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NEWTON, THE PARTS OF SPACE, AND THE HOLISM OF SPATIAL ONTOLOGY

Edward Slowik

This article investigates the problem of the identity of the parts of space in Newton's natural philosophy, as well as the holistic or structuralist nature of Newton's ontology of space. Additionally, this article relates the lessons reached in this historical and philosophical investigation to analogous debates in contemporary space-time ontology. While previous contributions, by Nerlich, Huggett, and others, have proven to be informative in evaluating Newton's claims, it will be argued that the underlying goals of Newton's views have largely eluded prior analysis and that Newton's approach is similar, and lends support, to several current structuralist trends in the conception of space-time ontology.

1. Introduction

Recently, Newton's enigmatic defense of the immobility of the parts of space has brought about much discussion among philosophers of space and time. Apart from the contributions of McGuire, DiSalle, Healey, Torretti, and others on this topic, there have appeared two important assessments by Nerlich and Huggett that more directly examine Newton's specific arguments. The question is whether Newton's structuralist or holistic conception of the identity of the parts of space ultimately undermines his overall theory of space, a problem that, interestingly, does not appear to be a consequence of his espousal of

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absolutism or substantivalism (i.e., the position that space is an entity of some sort that can exist apart from matter). Since Newton bases the identity of the parts on their structural relationships, and since all the parts in infinite Euclidean space bear the same structural relationships with one another, do these parts thus lack the requisite identity criterion for a consistent theory of space? In order to better grasp Newton's treatment of these issues, this article will explore the background of, and possible sources of influence on, Newton's theory, as well as critique the interpretations and arguments advanced by commentators. Yet, this article is not limited to a historical analysis of seventeenth-century theories alone since a contemporary analogue of the problems and issues that Newton faced finds a home in contemporary space-time debates. The intention of this article, consequently, is, first, to provide the historical and philosophical analysis of Newton's spatial holism necessary to refute the problems raised by Nerlich and Huggett and, second, to argue that modern debates on the ontology of space-time, some of which have been prompted by similar problems, have either unknowingly followed or could benefit from Newton's holistic conception.

While section 2 will explore Newton's "immobility arguments," the historical context of Newton's arguments will occupy section 3, specifically, the crucial role of the "holistic" nature of space (i.e., its simplicity and oneness), which from the modern perspective can be seen as the interplay of metrical and topological concepts. In section 4, the lessons gathered from our examination will be contrasted with similar issues and strategies in contemporary space-time debates, thus demonstrating the continuing relevance of these issues for contemporary space-time theorists.

2. Newton's Immobility Arguments

Following Huggett, Newton's arguments for the immobility of space, which appear in a famous passage from the unpublished *De gravitatione* (hereafter *De grav*; probably early 1680s), will be labeled Ai and Aii:

> [Ai] The parts of space are motionless. If they moved, it would have to be said either that the motion of each part is a translation from the vicinity of other contiguous parts, as Descartes defined the motion of bodies, and it has been sufficiently demonstrated that this is absurd; or that it is a translation out of space into space, that is out of itself, unless perhaps it is said that two spaces everywhere coincide, a moving one and a motionless one. [Aii] Moreover, the immobility of space will be best exemplified by duration. For just as the parts of duration are individuated by their order, so

> that (for example) if yesterday could change places with today and become the later of the two, it would lose its individuality and would no longer be yesterday, but today; so the parts of space are individuated by their positions [*positiones*], so that if any two could change their positions, they would change their individuality at the same time and each would be converted numerically [*numerice*] into the other. The parts of duration and space are understood to be the same as they really are only because of their mutual order and position [*ordinem et positiones inter se partes*]; nor do they have any principle of individuation apart from that order and position, which consequently cannot be altered. (2004, 25)

An argument similar to Ai also turns up in the scholium on space and time in the first edition of the *Principia* (1687), a passage we will identify as B.

> [B] Just as the order of the parts of time is unchangeable, so, too, is the order of the parts of space. Let the parts of space move from their places, and they will move (so to speak) from themselves. For times and spaces are, as it were, the places of themselves and of all things. All things are placed in time with reference to order of succession and in space with reference to order of situation [*situs*]. It is of the essence of spaces to be places, and for primary places to move is absurd. They are therefore absolute places, and it is only changes of position [*translationes*] from these places that are absolute motions. (2004, 66)

In brief, Ai and B argue that the parts of space cannot move since that would entail the contradiction that a part could move "out of itself," Ai, or that parts could move "from themselves," B. (In what follows, "parts" and "points" will be used interchangeably.)

We will return to Ai and B in section 3, but a more in-depth examination of the "identity" argument, Aii, is in order: since the parts of space are understood to be the same due to their "mutual order and position" and since any interchange of parts preserves the same mutual order, there can be no interchange of parts, and thus the parts did not really move/interchange. The trouble with Aii, as Huggett succinctly puts it, is that "if any two parts of space are indistinguishable with respect to their metrical relations to the other parts of space, then they are strictly identical" (2008, 396–97). More carefully, Newton claims that points have no "principle of individuation apart from [their] … position," where Newton's phrase is taken by Huggett as pertaining to the metrical relations between points; thus, given the symmetries of (infinite) Euclidean space (where every point has the same metrical relations to every other point) and given that there are no previously identified points relative to which others can be identified, it follows that the points of Newton's (Euclidean) space are really the same point—henceforth, we will refer to this as the "collapse" problem or argument. In order to establish this obstacle for Newton's theory of space, something like Leibniz's principle of the identity of the indiscernibles, PII, must be in play: if two things have identical properties (such that neither has a property different from the other), then they are the same thing. Nerlich's diagnosis of the Aii collapse problem is similar (2005, 123).

As will become evident later, a central issue is whether Newton's "mutual order and position" description really pertains to metrical (distance) relations. In section 3, this will be shown to be largely correct, although it needs to be qualified since Newton conceives order and position as attributes of space, which is a quantity.

3. The Background to Newton's Immobility Arguments

Needless to say, it is the symmetric and homogeneous nature of Newton's Euclidean space that generates the collapse problem, although other symmetric spaces, such as a spherical or hyperbolic space, would suffer the same fate, but most variably curved and dynamical spaces would not (see sec. 4 and Wüthrich [2009], for an Aii-like criticism of space-time structuralism). Huggett ultimately attempts to deny the implications of Aii by using a form of *de re* representation of points across states or worlds (although it is not examined this article, but see n. 11). Yet, as will be argued, a more in-depth historical analysis of Newton's conception of space, and the "immobility" arguments in general (i.e., Ai, Aii, and B), can sidestep the problem raised above.

