The Dynamical Approach as Practical Geometry

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This article introduces Harvey Brown and Oliver Pooley's 'dynamical approach' to special relativity, and argues that it may be construed as a relationalist form of Einstein's 'practical geometry'. This construal of the dynamical approach is shown to be compatible with related chapters of Brown's text and also with recent descriptions of the dynamical approach by Pooley and others.

1. An Introduction to the Dynamical Approach. In *Physical Relativity*, Harvey Brown (2005) promotes an unorthodox interpretation of special relativity, which shall be referred to here as the 'dynamical approach'.[1] In brief, the dynamical approach argues for the priority of dynamics over geometry in the context of explanation. Relativistic kinematical phenomena such as length contraction and time dilation, along with inertial motion and even Minkowski geometrical structure, are to be explained by the fact that the dynamical laws governing the behavior of material objects are Lorentz covariant.[2]

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1. In an earlier collaboration with Pooley (Brown and Pooley 2001), the dynamical approach was introduced as 'the truncated Lorentzian pedagogy'. This and their later collaboration (Brown and Pooley 2006) are subsumed in Brown (2005).

2. See Brown (2005, vii–viii, 24–25, chap. 8). Note that Brown and Pooley (2006, 82) distinguish the dynamical approach from a 'fully constructive' theory, which would offer explanations that appeal to the complete details, rather than to merely the symmetries, of the dynamical laws. They also distinguish it from a neo-Lorentzian approach, which would advocate the existence of a preferred frame (Brown and Pooley 2001, 257).

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In addition to these explanatory claims, it has been pointed out by others that if the symmetries of the dynamical laws are to somehow explain Minkowski geometry, then there is also an implicit ontological claim being made. Indeed, this ontological claim is evident in the title of Brown's collaboration with Oliver Pooley: "Minkowski Space-Time, a Glorious Non-entity" (Brown and Pooley 2006). That is, while the primary focus of Brown's work is not the ontological status of space-time, the dynamical approach to relativity is most naturally construed as a form of relationalism, according to which space-time does not exist primitively. Otherwise, it could not be said that the symmetries of the dynamical laws somehow account for its geometrical structure.[3]

More importantly, it should also be pointed out that this explanatory claim comes with an implicit *ideological* claim: that material objects' primitive properties do not constitute a Minkowskian geometrical structure.[4] For instance, according to the dynamical approach, material objects cannot stand, primitively, in the same chronometric relations that they would if existing in substantival Minkowski space-time. Otherwise, it could not be said that the symmetries of the dynamical laws somehow account for the material world's Minkowskian geometrical structure. Rather, the latter would be constituted by the fundamental entities' primitive chronometric relations; the fundamental entities would instantiate Minkowski geometry on their own. This would not do for the dynamical approach, which describes Minkowskian geometrical structure as "parasitic on the relativistic properties of the dynamical matter fields" and as "no more than a codification of the behavior of rods and clocks" (Brown 2005, 9, 100).[5]

Thus, of the explanatory claims listed above, the idea that dynamics explains geometry is what first associates the dynamical approach with relationalism, and it is also what illustrates the difference between the dynamical approach and a more 'traditional' relationalist approach: in the latter, the material world's spatiotemporal geometry is constituted by material objects'

3. As mentioned below, Pooley describes the dynamical approach as a form of relationalism in later work (Pooley 2013, sec. 6.3.2). However, the dynamical approach is actually compatible with a form of substantivalism according to which space-time has less geometrical structure than that which best codifies the behavior of material objects. This is addressed further in n. 20.

4. Following Quine (1951), the ontology lists the entities to whose existence the theory is committed, and the ideology lists those entities' primitive properties or relations.

5. See also Brown (2005, chap. 8, esp. 142–43). Note that Brown is not idealizing rods and clocks as privileged entities in the way Einstein (1905) did and later regretted (Einstein 1949, 59–61). (See Einstein [1952] for an English translation of Einstein [1905]. Other English translations are provided by Stachel [1998, 123–60] and Miller [1981, 392–415].) Rather, Brown (2005, 4) understands rods and clocks to be atomic (or field) configurations governed by Lorentz-covariant dynamical laws.

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primitive properties; in the former, it supervenes on the symmetries of the dynamical laws.[6]

2. Ideological Relationalism and the Constructive Project. The dynamical approach has received a number of responses in the literature. For the most part, these have focused on the explanatory claims mentioned above,[7] while less attention has been given to the implicit ontological claim mentioned above.[8] Insofar as the two can be decoupled, this essay will focus primarily on the latter, with an emphasis on the aforementioned ideological claim.

