presumption that there are no historical precedents for this strategy. Returning to the main historical analogy developed in this essay, it is understandable that philosophers may have misgiving about employing Leibnizian ubeity in an analogy with contemporary non-spatiotemporal hypotheses, since the former seems pseudo-scientific. But, the best way to counter the impression that these seventeenth century non-spatiotemporal hypotheses are akin to magic or astrology is to historically connect them with current, widely-accepted scientific (as opposed pseudo-scientific) hypotheses that are similar in structure and purpose as regards physical emergence (i.e., leaving aside the mind/soul aspect of these Early Modern theories while focusing exclusively on the material and spatiotemporal components of their emergence concepts). As revealed in section 3, there are close similarities between the Early Modern and QG hypotheses on specific spatiotemporal properties or features that obtain at the foundational and derived levels of reality, thus our detailed investigation is justified on these grounds. Likewise, while the seventeenth century ubeity idea may seem from our current perspective to be outside the realm of natural philosophy, it was not judged so by Leibniz and Newton, a realization that demonstrates the historically-situated, contingent nature of any attempt to label an hypothesis as pseudo-scientific. Furthermore, many of Leibniz' ideas, in particular, that force is essential to matter, have been embraced by modern physics, and so maybe he was right about the non-spatiotemporal basis of macrolevel material entities as well.

Finally, to recap one of the themes of the discussion in section 2, the manner by which a non-spacetime theory gains physical salience seems commensurate with the way other theoretical entities in different physical theories have achieved that same status, whether it is the atomic hypothesis or the neurobiological basis of the mind. That is, just as a material body seems to have properties (color, solidity, etc.) that are not possessed by its sub-atomic constituent elements (protons, electrons, neutrons, which are neither colored nor solid), so it is possible that the macrolevel spatiotemporal structure of the world is an emergent feature of a hidden realm of entities that possess radically different spatiotemporal properties. As Huggett and Wüthrich have argued, moreover, the case against these non-spatiotemporal hypotheses, whether advanced by Maudlin or Lam and Esfeld, begs the question; and, if one of these hypotheses were indeed to successfully incorporate QM and GR, then the rationale for accepting a non-spatiotemporal realm of QG entities would be extremely difficult to dismiss.

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