3.1. Oneness, Indiscerpibility, and Simplicity

Starting probably with Zeno's paradox of place, one of the traditional difficulties with the concept of place is the potential regress that ensues given the stipulation that all things, except God, require a place: if place required a place, then the "place of place" would need a place, too, and so on (see Grant 1981, 18, on medieval precedents). The Cambridge neo-Platonist Henry More may have addressed the regress issue, albeit indirectly, in his *Enchiridium Metaphysicum* (1671), a work that almost certainly greatly influenced Newton's *De grav.*[1] More's insistence that infinite spatial extension is "one" would seem

1. On Newton's indebtedness to his predecessors (e.g., Charleton, More, Barrow, Wallis), see, e.g., McGuire and Tamny (1983), Hall (2002), and Slowik (2009).

to incorporate concerns about a multiplicity of places: "infinite extension distinct from matter … is one to the extent that it is absolutely impossible that to that one there be many, or that it make many, since it has no physical parts from which they can be combined and into which they can be truly and physically divided" (1995, 58).

On More's estimation, this oneness of space is inextricably linked with its "simplicity" (that space is without parts) and "indiscerpibility" (a word coined by More which denies the "actual" divisibility of space, i.e., physically or metaphysically, by a process of tearing or cutting; see Holden 2004). In the *Enchiridium*, More groups these features of infinite spatial extension with immobility. He aims to relate "in what way that infinite immobile extension distinct from matter is one, simple, and immobile," after which he defines oneness and simplicity: "[infinite extension] is aptly called simple, seeing that it has, as I have said, no physical parts" (1995, 58). More continues: "And this simplicity, however, is easily understood of its immobility. For, no infinite extension which is not combined from parts, nor is condensed or thickened in some way, can be moved, either from part to part, since the whole is simple and indiscerpible, nor can the whole at the same time, since it is infinite, be contracted into less space, since it is not condensed anywhere nor can it leave its place, since this infinite is the intimate place of all things, within or beyond which there is nothing" (58). In short, (1) the immobility of the parts of space follows directly from the oneness, simplicity, and indiscerpibility of infinite extension, and (2) the whole of space cannot move since there is nothing (e.g., a second place/space) relative to which it can move. While 2 does provide a rationale for 1, the simplicity and oneness of space does not necessarily rule out a regress of one, simple spaces. Apart from the sheer unintelligibility of a regress of space, however, More (and probably Newton, as will be argued below) appealed to ontological concerns of a deeper sort—namely, God—to justify acceptance of 2. More claims that immobility "is celebrated as the most excellent attribute of First Being in Aristotle" (58) and contends that space is God's attribute (57), thus securing space's immobility as whole by brute ontological fiat.

That Newton's immobility arguments, Ai, Aii, and B, are predicated on a set of beliefs similar to More's is practically indisputable. In an unpublished tract from the early 1690s, entitled "Tempus et Locus" (hereafter TeL), Newton openly declares that "space itself has no parts which can be separated from one another. … For it is a single being, most simple, and most perfect in its kind" (McGuire 1978, 117). The likely motivation for both Newton's and More's views is the prospect that discerpibility thus may be ascribed to the ontological foundation of space, the omnipresent God. In *De grav*, Newton cautions that "lest anyone should … imagine God to be like a body, extended and made of divisible parts, it should be known that spaces themselves are not actually divisible" (2004, 26). By denying that space is composed of separable parts, Newton thus blocks any maneuver, such as Leibniz's insinuation in the Leibniz-Clarke correspondence (Leibniz and Clarke 2000, 45; L.V.42) that attributes parthood to God via spatial divisibility.[2] Given the assistance that Newton likely rendered to Clarke, it is thus not surprising that many of the themes of oneness, simplicity, and indiscerpibility (for both space and God) figure prominently in Clarke's detailed replies: "For infinite space is one, absolutely and essentially indivisible, and to suppose it parted is a contradiction in terms, because there must be space in the partition itself, which is to suppose it parted and yet not parted at the same time. The immensity or omnipresence of God is no more a dividing of his substance into parts than his duration or continuance of existing is a dividing of his existence into parts" (19; C.III.3). "Infinite space, though it may be … conceived as composed of parts, yet since those parts (improperly so called) are essentially [indiscerpible] and immovable from each other and not able to be parted without an express contradiction in terms, … space consequently is in itself essentially one, and absolutely indivisible" (31; C.IV.11–12).[3] As regards Newton's immobility arguments, Clarke's contention that there would "be space in the partition" is the likely analogue of Newton's earlier claims that a part of space would move "out of itself" or that parts could move "from themselves."

Before leaving this topic, it is worth reflecting further into the connection between, on the one hand, the regress argument and, on the other, Newton's views on the oneness, simplicity, and indiscerpibility of both God and space. As noted above, the oneness, and so on, of space does not necessarily stop a regress of spaces (places), but since Newton maintains that the ontological foundation of space is an infinite God, there is accordingly a unique irreducible "object" that grounds the existence of space, as well as its immobility and infinity (as also noted in the case of More). There are abundant passages from which to choose, for example, in *De grav*—"space is eternal in duration and immutable in nature because it is the emanative effect of an eternal and immutable being" (Newton 2004, 26)—and the General Scholium, *Principia* (1713), "He [God] endures forever, and is everywhere present; and by existing always and everywhere, he constitutes [*constituit*] duration and space" (91). This last conjecture, that God "constitutes" space, would hence seem to rule out the possibility that any

2. Citations to the Leibniz-Clarke correspondence include the author (L or C), letter number, and section.

3. As Koyré and Cohen point out (1962, 91), most modern translations incorrectly use the term "indiscernible" in place of "indiscerpible," the latter being the term actually used in Clarke's original reply but mistranslated in the published versions of the correspondence.

regress of spaces (places), or a motion, is applicable to this entity (against Khamara 2006, 111–12). That is, it only makes sense to entertain a regress of spaces for God if it is possible to meaningfully discuss a space apart from God, but since space is "brought about" by God, there can be no spatial backdrop, or second place or space, on which to establish the meaningfulness of this entity's regress or motion. This explanation is possibly supported by a passage in TeL, wherein Newton asserts that God contains "all other substances in Him as their underlying principle and place" (McGuire 1978, 132). Whether this form of response would constitute a successful resolution of the regress problem is debatable, but it apparently forms an instance of a conception popular from the early medieval period up through Newton's own time, namely, that God was "in Himself" before the creation of the world (and there are seventeenth-century precedents for equating God's being "in Himself" with not being in a place; see Grant 1981, 330 n. 57).[4]