The question at hand is this: if Minkowskian geometrical structure is to supervene on the behavior of material objects that act in accord with Lorentz-covariant dynamical laws, then in what kind of primitive spatiotemporal relations could those material objects stand, or what kind of primitive spatiotemporal structure could they instantiate? From just the brief description above, it should be clear that chronometric 'interval' relations cannot feature in the list of material objects' primitive properties (i.e., in the 'ideology'). Instead, the dynamical approach must be what might be called an ontologically and ideologically relationalist approach to Minkowski geometry. Like a traditional relationalist approach, it must provide a material ontology that excludes Minkowski space-time. But unlike other traditional relationalist approaches, it must also provide a spatiotemporally scant ideology, the spatiotemporal components of which do not constitute Minkowski geometry. Then, with respect to some such metaphysics, it must be shown that Minkowski geometry is derivative of facts about the symmetries of the dynamical laws.

This ideologically relationalist aspect of the dynamical approach is what has led some to refer to it as 'constructive relativity'. In recent work, John Norton describes the 'constructivist project' as the task of inferring Minkowski geometry "from the properties of matter without recourse to spatiotemporal presumptions or with few of them" (2008, 821). The key word here is "few," for the explanatory claims of the dynamical approach certainly do not require that all geometrical structures or concepts supervene on the symmetries of the dynamical laws. As Pooley has recently noted, "the project was to reduce chronogeometric facts to symmetries, not to recover the entire spatiotemporal nature of the world from no spatiotemporal assumptions whatsoever" (2013, 573). Hence, what the constructivist proj-

6. The viability of such a 'traditional' relationalist approach to Minkowski space-time structure is explored by Earman (1989, sec. 6.10), Maudlin (1993, sec. 5), and Pooley (2013, sec. 6.1). Pooley goes into further detail elsewhere (Pooley 2002).

7. Many of these (among others) also focus on Einstein's claims about the difference in explanatory power of 'principle' and 'constructive' theories.

8. The implicit ontological claim is acknowledged by Huggett (2009) and Pooley (2013). It is emphasized by Nerlich (2013, chap. 5) and especially by Norton (2008).

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ect actually involves is the specification of some primitive spatiotemporal structure that, while not constituting Minkowski geometry itself, could somehow support the use of Lorentz-covariant laws in systematizing material objects' degrees of freedom. This would seem to require that the dynamical laws be written in terms of more geometrical structure than is ascribed primitively to the material world, and it will be argued below that this commitment gives the dynamical approach a unique position in the empiricist–conventionalist spectrum of traditional approaches to geometrical structure.

To begin, Einstein's well-known contrast between 'pure' and 'practical' geometry is outlined in section 3. It is then argued in section 4 that the dynamical approach is best understood as a form of practical geometry, according to which Minkowski geometry supervenes on the behavior of rods and clocks. Finally, in section 5 this construal of the dynamical approach is shown to be consistent with relevant sections of Brown's book.

3. Einstein's 1921 *Geometrie und Erfahrung*. The idea that space-time geometry is an empirical issue, and that it should therefore be described as a branch of physics, was popularized by Einstein in a lecture before the Prussian Academy of Sciences, which was published under the title *Geometrie und Erfahrung* in the same year (Einstein 1921).[9] In the opening paragraphs, Einstein makes an important distinction between what he calls 'pure' or 'axiomatic' geometry and 'practical' geometry.[10] The former is Einstein's name for the formal, axiomatic mathematics itself, which consists of primitive terms that are defined implicitly by the axioms they satisfy:[11] "[Pure] geometry treats of objects which are denoted by the words straight line, point, etc. No knowledge or intuition of these objects is assumed, but only the validity of the axioms, . . . which are to be taken in a purely formal sense, i.e. as void of all content of intuition or experience" (Einstein 1954, 234). On this view, pure geometry can make no empirical claims. Instead, its value lies in the certainty of its mathematical claims.

Practical geometry, on the other hand, is what results from making some coordination between material objects and the primitive terms of pure geometry. With some such coordination in place, the logical deductions of pure geometry can be translated into hypotheses about the behavior of material objects. In this way, space-time geometry becomes a branch of physics:

9. All quotations and page numbers are taken from the English translation (Einstein 1954).

10. Einstein makes the same distinction elsewhere (Einstein 1925). Carl Hempel (1945) also gives a similar introduction. Note that some authors call the former 'mathematical' geometry and the latter 'physical', 'applied', or 'empirical' geometry.

