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Chapter 5

Absolute Time versus Absolute Motion: Comments on Lawrence Sklar

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Three hundred years after the publication of Newton's Scholium on absolute space, time, and motion, the debate between absolutists and relationalists is as vigorous as ever. Earlier in this century it was widely held that Einstein's theory of relativity showed once and for all the falsity—if not the incoherence—of Newton's absolutist position. But much progress has been made since then. We now know that Einstein and other modern relationalists tended to conflate different senses of "absolute." Relativity theory teaches us that space, time, and motion are not absolute only for *some* senses of "absolute." Once the different senses have been carefully distinguished, it becomes clear that philosophically important versions of absolutism can survive the advent of relativity theory (although absolute space and absolute time must be traded in for absolute *space-time*).[1]

It is especially important to distinguish those senses of "absolute" that do and those that do not have ontological implications. *Ontological absolutism*—or *realism*—holds that space and time[2] are entities that exist over and above the objects and events of the material world. Reference to space and time is to be take literally. When one asserts that a material object occupies a part of space or endures through an interval of time, one asserts that a genuine relation holds between distinct entities, one material and one immaterial, not merely that some complex property applies to material things. Indeed part—or the whole—of space or time could exist even though no matter occupied that space or endured through that time. *Ontological relationalism*—or *representationalism*—by contrast, holds that space and time exist only as mathematical models or representations of the spatiotemporal properties and relations among material objects and events; if there were no matter, there would be no space or time. On this view, all reference to space and time is to be interpreted by way of complex structural properties of the material world. It is important to emphasize that the debate between realists and representational-

ists is over whether space and time have independent existence, not over whether spatiotemporal properties and relations are in some sense reducible to observable features of the world. The representationalist, as well as the realist, can allow unobservable spatiotemporal properties and relations among material objects and events.[3]

In "Real Quantities and Their Sensible Measures," Larry Sklar tries to uncover the competing intuitions that have fueled the realist-representationalist debate. He returns to Newton's Scholium, and claims that two rather different sorts of problem are being addressed. The *problem of absolute time* is concerned with the question of which material clocks, if any, provide an accurate measure of time, and how inaccurate clocks may be corrected. The *problem of absolute motion* is concerned with the question of which material objects are truly at rest, which in motion, and how the quantity and direction of such motion—and thus the object's space-time trajectory—can be determined. This latter problem may be divided (although Sklar does not do so) into two subproblems: the *problem of absolute velocity* and the *problem of absolute acceleration*. These problems are related as follows. Information about the absolute velocity of any object throughout an interval of time (magnitude *and direction*) completely determines[4] the object's space-time trajectory, and so provides all there is to know about its properties of absolute motion throughout that interval; information about the absolute acceleration of the object constrains, but does not completely determine, the object's space-time trajectory.[5] Newton notoriously failed to distinguish explicitly the problems of absolute velocity and absolute acceleration in the Scholium, but it will behoove us to do so in what follows.

Why does Sklar think it important to separate the problems of absolute time and absolute motion? There has been a tendency on both sides, he claims, to assume that arguments for or against realism with respect to one problem would apply *mutatis mutandis* to the other. But this, he thinks, may not be so. In particular, the realist arguments seem strongest when applied to the case of absolute motion—specifically absolute acceleration—but sound wrong or peculiar when applied to the case of absolute time; the representationalist arguments stand in the reverse relation. The reason for this, Sklar suggests, is that the inertial effects of absolute acceleration cry out for causal explanation, and such explanation, to be satisfying, will tend to invoke the reality of space and time, whereas the distinction between accurate and inaccurate clocks can be understood without invoking an immaterial entity, such as absolute time, as a causal agent.

In what follows I will argue that the distinctions Sklar draws do not

go very deep: they depend on the fact that absolute acceleration is, by definition, a property of material objects, whereas absolute time is not. If the problems of absolute time and absolute acceleration are characterized in a parallel fashion in terms of the temporal and motional properties of material objects and events, the distinctions Sklar draws tend to vanish. The realist can and should apply his arguments and intuitions equally to both problems; the representationalist can and should do the same. I thus conclude that Sklar's distinctions do not go to the heart of the realist-representationalist debate.