3.2. Simplicity and Spatial Holism

At this juncture in our historical examination of the immobility arguments, it is essential to assess the background of the identity argument, Aii, which leads, purportedly, to the parts of space being identical since their mutual order relationships are identical (i.e., the collapse problem). One route out of this difficulty is to embrace a form of spatial holism, or monism, such that the parts (points) of space are no longer viewed as independent elements that directly form or construct the whole of space. Rather, the dependence relationship goes in the other direction, with the whole of space comprising the basic ontological entity and the parts as derived from, or supervening on, the whole; hence, each part upholds the PII, and the collapse problem is avoided. Nerlich, drawing on Healey (1995), ultimately favors this interpretation of Newton's spatial theory: "Assume that space is real, but it is not *made up* of its parts, nor yet *analyzable into* parts with any kind of ontic *independence*. Perhaps, even, that spatial parts and their relations are, ontologically, *supervenient* on the structure of space" (Nerlich 2005, 131).

In keeping with the PII, each part of space retains a unique identity, although it is now conceived as a supervenient feature of the whole of space. The collapse argument, in contrast, relies on the relations among the parts to determine each part's identity, thereby leading to the collapse of space into a

4. It is also interesting that the main published works that link the ontology of God and space do not appear until the General Scholium of the second edition of the *Principia* (1713), although this would seem consistent with Newton's general avoidance of God's role in his published natural philosophy before his later years (post-1700).

single part via the PII (because these mutual relations are identical for all parts/points). There are a number of ways to view the holistic nature of space, but some of the main contenders might be as follows: (i) invoke the supervenience of parts on the whole of space, which includes all structures in space and does not single out any one in particular; (ii) limit the supervenience to just the distance (metrical) relations, such that metric relations are primary, with the parts/points as derived; or claim (iii) that spatial relations are internal relations of each point and not external relations (although this last strategy might be deemed only indirectly holistic or structuralist).[5] On the holistic interpretation in general, it may be difficult to distinguish spatial parts, given the homogenous nature of infinite Euclidean space, but this is an empirical problem far removed from the troubling ontological worries associated with Huggett's reading of Aii, which apparently conceives of space as derived from a ground floor of points and "their metrical relations to one another" (2008, 397).[6] There are objections that might be raised against this interpretation that draw on the division of labor, topological and metrical, in modern differential geometry, but we will postpone that discussion until section 3.3.

This holistic strategy for interpreting Newton's Aii, which has been advanced by Howard Stein as well (e.g., 2002, 272), might also bear a rough resemblance with structuralist hypotheses in the philosophy of mathematics, as Healey's remarks in connection with Newton's immobility arguments would seem to imply: "It is its place in a certain relational structure that makes *p* the spacetime point that it is. In this respect spacetime points are analogous to mathematical objects. It is its position in the natural numbers which makes 3 the number that it is" (1995, 303).[7] In an ironic twist, the holistic conception

5. If one interprets our holistic maneuver as view ii, that metrical relations are primary, with the identity of points dependent on these relation, what then accounts for the identity of metrical relations? This new version of the collapse problem (for metric relations) fails, however: given any two metric relations among points, say g^1 and g^2, their identity will be secured via a larger metrical relation, g^3, which includes both g^1 and g^2 within its scope, and so on, for any extent of space (to infinity). Internal relations are employed in iii, where internal relations are sometimes described as the relational equivalent of an essential or monadic property: i.e., the relation, *R*, that a point, *p*, bears with another point, *q*, is viewed as an internal relation of *p*, if *p* bears *R* to *q* in all possible worlds. Unlike an external relation among points, therefore, an internal relation *R* incorporates the identity of the point *p* and thereby does not violate the PII and is not subject to the collapse argument (a strategy suggested by a referee). Since iii refers to individual points and their properties, it exhibits a somewhat nonholistic appearance, but it leads to the same interconnected holism of space as in i and ii. A further investigation of strategies i, ii, and iii, and all of the other possible constructions, is clearly required, but it will not be undertaken in this article.

6. Some material thing would seem to be required to serve as a coordinating basis to resolve these epistemological worries. Moreover, references to the "whole" of space include, unless otherwise noted, all structures in space along with lesser (non-three-) dimensional structures and the $\mathfrak{R}^3$ point manifold.

7. In correspondence, Nick Huggett has pointed out that a more adequate analogy would be to a set with the ordinal properties of the integers alone, without labels (such as 3), since every member of this set

of space that both Healey and Nerlich posit can be best described using the neo-Platonic terminology employed by More and Newton, namely, that space—including the metric (which is roughly akin to Newton's order of position of spatial parts)—is one, simple, and indiscerpible. Although Healey, Nerlich, and Stein do not provide any historical support for their interpretations, the discussions above do indeed confirm a conception of Newton's spatial theory that is consistent with a holistic/monistic interpretation of the parts of space—an interpretation, moreover, that has much in common with the philosophy underlying contemporary space-time structuralism and the sophisticated brands of both substantivalism and relationism (see sec. 4).

The intent of Aii, put simply, is to make the case that space is a nonaggregate, partless whole, such that the very individuality of its parts derives from the whole. The Aii argument, hence, provides a more detailed elaboration for why the motion of the parts of space, critiqued initially in Ai, is not possible. In a previously quoted passage from TeL, space's nonaggregate structure—as single and simple—is defended using the same arguments, in the Ai and Aii vein, about the immobility of spatial parts:

> But neither does Place argue the divisibility of a thing or the multitude of its parts, … since space itself has no parts which can be separated from one another, or be moved among themselves, or be distinguished from one another by any inherent marks. Space is not compounded of aggregated parts since there is no least in it, no small or great or greatest, nor are there more parts in the totality of space than there are in any place which the very least body of all occupies. In each of its points it is like itself and uniform nor does it truly have parts other than mathematical points, that is, everywhere infinite in number and nothing in magnitude. For it is a single being, most simple, and most perfect in its kind. To be bounded in time and in place, or to be changeable does argue imperfection, but to be the same always and everywhere is supreme perfection. (McGuire 1978, 117)

Newton asserts that space only has parts in the sense of "mathematical points, that is, everywhere infinite in number and nothing in magnitude" and adds that "nor are there more parts in the totality of space than there are in any place which the very least body of all occupies." In other words, his conception

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bears the same relation to some other member, such that this relationship is preserved under the mapping. Furthermore, the comparison with structuralism in the philosophy of mathematics should not be exaggerated since the modern approach is based on modern mathematical techniques and formalisms and is thus far removed from the structuralist holism of Newton's classical geometric conception.

of the part-whole constitution of space follows what we may call the classical or Aristotelian-Euclidean view of geometry, wherein a line of any length can be conceptually decomposed into an infinity of points, although the line itself is not actually constructed by a process of adding points (since they have no magnitude). This aspect of Newton's theory clearly has holistic overtones, but the truly nonreducible character of the spatial metric, and its relationship with Aii, will only become evident provided further analysis.