11. It should be noted that this understanding of geometry comes originally from David Hilbert (1971).

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> It is clear that the system of concepts of axiomatic geometry alone cannot make any assertions as to the behavior of real objects of this kind, which we will call practically-rigid bodies. To be able to make such assertions, geometry must be stripped of its merely logical-formal character by the coordination of real objects of experience with the empty conceptual schema of axiomatic geometry. To accomplish this, we need only add the proposition: solid bodies are related, with respect to their possible dispositions, as are bodies in Euclidean geometry of three dimensions. Then the propositions of Euclid contain affirmations as to the behavior of practically-rigid bodies. . . . The question whether the practical geometry of the universe is Euclidean or not has a clear meaning, and its answer can only be furnished by experience. (Einstein 1954, 234–35)

However, the price of some such coordination is that the certainty of pure geometry is lost in the applied, practical geometry; the same experience that provides answers to the question of the material world's geometrical structure is also what spoils the purity of those answers, hence Einstein's claim that "as far as the propositions of mathematics refer to reality, they are not certain; and as far as they are certain, they do not refer to reality" (233).

Now, Einstein's purposes in making the distinction are clear: it comes as part of his response to a certain epistemological question about geometry—namely, the question of whether geometry can provide us with synthetic a priori knowledge. At the time of Einstein's writing, advocates of the neo-Kantian tradition held that it could, and Einstein's response has typically been taken as illustrating his ties with logical positivism. For until some coordinations are made between the pure geometrical primitives and the material world, 'pure' geometry itself provides no information about the material world.[12]

Whatever Einstein's position on the epistemic question, he has emphasized more than once that without this conception of geometry, he could not have developed general relativity (Einstein 1954, 235).[13] But the fact that Einstein found it so useful does not make it uncontroversial. Later in the same article, Einstein goes on to introduce a rival, conventionalist view of geometry, which is best known by its promotion in the work of Henri Poincaré (1898, 1905/1952, chap. 5). In short, Poincaré rejects the coordination of pure geometry's primitive terms with material objects, and his reasons are clear: Einstein's coordination involves rigid bodies, of which there are none. Any potential candidates—Einstein refers to "measuring lines, measuring wands, etc." as examples (1954, 234)—are subject to conditions like temperature and pressure, to a degree that would be specified by a theory of matter. What's more, Poincaré argues that even when those influences are accounted

12. Friedman (2002), Giovanelli (2013), and Howard (2014) discuss this further.

13. See also the references provided by Friedman (2002, 207ff.).

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for by a matter theory, any talk of rigidity would be made in relation to some geometry, meaning that a geometrical structure would have been assumed already. As Einstein explains, Poincaré's denial of the necessary coordination eliminates the possibility of 'practical' geometry at all and leads to the view that space-time geometry is not an empirical issue but a conventional one (236ff.). And were the choice up to him, Poincaré would prefer to use Euclidean geometry over anything more complicated or unfamiliar.

4. Practical, Supervenient Geometry. We now return to the question of where the dynamical approach could fit into the empiricist–conventionalist divide. While the preceding section provides nothing near a comprehensive overview of the perspectives in the empiricist–conventionalist spectrum, the two views introduced above will be used as familiar examples.

To begin, it should be pointed out that if emphasis is placed on the explanatory claims of the dynamical approach, then one might be led to think that Brown is advocating empiricism. Along these lines, Bradford Skow shows us how far the comparison could be taken:

> Maybe Brown thinks that the symmetries of the laws explain why spacetime has the structure it does because the spacetime metric is somehow analyzed in terms of the laws. In several places his discussion suggests that, on his view, a field only gets to be the *metric* field when the dynamics prescribe that material bodies behave in the right sort of way with respect to it (see, for example, pages 100 and 160). Compare this to a Reichenbachian view according to which distance between points of space is analyzed in terms of the behavior of measuring rods—though Brown rejects this view (23), his view does seem to resemble it: both of them make spacetime geometry an extrinsic matter. (Brown's apparent denial that spacetime geometry is "self-standing" and "autonomous" looks like a denial that it is intrinsic (143).) (2006, 4)

As Skow notes, Brown seems to reject the 'practical geometry' approach in its strongest form, according to which the existence of practically rigid bodies paves the way for the world's primitive geometry to be determined empirically. After all, Brown is careful to treat rods and clocks as complex entities governed by dynamics, and not as privileged entities that could play a role in the coordination process outlined above.[14] Indeed, given Brown's emphasis on Einstein's misgivings about privileging rods and clocks in the development of special (and general) relativity, his work might even be taken as supportive of Poincaré's conventionalism—but for the fact that Brown is arguing for Minkowskian rather than Euclidean geometry, and speaks freely about the symmetries of dynamical laws without assuming some geometrical structure first.