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I would like to begin by discussing Sklar's interpretation of Newton's Scholium.[6] According to Sklar, the tendency to treat the problems of absolute time and absolute motion alike, and the resulting peculiarities of language, originate with Newton himself. For example, by applying to the case of motion talk about sensible measures that is appropriate to the case of time, Newton is led to the peculiar assertion that relative motion provides a sensible measure of absolute motion. Conversely, by applying to the case of time talk about causes and effects that is appropriate to the case of motion, Newton (or his expounder) is led to peculiar assertions such as that the intervals of absolute time cause material clocks to tick the way they do. Although Newton may try to avoid saying some of these things, he is committed to them nonetheless. Or so Sklar claims.

I will argue that the first peculiarity having to do with sensible measures can be understood without supposing that Newton conflated the problems of absolute time and absolute motion. My main focus, however, will be the second sort of peculiarity having to do with causation. I will argue that it is not to be found in anything Newton said or would be led to say, and that Sklar's claim that Newton treats absolute time and absolute motion alike with respect to talk of causes and effects is ungrounded.

It is odd on the face of it to say that Newton treats alike the problems of absolute time and absolute motion. The Scholium begins by separately characterizing and illustrating, for each of the quantities time, space, place, and motion, the distinction between absolute and relative. It then contains a paragraph devoted exclusively to the problem of absolute time, the problem of how absolute time can be distinguished from relative time, and why such a distinction is necessary. It concludes with a lengthy discussion devoted exclusively to the problem of absolute motion with reference to the renowned rotating bucket and the revolving globes. Indeed the only place Newton treats

absolute time and absolute motion together is in the summarizing paragraph quoted by Sklar at the beginning of his paper (and in the Scholium's introductory remarks). However, in that paragraph, it is true, the relative quantities are all treated alike in at least one respect—namely, that they are all sensible measures, accurate or inaccurate, of the real quantities, from which it follows in particular that relative motion is a sensible measure, accurate or inaccurate, of absolute motion.[7]

Why does this claim sound peculiar? Newton could have said: relative motion is some measure of motion relative to a body assumed to be at rest; it is an accurate measure of absolute motion when the reference body is at rest in absolute space, otherwise inaccurate. Given Newton's assumptions, this definition of when the measure is accurate or inaccurate is perfectly meaningful. The problem, I take it, is that it is not possible, even in principle, to determine whether the measure is accurate or inaccurate because it is not possible to determine whether the reference body is at rest in absolute space. In Newtonian mechanics one can measure the absolute *acceleration* of the body by measuring the forces acting on it;[8] but one cannot infer the absolute *velocity* of the body, which might have any value whatsoever. Thus the accuracy of the measure cannot, even in principle, be established.

On this account Newton's statement is peculiar because the relation between relative motion and absolute motion is too weak. If a sensible measure is to count as a measure *of* some quantity, there must be an appropriate connection between the sensible measure and the quantity to be measured, some lawlike or causal connection that allows one to infer the real quantity from the observations of measurement (perhaps together with other observations). For example, within Newtonian mechanics the solar day provides a sensible measure, albeit inaccurate, of absolute time because the laws of celestial mechanics determine the length of the solar day as a function of time, which then allows the true elapsed time to be calculated from the sun's apparent location by way of the inverse function. Relative motion, by contrast, does not provide a sensible measure of absolute motion within Newtonian mechanics, accurate or inaccurate, because there is no lawlike connection that would allow one to infer the quantity of absolute motion from observations of relative motion, even together with observations of forces.

Might not, however, the notion of being a sensible measure of a quantity be susceptible of a weaker interpretation, one that allows a weaker connection between the measure and the measured quantity?

On this interpretation the measure must provide *some* information about the quantity being measured, or a component of the quantity, but it need not be possible to infer everything about the quantity from the measurement data. I want to suggest that Newton may simply have had this weaker interpretation in mind. This is confirmed by Newton's final illustration: the case of the two globes surrounded by bodies whose position is fixed relative to one another (p. 12). Newton uses this case to illustrate how relative motion can provide a measure of absolute motion. He argues that the state of absolute circular motion of the fixed bodies—both its quantity and its direction—can be determined by measuring the bodies' circular motion relative to the two globes, whose state of absolute circular motion has been determined by measuring the tension in the connecting cord. Newton clearly considers this a case of measuring absolute motion, even though it is only absolute *circular* motion that is measured—that is, absolute acceleration but not absolute velocity. This suggests that Newton has the weaker interpretation of "sensible measure" in mind. Perhaps his claim would sound less peculiar if explicitly qualified: relative motion (in conjuction with forces) provides a sensible measure of *some* kinds of absolute motion—namely, circular motion or accelerated motion.[9] In any case, the peculiarity in Newton's language, if there is any, would not result, as Sklar suggests, from a conflation of the problems of absolute time and absolute motion.