3.3. The Order of Position of Spatial Parts

Despite its later origins, the classical geometric inclinations in *De grav*, *Principia*, and TeL can be traced back to one of Newton's earliest investigations, namely, the Trinity notebooks from 1664 to 1665 (*Questiones*). The similarities with these later writings can be described, roughly, as pertaining to the individuation of points and the continuity of space, two aspects of Newton's treatment that are intimately linked to the question of the holistic, or simple, nature of space.

In the *Metaphysics* V.6.1016b24–27, Aristotle (1984, 1605) explains what may be the principal idea underlying Newton's Aii: "that which is indivisible in quantity is called a unit if it is not divisible in any dimension and is without position, a point if it is not divisible in any dimension, and has position." In short, points are without dimension but (unlike units/numbers) have a position. As McGuire and Tamny clarify, in the Aristotelian-Euclidean tradition, "the point itself lacks existence independent of the line, but it can be distinguished by its position relative to another point, or with respect to the line itself" (1983, 62). The motivation behind the use of position as a means of identification likely resides in the unique difficulties associated with points and the definition of continuity (see, e.g., *Physics* VI.1.231a21–231b18). Since points are "partless," points cannot touch without completely overlapping, or, put differently, if two points were in contact they would then possess common extremities, but two points that possess common extremities are continuous and one since they occupy the same place. This interrelationship between place and continuity is echoed in Newton's *Questiones*: "Extension is related to places, as time to days, years, etc. Place is the *principium individuationis* of straight lines and of equal and like figures; the surfaces of two bodies becoming but one when they are contiguous, because in but one place" (McGuire and Tamny 1983, 351). Likewise, "if you say then that [a point] might touch one of the other points that makes the line, I say then that that point is in the same place with the point that it touches" (421). As in Aii, the geometric elements themselves are individuated via the overall spatial backdrop (places, order of spatial parts) since the peculiar character of geometric elements on the

Aristotelian-Euclidean scheme renders them incapable of securing their own individuation (due to the continuity problem). Needless to say, this form of reasoning undermines any attempt to construct the metric of space from the relationships among independently established parts—indeed, if the actual identity of the parts is dependent on the whole of space, which includes its metric, then Nerlich's claim that the parts supervene on the overall structure of space would appear to be vindicated.

In response, the critic might argue that Newton's appeal to place as a means of individuating geometrical elements only commits him to the weaker (topological) notions of coincidence/noncoincidence and not a metric, the latter being approximate to "order of spatial parts." Newton's explanation that "extension is related to places, as time to days, years, etc." would seem to undermine this line of reasoning, nevertheless. Since a day or year is a part of duration in the sense that it has a particular finite duration, it follows that place is likewise a part of extension in that it possesses a particular finite extension—hence, it is very difficult to tie Newton's use of "place" exclusively to a nonmetrical, topological conception. This last inference is, in addition, supported by arguments put forth in the Leibniz-Clarke correspondence, where space and time are categorized as "quantities, which situation and order [are] not" (Leibniz and Clarke 2000, 72; C.V.54). Clarke continues: "the distance, interval, or quantity of time or space … is entirely a distinct thing from the situation or order and does not constitute any quantity of situation of order; the situation or order may be the same when the quantity of time or space intervening is very different" (73). Situation and order are likened to ratios and proportions, which "are not quantities but the proportion of quantities" (73). Clarke's explanation nicely demonstrates that the Newtonian worldview presumes, at the least, the metric (distance) as a basic quantitative feature of space, and this, of course, imparts a metrical significance to all of its constitutive parts, whether points, lines, surfaces, or volumes. The scholium on space and time raises the same issue in a passage we shall label C:

> [C] Place is the part of space that a body occupies, and it is, depending on the space, either absolute or relative. I say the part of space, not the situation [*situs*] of the body or its outer surface. For the places of equal solids are always equal, while their surfaces are for the most part unequal because of the dissimilarity of shapes; and situations, properly speaking, do not have quantity and are not so much places as attributes of places [*quam affectiones locorum*]. (Newton 2004, 65)

As with Clarke's description, situations "properly speaking" do not have a quantity, unlike space/places. Indeed, situation is an attribute of the quantity place and hence space, given the oneness of space discussed above. Since Newton specifically mentions "the situation of the body or its outer surface," it would seem that, like Clarke, his goal in C is to criticize the general relationist idea that place is determined by the mutual situations of bodies, as well as the Scholastic/Cartesian idea that place is the boundary of the contained/containing bodies (Descartes 1991, 45–46; *Principles*, II §13–15). Moreover, as Rynasiewicz has noted, Newton's explanation that "the places of equal solids are always equal, while their surfaces are for the most part unequal because of the dissimilarity of shapes" is a reference to the inherent volume of place (as opposed to the surface area of the body's boundary or the nonquantity order/situation of bodies), and volume is a metric measure (1995, 141). Thus, when C is added to the holistic, simple characterization of space in the *De grav*, TeL, and so on, above, the basic metrical nature of space, as a quantity with the attribute of order/situation, becomes readily apparent.