14. See earlier comments in n. 6.

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Thus, Brown's work cannot easily be read as a support of either 'ism' outlined in section 3, nor should it. The strict empiricist perspective would not support the explanatory claim in which symmetries of the dynamical laws account for Minkowski geometry, but only that those symmetries can reveal to us the world's primitive spatiotemporal structure. Already it has been explained that the dynamical approach is not compatible with an ideology in which Minkowski geometrical structure is taken as primitive. On the other hand, Poincaré's conventionalist approach would require an argument in favor of Minkowski geometry on the basis of its simplicity relative to other geometrical structures. And even if such an argument could be made, it would get us nowhere in accounting for that geometry by appealing to the symmetries of dynamical laws. Instead, the dynamical approach seems to land somewhere in between: rigid bodies are not taken as privileged entities, and yet the behavior of material bodies plays a substantive role in arriving at some particular geometrical structure. Furthermore, a crucial difference between the dynamical approach and Einstein's practical geometry is that the former's arrow of explanation from dynamics to geometry would require that the geometrical structure determined by the methods of 'practical geometry' should not be taken as a primitive feature of the world, but as somehow supervening on the behavior of material objects themselves.

To see how such a project might succeed, recall from above (sec. 2) that the dynamical approach is not prohibited from assuming some kind of submetrical spatiotemporal structure, so long as the full structure of Minkowski space-time is still somehow picked out by the symmetries of the dynamical laws. Although the technical details of such an approach are beyond the scope of this paper, the general scheme could be completed as follows. First, take a certain Humean conception of natural laws, according to which regularities in the 'Humean mosaic' may be described with the aid of more geometrical structure than is actually present in the mosaic.[15] If, for a particular Humean mosaic, the best-systems dynamical laws are in fact written in terms of some such supplementary geometrical structure, then that structure would supervene on the symmetries of the dynamical laws. To put it in other words, a material system with submetrical spatiotemporal structure could always be labeled by sets of coordinates that are related to one another by transformations corresponding to the symmetry group of a richer geometrical structure. And if some such set of coordinatizations is the one with respect to which the best-systems dynamical laws are written, then that set is used in determining the mosaic's supervenient geometrical structure.

15. This 'liberalized' Humean conception of dynamical laws is introduced by Huggett (2006).

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In this way, a world in which rigid bodies clearly do not exist (e.g., a world with primitive topological or differentiable structure) is still a world in which the methods of Einstein's practical geometry can be applied. In the process, the dynamical approach's arrow of explanation from dynamics to geometry is vindicated: the primitive spatiotemporal structure of the material world is submetrical, while Minkowski geometry supervenes on the symmetries of the best-system dynamical laws.

5. Brown's Coordinatization Project. In the opening of the second chapter of *Physical Relativity*, Brown raises a question that occupies his attention for the remainder of that section: "It is common in discussions of the principle of general covariance in Einstein's general theory of relativity to find the claim that coordinates assigned to events are merely labels. . . . Before we consider labeling them, what *physically* distinguishes two different events of exactly the same kind?" (2005, 11). Brown's response reveals that he has in mind an ontology and ideology consisting of physical fields with some kind of submetrical structure.

Brown begins his response by casting doubt on the existence of points of substantival space-time. He reviews Robert Geroch's (1978) distinction between a localized 'material event'—like a firecracker or finger snapping, and which Brown calls a physical 'marker'—and the point of space-time at which the event is taken to occur in a substantivalist perspective. Whereas Geroch was allegedly hesitant to make a distinction between the 'point' and its 'marker', Brown is clear in stating that he does not distinguish the two at all. That is, Brown is not interested in the relationships between points of space-time, but rather in the relationships between their markers. Thus, an ontological relationalism is suggested, even if it is not crucial to Brown's thesis.[16] And in the place of substantival space-time points, Brown suggests a fundamental ontology of 'markers' (material events) that comprise coincident values of physical fields.[17]