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Let us turn now to the second sort of peculiarity having to do with causal attributions. According to Sklar, Newton treats absolute time and absolute motion alike with respect to questions of causation: in both cases, they are inferred by some sort of causal inference from observable phenomena, and thus both absolute time and absolute motion are, in some sense, causes that have material effects. This dual treatment will compel Newton to say not only sensible things, such as that absolute motion causes inertial forces, but also peculiar things, such as that the intervals of absolute time cause clocks to tick the way they do.

But on what grounds does Sklar claim that Newton treats absolute time and absolute motion alike with respect to causation? The discussion of causes and effects in the Scholium is devoted entirely to absolute motion; one searches in vain for any passage in which Newton speaks of the causes or effects of absolute time. Yet, according to Sklar, Newton holds across the board that "the real quantities are

known to us only by their causes and effects, that is, by causal inference from the behavior of the sensible measures which are available to our sensory inspection." In fact, Newton never talks about the causes and effects of any real quantity other than absolute motion.

With respect to absolute space, Newton explicitly asserts that it cannot be known by its causes and effects. He twice emphasizes in the Scholium that the parts of absolute space "by no means come under the observation of our senses" (p. 12).[10] I thus find it doubtful that any of Newton's arguments in the Scholium can be interpreted as involving a "causal inference" to the existence of absolute space, as Sklar seems to think. Newton's inference to absolute space appears to be much less direct, perhaps by way of the assumption that absolute motion entails absolute space, perhaps by way of more general theoretical considerations of the sort Sklar mentions toward the end of his paper. In any case, realism about space and time is presupposed in the Scholium, not argued for directly.[11] Newton's arguments in the Scholium are primarily concerned with questions of reducibility and observational distinguishability. Can an object's absolute spatiotemporal properties be defined in terms of its sensible relations to other objects? If not, how can its absolute spatiotemporal properties be distinguished observationally from those properties that are merely relative? As I mentioned at the beginning of this paper, these questions are independent of the ontological debate; or at least the connection requires argument and cannot be taken for granted.

Thus I cannot agree with Sklar's claim that, with respect to causation, Newton treats all the real quantities, and in particular absolute time and absolute motion, alike. Indeed the basis on which Newton treats the various quantities differently with respect to causation is not, I think, far to seek. It has to do with a fundamental difference in the way these quantities are initially characterized. Absolute space and absolute time are entities that exist independently of material objects and events; not so for absolute motion. Absolute motion is defined by Newton as "the translation *of a body* from one absolute place to another" (p. 7, my emphasis). It is thus a *property* or *state* of material objects; if there were no material objects, there would be no motion.[12] Thus, the fact that Newton speaks about the causes and effects of absolute motion, but not of absolute space and time, can be understood on the following simple hypothesis: Material objects, their properties and states stand in causal relations; space and time, which are immaterial entities, do not. What makes Sklar's causal statements about absolute time peculiar is that they violate this natural precept. Newton would certainly reject them.

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There is a sense, however, in which Newton can and would treat absolute time and absolute motion alike with respect to causation. This sense emerges if, in comparing causal statements about absolute motion with causal statements about absolute time, we make sure to compare like with like—something Sklar fails to do. As I have just noted, Newton's statements about the effects of absolute motion are always about the absolute motion *of some material object or system*; for example, the absolute motion *of the water* causes the surface to go concave. If Newton were to treat absolute time analogously to absolute motion in this respect, this would require him to attribute material effects not to the intervals of absolute time itself (as Sklar would have it), but rather to the duration of material events and processes; and causal statements of this sort are by no means peculiar. For example, the telephone's ringing for thirty seconds caused my answering machine to pick up; or, my watch's running slow caused me to miss the meeting. It is statements of this sort that are analogous to the causal statements Newton cites about absolute motion, not statements claiming that the intervals of absolute time cause material clocks to tick the way they do. In sum, we can say that material objects or events have causal powers by virtue of their motional *and temporal* properties without having to say that absolute time itself has material effects.