Before leaving this section, it would be fruitful to examine a passage from *De grav* that demonstrates Newton's adherence to the Aristotelian-Euclidean conception of the continuity of geometry/space and that also highlights the relationship between parts and points:

> In all directions, space can be distinguished into parts whose common boundaries we usually call surfaces; and these surfaces can be distinguished in all directions into parts whose common boundaries we usually call lines; and again these lines can be distinguished in all directions into parts which we call points. And hence surfaces do not have depth, nor lines breadth, nor points dimension, unless you say that coterminous spaces penetrate each other as far as the depth of the surface between them, namely what I have said to be the boundary of both or the common limit; and the same applies to lines and points. Furthermore, spaces are everywhere contiguous to spaces, and extension is everywhere placed next to extension, and so there are everywhere common boundaries of contiguous parts. (2004, 22)

This explanation nicely relates both the geometrical nature of Newton's ontology of space and its composition: points, lines, surfaces, and thus volumes are all elements of Newton's one, simple, and indiscerpible space (much as TeL describes space's parts as "mathematical points"). Indeed, lines are the "common boundaries" of surfaces, and points the common boundaries of lines: contra the collapse argument, points are not freestanding or independent geometric entities that form relations (distance) among other independent points, such that those relations supervene on the points. If supervenience is involved, it is points that supervene on lines, and lines on surfaces, and so on, which is in keeping with the holism examined above. This realization thereby undermines any attempt to foist the distinctions of modern differential geometry on Newton's conception of space since the clear division between a topological manifold and an overlaying metric in the modern theory finds scant support in Newton's classical approach. It might be objected that the holistic supervenience ontology examined above is unintuitive in some fashion, for instance, in that it fails to conform to our experience since parts do retain their identity apart from the whole. While the philosophical basis of the holistic interpretation is indeed a difficult topic, it must be conceded that the ontology of all spatial theories suffers from a similar defect but in different ways. For example, as regards the layered ontology of structures just mentioned in differential geometry, it is hard to grasp the reality of a bare topological point manifold bereft of metric structure, or a finite space, and so on, so it is difficult to gauge their relative coherence as a result. More, Newton, and Clarke, it should be recalled, used a reductio argument on the counterintuitive notion of separating the parts of space as a means of proving their holistic thesis.

3.4. Least Distance

The inference that space has an essential metric structure is corroborated elsewhere in the Trinity notebook, where Newton explores, and ultimately rejects, the possibility that spatial lengths may be composed, bottom up, from a least unit of distance linked to the topology of its constitutive mathematical points. The main goal of these investigations seems to be the Epicurean atomist idea that there exists a minimal indivisible quantity of matter, such that the minimal distances become "the basis of all other extensions and the mould of atoms" (McGuire and Tamny 1983, 423). Newton employs a cipher method of marking off the points on a line, with the stipulation that the ciphers "resist being the same" (421), that is, they retain a power of noncoincidence (cf. Huggett 2008, 398). The collection of ciphers thereby represents the units of least distances among the points, *partes extra partes*, along the line. Given a point, if "there be another point with which it refuses to be joined, … then there is distance between the two, though indivisible, and the least that can be" (McGuire and Tamny 1983, 423). Newton's assumption that these least distances are indivisible nevertheless runs into the obvious difficulty that, at least conceptually, "the least extension is infinitely larger than a point and therefore can contain it and be divided by it" (425). This prompts the reply, "I confess it is so," along with an abortive effort to insist that, although a least distance "has no inside, no midst, nor center," it therefore must be the case that the infinite number of points in that least extension "must be all in the borders or sides and outward superficies of it, and that cannot make out a place for division" (425). For our purposes, the important development is that Newton crossed out these notebook pages, that is, the pages that elaborate his least distance thought experiment, likely due to the untenability of his defense of its indivisibility.

Another difficulty with Newton's least distance hypothesis, which may have contributed to its abrupt demise, is the inevitable implication that there must exist a direct correlation between the length of a line (figure) and the likely finite number of its constitutive points. Central to Newton's hypothesis, of course, is the notion that the points "are imbued with such a power as that they could not touch or be in one place," which leads to the following conclusion: "add these [points] as close in a line as they can stand together. *Every point added* must make *some extension* to the length, because it cannot sink into the former's place or touch it" (McGuire and Tamny 1983, 343; emphasis added). This inference not only contradicts other sections of the notebooks (e.g., "points added between points infinitely are equivalent to a finite line"; 345), but it is clearly alien to the Aristotelian-Euclidean direction that Newton's mathematical thought would increasingly take after 1665. Recalling Newton's claims, in TeL, that "space is not compounded of aggregated parts" and his denial that there are "more parts in the totality of space than there are in any place," space would thus seem to have acquired its simple, holistic quality fairly early since his nonsimple, nonholistic conception of an atomic least distance is absent from all later works subsequent to these (deleted) pages from the Trinity notebook.[8] In short, given his failure to construct a metric from a topology of points (which possess an elemental power of "nonconjunction"), and since his geometrical elements are individuated by a metrically influenced concept (e.g., *Questiones*, 351), it is thus not surprising that his later use of the order of position/situation of spatial parts, in Aii and B, is similarly imbued with a metrical significance.[9]

8. Koslow (1976, 254) and McGuire (1982) attempt to make a case for a least spatial unit in Newton's post-*Questiones* natural philosophy or that Newton's spatial ontology at least does not countenance dimensionless points. But, the passage quoted from TeL above (McGuire 1978, 117) utterly refutes these readings (and McGuire, in fact, rejects the least distance interpretation in an endnote added later to his essay; 1982, 185).

9. McGuire and Tamny also foreshadow the collapse problem when they comment, on the *De grav*'s Aii, that "positions are positions of parts, and they depend for their character on the parts themselves," but the infinity of space necessitates that "one position, any one, be nameable independent of the others," which "cannot be done" (1983, 72). As with later commentators, however, McGuire and Tamny err by overlooking the oneness of space: to claim that the positions of parts "depend for their character on the parts themselves" is to ask for a criterion of their individuality separate from the whole, which conflicts with Newton's many nonreductive, holistic claims—e.g., "nor are there more parts in the totality of space than there are in any place which the very least body of all occupies" (McGuire 1978, 117). How does one make sense of this passage on McGuire and Tamny's suggestion?

4. Contemporary Space-Time Debates and the Immobility Arguments

To briefly summarize section 3, we have seen that Newton posits a holistic notion of space, such that the identity of the parts supervenes on the whole, thereby avoiding the collapse problem. This conclusion is supported not only by an analysis of his writings on the oneness and simplicity of space that are directly linked to, and the basis of, the immobility arguments themselves (esp. McGuire 1978, 117) but likewise as regards his abandonment of the nonholistic least distance hypothesis in the Trinity notebooks. In the remaining sections, we will continue our examination of the more prominent contemporary research that is pertinent not only for understanding Newton but increasingly as regards its relevance for current debates on the ontology and structure of space and space-time.