Then, Brown's ideology is revealed by his approach to distinguishing such material events for the purposes of coordinatization.[18] As Brown (2005, 13) explains, there will surely exist various types of material events that are intrinsically indiscernible. And at this point, Brown finds himself in a more difficult situation than the traditional relationalist. If Brown were to admit Minkowski intervals as primitive relations between material events, then indistinguishable material events would not be an issue for any but the most unrealistically homogeneous or symmetric universes. Rather, the

16. See nn. 3 and 20.

17. See Brown (2005, 13). This is consistent with what Brown has written elsewhere (Brown 1997, 68).

18. In what follows, I refer to markers as 'material events'.

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possible coordinatizations would be fixed by the requirement that they respect the structural properties that supervene on the field values' spatiotemporal relations. But so far, Brown has only admitted material events, and in order to justify any particular choice of coordinatization, he must begin to build up an appropriately rich spatiotemporal ideology without undermining the goal of accounting for metrical structure in terms of the symmetries of dynamical laws.

Toward that end, Brown argues that each individual material event stands in a unique relationship to the universe as a whole. That is, material events "have different coordinates because they are distinct, and they are distinct not in virtue of what they are *locally* but in virtue of the fact *that they stand in different relations to the rest of the universe*—to the rest of the markers" (Brown 2005, 14). Of course, Brown's description is easy enough to understand when the world is taken to have some kind of Riemannian, pseudometrical structure. But what sense can be made of it if some such structure cannot be assumed, so that it remains to be accounted for by the symmetries of the dynamical laws? Granted, questions of this sort are not Brown's primary focus, but it is clear that Brown must be assuming at least some kind of primitive ordering or arrangement to the world's material events. Indeed, it is as if Brown's material events have all the submetrical continuity structure of a differentiable manifold, but not any metrical structure. Thus, it would be fair to say that Brown's fundamental metaphysics seems to be a collection of material events with some particular *topological*, or perhaps even *differentiable*, structure.[19]

From this we see that Pooley's reminder above (sec. 2) is apt: the dynamical approach to special relativity need not account for all geometrical structure by an appeal to the symmetries of the dynamical laws, and indeed Brown seems to have had in mind a primitive submetrical structure all along. The dynamical approach's arrow of explanation from dynamics to geometry can then be understood along the lines above: as an application of Einstein's practical geometry to a topological (or differentiable) space of field values, which finds Minkowski geometry to supervene on the symmetries of the best-system dynamical laws.

6. Conclusions. In the sections above, it has been argued that the dynamical approach to special relativity involves explicit explanatory claims—as well as implicit ontological and ideological claims—that give it a unique position in the spectrum of traditional approaches to space-time geometry. The explanatory, ontological, and ideological claims can be satisfied when a primitive submetrical structure is ascribed to material bodies in such a

19. In fact, Norton cites personal correspondence with Brown that supports this (Norton 2008, 829).

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way that, given the range of coordinatizations respecting that submetrical structure, the coordinizations in terms of which are written the best-system dynamical laws are related to one another by elements of the Poincaré group.[20]

In fact, this form of practical geometry has appeared in recent commentaries on Brown's work. For example, Norton (2008, 833) suggests that an advocate of the dynamical approach might take a topologically structured space-time as primitive, although no comments are made as to whether that topological structure could instead be assigned to the material objects themselves. A similar suggestion has also been made by Huggett (2009, 418) and even more recently by Pooley (2013, sec. 6.3.2). The common idea is that the constructivist project can be carried out by considering a material world with submetrical spatiotemporal structure and allowing the best-systems dynamical laws to be written in terms of some geometrical structure that supervenes on those laws' being best. This is, effectively, an application of Einstein's 'practical geometry' in which the dynamical approach's arrow of explanation is satisfied.[21]

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20. Following on from n. 3, the dynamical approach would also be compatible with a form of ontological substantivalism, according to which there exists a substantival space-time manifold with submetrical structure, from which the inhabiting material objects inherit their own. Minkowski geometry could still supervene along the lines above. Some of Brown's claims about geometry appear open to interpretation along these lines (Brown 2005, 9, 100, 133, 142), although there is nothing to suggest that Brown actually has this in mind.

21. Despite the fact that Brown sometimes quotes Robert DiSalle's work approvingly, the interpretation of the dynamical approach presented here should not be confused with the approach to space-time theories promoted by DiSalle (1995), in which the author argues that space-time theory is a kind of 'practical geometry'.

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