But is the case of temporal properties fully analogous to the case of states of motion? Newton argues not just that the absolute motion of objects has material effects, but that those effects can be used to distinguish an absolute from a purely relative motion. Can we also say that the absolute duration of events has effects that allow us to distinguish absolute from relative time? Indeed we can. For Newtonian mechanics allows us to distinguish by the measure of centrifugal forces not only the state of absolute rotation from absolute nonrotation but also the state of absolute *uniform* rotation from absolute nonuniform rotation. Now, suppose we have an object in some state of absolute rotation. Any such object is a clock that ticks off one unit of time for each complete rotation. Whether or not such a clock keeps absolute time can be determined by examining the causes and effects of the ticking of the clock, just as whether a body is in absolute rotation can be determined by its causes and effects. Thus, absolute time and absolute motion can be treated alike with respect to causation; both the absolute uniform ticking of a clock and the absolute motion of an object can, at least sometimes, be determined by their causes and effects.

Absolute space, however, is different. The problem of absolute space, for Newton, is the problem of determining whether an object is in the same absolute place at two different times. Since this property of being in the same absolute place at different times has no material effects within Newtonian mechanics, it is not possible to distinguish absolute from relative space by examining causes and effects. This suggests that, at a deeper level, the problems that should be kept distinct are not, as Sklar claims, those of absolute time and absolute motion, but those of absolute time and absolute motion on the one hand, and that of absolute space on the other. Or, to be more exact, the problems of absolute time and absolute *acceleration* on the one hand, and absolute space and absolute *velocity* on the other. Properties of material objects and events involving absolute space and velocity are unobservable by any means; properties involving absolute time and acceleration are observable, at least indirectly, by means of forces and material clocks. This might explain why Newton twice emphasizes that absolute space is insensible and in no way comes under our observation, whereas he never asserts the same about absolute time or absolute motion. Am I here disagreeing with Sklar's claim that, according to Newton, *none* of the real quantities is "available to the senses"? Perhaps by "not available to the senses" Sklar means only "cannot be sensed without the mediation of material objects or events," in which case there is no disagreement. I am claiming that Newton may have meant something stronger than this when he asserted the insensibility of absolute space, something that does not apply across the board to all the absolute quantities.

Let us return to the peculiar causal statements about absolute time. I have argued that one can treat absolute time and absolute motion (that is, acceleration) alike with respect to causation, in both cases focusing on properties of material objects or events, without being committed to the peculiar statements in question. But what if we focus in both cases on the immaterial entities—space, time, or space-time? I claim that we can still treat absolute time and absolute motion alike with respect to causation. For the case of motion, we should ask about the effects of the four-dimensional affine structure of space-time, since it is the affine structure that determines which space-time trajectories are and are not absolutely accelerated. What corresponds to the peculiar statement that the intervals of absolute time cause clocks to tick uniformly is then not that the absolute motion of some material object causes certain inertial effects, but rather that the affine structure of absolute space-time causes material objects to move the way they do. And that latter statement sounds just as peculiar as the statement about intervals of absolute time. Newton can hold that

absolute space, time, and space-time play a role in causal explanations without taking them to be *causes* of material events. Thus, he might say that material objects and events have causal powers in virtue of occupying the regions of absolute space-time that they do. But causal powers need not ever be attributed to the regions of absolute space-time themselves.

I say "need not." In Einstein's general relativity absolute space-time becomes a dynamical object, and it becomes more natural to attribute causal powers to space-time itself. In general relativity it is common to say things like: Matter causes space to curve, which in turn causes matter to move as it does. But in Newtonian theory there can be no genuine interaction between matter and the structure of space because the structure of space is immutable; and that, I think, is why it sounds peculiar to attribute causal powers to absolute space itself. Thus we *need not* attribute causal powers to absolute space and time, and, within the context of Newtonian theory, if we do not want to sound peculiar, we *should not*. Moreover, if what I have said has been correct, Newton *did not* and *would not* attribute such powers to absolute space and time themselves.