4.1. Transformations

Returning to the *De grav* version of the immobility arguments, Torretti has proposed that Aii can be interpreted as providing a criterion of the identity of points "but only up to isomorphism" (i.e., a structure-preserving one-to-one mapping; 1999, 55): "Newtonian—that is, Euclidean—space admits an infinity of distinct internal isomorphisms. … In particular, if we designate one of these copies be *E* and we represent by the vector **v** a translation of each point of *E* in the direction of **v** by a distance equal to **v**'s length, then … the translation *t***v** yields the successive positions of a frame *E***v** moving through *E* with a constant velocity **v**" (56). Torretti draws the conclusion that, on the basis of this reading of Aii, "all inertial frames are equivalent" (56) and hints that this Newton-inspired approach can also help to resolve Einstein's "hole" argument: that is, the hole argument "forgets the fact, so clearly set forth by Newton, that points in a structured manifold have no individuality apart from their structural relations" (297). While Torretti is correct in his overall holistic conclusions as regards the lack of primitive identity for Newton's points, the implications that he draws for other aspects of Newton's ontology of space are much more suspect. Nerlich rightly criticizes Torretti's analysis as inconsistent with the last sentence of B, which posits motionless absolute places, such that "changes of position from these places … are absolute motions" (2005, 129). To be specific, while Newton's *Principia* draws a distinction between absolute and relative space (with the latter being inertially related copies of absolute space), the true rest frame of the material world is absolute space, and thus not all inertial frames are ontologically equivalent (more on this below).

Yet, it is more instructive to examine Torretti's reading against the backdrop of the *De grav*'s immobility arguments, since he employs these passages to support his interpretation, and not the *Principia*'s B. While not a mathematical mapping of the parts of space per se, Ai does offer two reasons for rejecting the idea that spatial parts can move. First, Newton suggests that the motion of a part of space might be "a translation from the vicinity of other contiguous parts, as Descartes defined the motion of bodies, and it has been sufficiently demonstrated that this is absurd" (2004, 25). In a preceding section of *De grav*, Newton rejects Descartes' definition of motion as change of external place, with external place being the boundary between the contained and the containing bodies (Descartes 1991, 51; *Principles*, II §25). Newton reasons that "after the completion of some motion the position of the surrounding bodies no longer stays the same" (2004, 19) since these contiguous plenum bodies must fill in the vacancy left after the body moves, and this eliminates the original material boundary, external place, required to determine the motion. Newton's accusation of absurdity in Ai would therefore seem to be based on a similar premise that the motion of a part of space/extension would bring about a corresponding reshuffling of the remaining parts, such that the motion of the part would likewise be indeterminate. Accordingly, it hard to grasp how this peculiar plenum model of the motion of the parts through space, along with all of its strange consequences, could qualify as the equivalent of a modern mathematical transformation.

This last point is evident in the second Ai criticism of the idea that spatial parts can move: "or … it is a translation out of space into space, that is out of itself, unless perhaps it is said that two spaces everywhere coincide, a moving one and a motionless one." We have already examined the alleged contradiction in claiming that space can move "out of itself" (see sec. 3.1). In the second half of this sentence, the phrase "unless perhaps it is said" apparently signifies that it is an exception to the idea that the part moves "out of space into space," and this is consistent with the remainder of the sentence: that is, Newton imagines that the so-called moving part does not actually leave its space but merely occupies two spaces simultaneously, the original motionless space and a moving space that "everywhere coincide[s]" with it. If this interpretation is correct, then this brief aside likely constitutes the closest approximation to a geometric transformation concept in Newton's spatial theorizing and demonstrates that he, at least temporarily, entertained the idea of multiple spaces. Yet, the type of transformation envisaged is not an active transformation, "a one-one mapping of spacetime onto itself" (labeled a "point transformation"; Torretti 1999, 263), since this implies a mapping "out of space into space," which Newton rejects. Nerlich also finds Torretti's exegeses a violation of the "out of space into space" prohibition (2005, 128), but Nerlich fails to take the transformation analogy a bit further. The mapping that best correlates with Newton's Ai explanation would more likely fall under a passive (or coordinate) transformation, where the geometric objects remain fixed under a substitution of coordinates—in the Ai case, it would be a transformation of a coordinate frame x at a point p to another coordinate frame y also at p, where y is related to x by a velocity boost $\mathbf{v}$, rather than as an active mapping h from p to its image under the mapping, hp (see, e.g., Friedman 1983, 51–53; Torretti 1999, 263–64). Consequently, if any proposed resolutions of Einstein's hole argument were to necessitate an active (point) transformation, as Torretti seemingly maintains (297), then his citing Newton's Ai as a historical precedent falls wide of the mark.[10]

To recap, it is important to bear in mind that Newton provides a fairly body-centered exegesis of absolute and relative place/space in the scholium: "relative space is any movable measure or dimension of … absolute space; such a measure or dimension is determined by our senses from the situation [*situm*] of the space with respect to bodies and is popularly used for immovable space" (2004, 64). This type of description could be seen as upholding a form of coordinate transformation, and it would naturally align with Corollary 5 of the *Principia*, that is, the principle of Galilean relativity. Nevertheless, it is not a transformation of the sort expressed in passage Aii from the *De grav*, wherein the transformation only involves the parts of space and is conceived metaphysically or conceptually. Rather, since the *Principia*'s Galilean transformations are defined using bodies (64–67), it follows that these active transformations operate at the purely phenomenal level, such that one, and only one, of the potentially infinite set of the transformations corresponds to Newton's immobile absolute place/space. The reading that Torretti favors, consequently, does not capture the intended meaning of Newton's Aii, which concerns the metaphysics of the parts of space and not the symmetries of material inertial systems.[11]

10. Then again, if the hole argument is conceived employing a passive (coordinate) transformation, as merely alternative representations of the same reality (whereas the active reading describes a troubling physical underdeterminism), then maybe Newton's Ai can indeed be seen as resolving this issue: i.e., different coordinate mappings of the same reality do not pose any epistemological or ontological mysteries, being trivial redescriptions. For a modern interpretation of Einstein's hole argument for space-time theories, see Earman and Norton (1987).

11. Different interpretations of Aii can be found in Huggett's *de re* representation account (2008, 400) and R. DiSalle's reading (1994, 267), although they have consequences similar to Torretti's approach. In particular, the respective appraisals of both Huggett and DiSalle lead to the conclusion that the material world could not have a different position or velocity in absolute space (called Leibniz shifts). Yet, as Huggett himself correctly remarks (2008, 404–5), Clarke admits that Leibniz shifts are distinct possible states of the world (Leibniz and Clarke 2000, 66–68; C.V.1–20), a stance that Newton apparently found unobjectionable in his review of the Leibniz-Clarke correspondence for Des Maizeaux (see Koyré and Cohen 1962). Indeed, one of the main goals of the scholium is to demonstrate

4.2. Conclusion: Modern Space-Time Comparisons

As a means of wrapping up our analysis, it would be useful to briefly contrast Newton's views on space, in their ontological and holistic aspects, with analogous debates in the contemporary philosophy of space-time, in particular, as regards the three main contenders: substantivalism, relationism, and structural realism. While the details will be explored in more depth below, the most basic distinction among these ontologies is that, unlike substantivalism, both relationism and structural realism reject the existence of space (space-time) in the absence of physical objects or fields. Furthermore, it is important to recall that analogues of the collapse argument can be advanced against these modern ontologies if they invoke a structuralist conception of parts similar to Newton's (as will be discussed below).

Overall, a plausible case can be made that many of the current crop of space-time theories, whether sophisticated substantivalism, sophisticated relationism, or structural realism, are consistent with the broad outlines of Newton's Aii conception. First, these theories all embrace Newton's holism by emphasizing the crucial role of the metric (approximate to Newton's "order of position of spatial parts") in securing the identity of the points of the manifold: to be precise, whereas manifold substantivalism accepts the primitive identity of manifold points (e.g., Field 1980), structural realism, sophisticated relationism, and sophisticated substantivalism all reject this primitive identity and instead strive to place both metrical and topological structure on at least an even footing. Indeed, the holistic/monistic character of space-time structure is a recurrent theme in many of these recent interpretations of classical gravitation theories, such as Newtonian theory or general relativity (GR), or other field theories, like quantum field theory (see, e.g., Auyang [1995] and the other references below). Second, in the context of GR, the rationale for claiming that these modern ontologies are consistent with Newton's theory is that all three predicate their holistic space-time structure on a pregiven "entity" of sorts, namely, the metric field (or metric plus manifold, the latter without primitive identity of points, of course).[12] In particular, the sophisticated substantivalist deems the metric field to be a unique substance, dubbed "space-time," that can nonetheless interact with other fields (e.g., Hoefer 1996); the sophisticated, nonreductive relationist

that "absolute and relative rest and motion are distinguished from each other" (Newton 2004, 66). It is thus not surprising that Huggett finds the demise of Leibniz shifts to be a major obstacle for his *de re* representation account (at least as regards Newton's own conception).

12. In what follows, similar conclusions can be reached for quantum gravity hypotheses, although a full discussion would introduce further complexities that exceed the bounds of this article. Hence, our analysis will remain confined to GR.

hypotheses view the metric, through its tie to the gravitational field connection,[13] to be just another material field (e.g., Rovelli 1997); and the structural realist judges the metric to be a unique physical field that is a kind of hybrid of the relationist's material field and the substantivalist's space-time (e.g., Dorato 2000).[14]

As discussed in section 3.1, Newton likewise predicates space on a unique entity: God "is everywhere present; and by existing always and everywhere, he constitutes duration and space" (2004, 91). So, given that both Newton and these modern ontologies invoke a holistic entity that undergirds spatial (spatio-temporal) properties (God or metric field, respectively), which is not merely mathematically/logically but substantivally/physically/(supernaturally) holistic, it follows that the collapse argument simply begs the question since its mathematical/logical machinery is being applied to a domain that is, by stipulation, already holistic in the substantival/physical/(supernatural) sense. Put differently, the collapse argument needs to rely on something like the following premise in order to gain purchase: the properties of the parts of a whole (here, identity) need to be fixed before examining the properties of the larger whole. But, the nonlocal nature of GR's metric and other physical fields (and possibly theological entities) would seem to stand as a direct counterexample to this line of reasoning, so why should a structuralist accept the collapse arguments basic premise? Finally, an additional consequence of this grounding issue is that, like Newton's theory, all three of our modern space-time ontologies allow vacuum solutions since the metric never vanishes in GR, even in a space empty of matter (more generally, stress energy), and this is quite unlike the more traditional nonsophisticated, nonmetric field relationism. However, while Newton's God is both extended and present in space, and can act on matter, God is beyond a reciprocal influence in the same way that matter (stress energy) acts on the metric, and thus there is a dissimilarity in the case of GR between Newton and these modern holistic space-time ontologies.

13. Throughout our discussion, all references to GR's metric incorporate its unique relationship with the gravitational field, via the Christoffel symbols of the metric. As Cao explains, "although the spatiotemporal relations are constituted by the chrono-geometrical structure (the metric), the latter itself is constituted, or ontologically supported, by the inertio-gravitational field (the connection)" (2006, 45).

14. The difference among these approaches is a difficult subject that is outside the scope of this article. However, there may be a merely conventional difference among these ontological positions since they all accept that (*a*) the metric provides the spatiotemporal individuation of the manifold points and for all other objects/fields and that (*b*) it is a dynamical field that affects, and is affected by, other objects/fields. In league with Dorato and many others, however, a structural realist ontology seems more apt since *a* is more on the substantival side, whereas *b* is more on the relational side, and so GR's metric does indeed seem to be a unique combination of traditional substantivalism and relationism.