v

Sklar's purpose in separating the problems of absolute time and absolute motion is not simply historical. He thinks it helps to shed light on the current debate as well. The case for realism is strongest when applied to the problem of absolute motion: "When we reflect on the water sloshing in the spinning bucket . . . we cannot believe that it isn't something real, say real timelike geodesics of a real space-time . . . which is *causally* responsible for the force." The problem of absolute time, however, supports representationalism, not realism: "But when we think about the variety of material clocks ticking away more or less uniformly relative to one another, the idea that there is a way of assigning numbers to pairs of events such that each such clock more or less accurately reveals that number seems to be the core of talking about time itself . . . There is no 'causal' explanation as to why clocks in general record time intervals more or less accurately." Sklar is reporting intuitions, not subjecting them to analysis. But I have doubts whether, even at the level of intuition, Sklar's contrast holds up under scrutiny. I will argue that the "realist" intuitions fostered by contemplating absolute motion are compatible with representationalism, and the "representationalist" intuitions fostered by contemplating absolute time are compatible with realism.

First, let us consider the problem of absolute motion. Let us grant

Sklar's assumption that the inertial forces generated by rotating buckets and the like demand *causal* explanation. When there is a "difference in the inertial forces felt by two test objects, [we] want to know why it is this one and not that one that feels the forces." Moreover, this requires positing some *cause* that makes the difference. Still, a causal explanation of the inertial forces might take any of three quite different forms:

(1) The inertial forces are caused by properties or states of motion of the objects in question, such as absolute acceleration. These properties are primitive, and do not entail the existence of immaterial entities: space, time, or space-time.
(2) The inertial forces are again caused by properties or states of motion of the objects in question, but the properties are not primitive. Objects have these properties by virtue of their relations to immaterial entities: space, time, or space-time. The immaterial entities are not themselves causes of the inertial forces, or of anything else.
(3) The inertial forces are directly caused by the action of an immaterial entity—space, time, or space-time—upon the material objects in question.

A representationalist who accepts the demand for causal explanation will offer an explanation of type (1); a realist will offer one of either type (2) or type (3). The difference between (2) and (3), I suspect, is mostly verbal; as I have noted, (3) sounds peculiar unless space-time is taken to be a dynamical object, but the ontological commitments will be the same either way. The realist rejects (1) on the grounds that positing primitive properties of absolute acceleration without positing absolute space and time, or space-time, is ad hoc, or unintelligible, or in some way theoretically unsatisfactory. The representationalist rejects (2) and (3) on the grounds that positing an immaterial space and time, or space-time, is otiose, or unintelligible, or in some other way objectionable. It is over grounds such as these that the battle between realists and representationalists will be fought. But both sides, it seems to me, can agree that rotating buckets and the like call for causal explanation. Why, then, does Sklar claim that the case of absolute motion supports realism over representationalism?

Sklar must think that a causal explanation of type (1) is for some reason ruled out for the representationalist. Perhaps he does not think the representationalist can help himself to a *primitive* property of absolute acceleration, and so lacks any means to explain the inertial forces. Thus Sklar writes at an earlier point: "It is hard to see how representationalism about absolute acceleration can be made compat-

ible with the view . . . that it is the absolute acceleration of the material object which is *causally responsible* for the generation of the inertial effects." But the representationalist, as far as I can see, need not reject absolute acceleration as a property possessed by material objects *over and above* the felt inertial forces: the representationalist *reinterprets* absolute acceleration in a way that avoids any commitment to a separate entity, space-time; he need not *eliminate* it in favor of the inertial forces. Thus, he is free to causally explain the inertial forces along the lines of (1). At any rate, it requires realist argumentation to see why such explanation is unsatisfactory, not merely the "realist" intuitions put forth by Sklar.[13]

What about the problem of absolute time? Sklar claims that "there is no 'causal' explanation as to why clocks in general record time intervals more or less accurately." But what can this mean? Certainly we would want to explain causally why some clock is inaccurate just as much as why some water is sloshing in a rotating bucket. For any mechanical clock, its accuracy or inaccuracy will be explained at least in part in terms of the inertial forces present, which in turn require the very same sort of causal explanation required in the case of absolute motion. So why should contemplating the problem of absolute motion lead to realism any more than contemplating the problem of absolute time?