As regards specific examples, there are a host of recent structuralist discussions that can be viewed as following the outlines of Newton's Aii argument. Cao's structuralism "takes the metric and connection as holistic structures that enjoy ontological priority over their components" and thus "takes the ultimate reality of spacetime as being field-theoretical in nature" (2006, 46; see n. 13). Stachel's structuralism draws on a distinction between quiddity, which refers to natural kind classifications, and haecceity, which pertains to individuality or "primitive thisness": "The points of spacetime [in GR] have quiddity as such, but only gain haecceity (to the extent that they do) from the properties they inherit from the metrical or other physical relations imposed on them. In particular, the points can obtain haecceity from the inertio-gravitational field associated with the metric tensor: For example, the four non-vanishing invariants of the Riemann tensor in an empty spacetime can be used to individuate these points in the generic case" (2006, 57). Among the sophisticated substantivalists, Hoefer likewise concludes that "the focus of [his] view is on the metric tensor as the real representor of space-time" (1996, 24). The emergence of a holistic interpretation might be detected in the work of Tim Maudlin, furthermore, especially if his earlier "metric essentialism" thesis—that the "parts of space bear their metrical relations essentially" (1988, 86; put forward in the context of Aii)—is regarded as akin to an internal relation of each point (see strategy iii in sec. 3.2 and n. 5). Yet, leaving aside the issue of the relationship between holism and internal relations, because Maudlin apparently relies on the standard separation of manifold and metric structures employed by differential geometry, metric essentialism likely amounts to a bottom-up approach, from points to the whole of space. The essential metrical qualities of the parts of Newton's space are secured by its oneness and simplicity, however, in a top-down fashion that is likely the converse of metric essentialism's scheme. Accordingly, Maudlin's later espousal of a fiber bundle formalism as a means of characterizing spatial length, wherein the base space of points is closely linked to the fibers and other higher structures, would seem to more accurately capture the spirit of Newton's spatial holism (see, also, the quotient space fiber bundle formulation in Stachel [2002], 234–35).

On Maudlin's assessment of fiber bundles, path lengths in space are primary, with the external relationship between points as derived (2007, 87). Since "all points related by distance to one another must be parts of a single, common, connected space" (89), fiber bundles could thus be seen as a contemporary analogue of Newton's holistic "points as boundaries" conception. Indeed, Maudlin refers to the ontology implicit in his account of fiber bundles as "Spinozistic" (102), which demonstrates its close allegiance to the holistic/monistic account of spatial geometry advanced in this article. Nevertheless, Auyang's more detailed investigation reveals that substantivalist and structuralist conceptions can be discerned among competing fiber bundles interpretations as well. If one takes a bottom-up stance, viewing the base space as the foundation on which all other structures are set up, then a fiber bundle version of manifold substantivalism can be defended. The top-down, structuralist approach, in contrast, is the proper holistic fiber bundle equivalent of Newton's conception. On this top-down view, the base space is "neither a substratum nor an entity that can stand on its own. Rather, it is an arching structure of the physical gauge field as a whole" (Auyang 2000, 492). This form of top-down structuralist strategy, whether for fiber bundles or other structures, would thus seem ideally suited for defeating the modern versions of the collapse problem (e.g., Wüthrich 2009), for the identity of the parts is determined by the whole physical field. That is, one's ontology need not posit an autonomous identity for the constituent points of a physical field before ascertaining the larger, global properties of that physical field—this is the general assumption, once again, that underlies the collapse argument's would-be trap of the unsuspecting structuralist. Rather, as in the case of Newton explored in section 3.2, the whole field comes before its supervening points.

Naturally, various components within Newton's theory of space would not be congenial to these modern holistic schemes, especially given the contemporary theoretical context. We have already touched on a few, namely, the lack of a reciprocal influence between matter and Newton's space-instantiating entity, God, which is unlike the relationship between matter (stress energy) and GR's space-instantiating entity, the metric/gravitational field. This difference is, of course, symptomatic of Newton's static conception of physical geometry, as opposed to GR's dynamic standpoint, but the philosophical basis of the former likely stems from the intersection of Newton's beliefs concerning theology and geometry. Much like the unchanging circular motions that comprised ancient celestial hypotheses, Newton's God-grounded ontology of space illuminates the infinite, unchanging nature of his spatial geometry. In the passage from TeL quoted in section 3.1, which refers to space but could equally describe his theology, he states: "to be changeable does argue imperfection, but to be the same always and everywhere is supreme perfection" (McGuire 1978, 117). Therefore, the metric properties of Newton's space can never change, a realization that calls into question the alternative, dynamic scenarios of his spatial metric envisaged by both Nerlich (2005, 131) and Huggett (2008, 403). And, just as God is really extended in space, so geometry is really in space. The structure of physical space is, in fact, practically equated with Euclidean geometry, as the last quote's ensuing discussion reveals: "For the delineation of any material figure is not a new production of that figure with respect to space, but only a corporeal representation of it, so that what was formerly insensible in space now appears before the senses. … We firmly believe that the space was spherical before the sphere occupied it, so that it could contain the sphere; and hence as there are everywhere spaces that can adequately contain any material sphere, it is clear that space is everywhere spherical. And so of other figures" (Newton 2004, 22).

By reckoning that bodies merely reveal the geometric forms that are really present in space, Newton's mathematical conception of space is thus not a mere metaphorical flourish but is quite literal. So, while it is true that many of the modern structuralist ontologies also draw inspiration from a realism about mathematical structures, they would almost certainly recoil from embracing the sort of quasi-Platonism central to Newton's spatial geometry; that is, since space would apparently lack existence absent Newton's instantiating entity, God, space does not qualify as Platonist in the full sense (see Slowik 2005, 2009). Unlike the contemporary space-time scene, moreover, Newton's Euclidean realism about spatial geometry benefits from the absence of an underdetermination of alternative geometric formalisms (twistors, Einstein algebras, etc.) or alternative physical constructions (à la Poincaré) that complicate the modern picture. As explained above, the *De grav*'s Aii is not a seventeenth-century analogue of a transformation argument, nor is the clean delineation of geometric structures (metric, manifold, affine, etc.) employed by modern differential geometry a part of Newton's brand of Euclidean realism.

In conclusion, the classical holistic conception of geometry implicit in Newton's ontology of space has long been a neglected aspect of his natural philosophy. This oversight might be rooted, at least for philosophers of physics, in the standard conception of differential geometry often used to interpret past spatial theories—a geometric scheme that employs a seemingly self-sufficient topological manifold on which higher structures are placed (e.g., the tensors on manifold method that has been the basis of philosophical reconstructions for the past half century and more). Given the problems that such a layered approach can engender (e.g., the collapse problem, as well as the hole arguments), there has been a growing awareness of the philosophical benefits that can be obtained either from a more holistic interpretation of these standard methods (e.g., sophisticated substantivalism, sophisticated relationism, structural realism) or for adopting different geometric techniques that more naturally lend themselves to a holistic interpretation (e.g., fiber bundles). That the modern "holistic turn" in physical geometry has a rough counterpart in the seventeenth century's classical geometric outlook is, therefore, both a topic ripe for further investigation and a cautionary tale of the potential historical bias that our modern methodologies can unwittingly impose.

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