Perhaps when Sklar says that the behavior of clocks does not require "causal" explanation, he means only that it does not require causal explanation of type (3), explanation that invokes absolute space, time, or space-time as a cause. This is confirmed by the fact that he uses "call for causal explanation" and "call for absolute time as a cause" interchangeably in the section under discussion. But both the realist and the representationalist can agree in rejecting explanations of type (3). Thus, the fact that the problem of absolute time does not call for explanations of this type cannot support representationalism over realism.

I suspect what has happened is that Sklar has ignored explanations of type (2), thus creating a false dilemma. He assumes here—as he did with Newton—that the realist will support his case by appealing to some sort of direct causal inference to the existence of space, time, or space-time. Then, since such an inference to absolute time as a cause of material events is especially implausible, he concludes that the case for realism is weak when applied to the problem of absolute time. But if the realist's inference to space, time, or space-time is less direct, if his causal explanations are of type (2), then he need not respond to the problem of absolute time as Sklar suggests. The realist need not choose between a representationalist view of time and the

view that absolute time somehow causes clocks to behave the they do. Sklar has posed a false dilemma.

In conclusion, the realist can consistently apply his intuition both the problem of absolute motion and the problem of abso time; the representationalist can consistently do the same. For reason I do not think the distinctions Sklar focuses upon go to heart of the debate between realism and representationalism.

Notes

1. For an untangling of some of the different senses of "absolute," and a rec defense of absolutism, see Michael Friedman, *Foundations of Space-Time Theo* (Princeton: Princeton University Press, 1983).
2. Or space-time. But for convenience I speak prerelativistically in what follo unless otherwise noted.
3. See Friedman, op. cit. pp. 217–223, for a more precise characterization of ontological debate in terms of the models of space-time theories.
4. Up to isometries of space and of time.
5. If one focuses instead on instantaneous states of motion, the relation chang neither absolute instantaneous velocity nor absolute instantaneous acceleratio suffices to determine the object's complete state of absolute motion at a tim higher-order derivatives are needed as well.
6. The Scholium on space, time, and motion occurs in the *Principia* just after the initi definitions and before the Axioms, or three laws of motion. Page references will b to Sir Isaac Newton, *Mathematical Principles of Natural Philosophy and His System of th World*, trans. Andrew Motte, rev. Florian Cajori (Berkeley: University of Californi Press, 1934).
7. Note that "more or less accurate" is Sklar's addition; Newton says "accurate o inaccurate" (p. 11).
8. Assuming, at any rate, that one can exclude the possibility of external forces, ar assumption Newton freely makes in the Scholium.
9. Related omissions of explicit qualifiers occur elsewhere in the Scholium. For ex- ample, Newton writes: "We may distinguish rest and motion, absolute and rela- tive, one from the other by their properties, causes, and effects" (p. 8). The force of this statement must be only that we may *in some cases* make the distinction, as Newton is well aware.
10. In his earlier unpublished work, "De Gravitatione et Aequipondio Fluidorum," Newton uses the causal inefficacy of absolute space as one of the chief features that distinguishes it from material substances (the other being immovability). Space is not "an entity that can act upon things" and is not capable of "exciting in the mind sensation or perception." (I owe this reference to Howard Stein.) See A. Rupert Hall and Marie Boas Hall, eds., *Unpublished Scientific Papers of Isaac Newton* (Cam- bridge: Cambridge University Press, 1962), pp. 121–156.
11. This view is cogently argued in Ronald Laymon, "Newton's Bucket Experiment," *Journal of the History of Philosophy* 16 (1978), 399–413. He summarizes: "It is not intended by Newton that these experiments [the rotating bucket and the two globes] have as their conclusions the existence of absolute space, since this exis- tence is already assumed by their explanation. The only support that these experi- ments give for the existence of absolute space is that they show that this concept

'does have some application and is part of a successful scientific theory" (pp. 410–411).

12. In this connection, note that prior to the Scholium Newton defines *quantity of motion* as mass times velocity—what we call momentum.
13. In *Space, Time, and Spacetime* (Berkeley: University of California Press, 1974), Sklar considers a view that posits a property of absolute acceleration without positing absolute space and time, or space-time. He denies that such a property can be used to *causally explain* the inertial forces, but no argument for this is given. See pp. 229–234.