Sklar's Maneuver*

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Abstract

Sklar ([1974]) claimed that relationalism about ontology—the doctrine that space and time do not exist—is compatible with Newtonian mechanics. To defend this claim he sketched a relationalist interpretation of Newtonian mechanics. In his interpretation, absolute acceleration is a fundamental, intrinsic property of material bodies; that a body undergoes absolute acceleration does not entail that space and time exist. But Sklar left his proposal as just a sketch; his defense of relationalism succeeds only if the sketch can be filled in. I argue that this cannot be done. There can be no (relationalist) dynamical laws of motion based on Sklar's proposal that capture the content of Newton's theory. So relationalists must look elsewhere for a relationalist interpretation of Newtonian mechanics.

1 Introduction

Distinguish relationalism about motion from relationism about ontology. According to relationalism about motion, all motion is the relative motion of bodies. According to relationalism about ontology, space and time do not exist. Substantivalism is the denial of relationalism about ontology.

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Unlike relationalism about ontology, relationalism about motion is not, on its face, an ontological doctrine. But many substantivalists and relationalists (about ontology) have thought that whether or not substantivalism is true depends on whether or not relationalism about motion is true. The standard argument for substantivalism contains, as a premise, the claim that relationalism about motion is false. The other premise is the claim that if relationalism about motion is false, then substantivalism is true. Newton gave a version of this argument in the *Principia* ([1999]).[1]

(At some points Newton appeals to his laws of motion in his defense of the first premise. Since we know that Newton's theory is false, at most Newton establishes that relationalism about ontology is incompatible with Newtonian mechanics.[2] Still, even though we know Newtonian mechanics is false, it is worth investigating whether relationalism about ontology is compatible with it: the question is interesting in its own right, and may shed light on whether relationalism about ontology is compatible with our current best theories.)

Sklar ([1974], pp. 229-34) disputes the second premise of the standard argument. Even if there are absolute states of motion—absolute states of acceleration, in particular—it does not follow, he claims, that space and time exist.[3] Relation-

[1] The exact form of Newton's argument is in dispute. According to the once-dominant interpretation, exemplified by Sklar ([1974], pp. 182-91), Newton argues that we must recognize a state of absolute motion in order to explain inertial effects. According to Rynasiewicz's more recent interpretation ([1995]), the existence of states of absolute motion was common ground between Newton and his relationalist opponents (principally Descartes); what Newton did was argue that absolute motion could not be defined in terms of relative motions. Rynasiewicz's defense of his interpretation is convincing. But on either interpretation, Newton argues that relationalism about motion is false.

[2] Of course, there are defenses of the first premise that appeal to more recent physical theories.

[3] Or, at least, this is the standard interpretation of Sklar's maneuver (see, for example, Earman [1989], p. 126). Most of Sklar's discussion supports this interpretation. For example, in one place he says that if we accept his view, 'we can have relationalism with absolute motion' ([1974], p. 231). That is, if we accept his view, then relationalism about ontology is true even though relationalism about motion is false.

But there is another interpretation of Sklar. On the same page I just quoted from alists should say that absolute acceleration is a fundamental, intrinsic property, not defined by reference to space and time.

Now, it is one thing to show that the falsehood of relationalism about motion does not *entail* substantivalism, and thereby show that the second premise of the standard argument is not a necessary truth. It is another thing to show that the second premise of the standard argument is false if Newton's dynamical theory is correct. To do that is to use Sklar's proposal to produce a relationalistically acceptable interpretation or reformulation of that theory. Sklar didn't propose a detailed theory, but many defenders of relationalism believe that such a theory can be developed. Belot ([unpublished]), for one, makes this claim, and Huggett ([1999]) describes what the models of such a theory should look like. Even John Earman, who doubts that Sklar's proposal can be turned into a detailed theory, thinks it blunts the force of the standard argument for substantivalism. That such a detailed theory can be developed is, he writes, 'at this juncture only a pious hope' (Earman [1989], p. 128)—but he does admit that there is hope.

I will argue that Sklar's proposal is a failure. There is no way to use Sklar's absolute accelerations to produce an adequate relationalist formulation of Newtonian gravitational theory. My argument, in outline, goes like this: an adequate formulation of Newton's theory will contain dynamical laws of motion with a well-

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he says he wants to reject 'the assumption that absolute motion is a *kind* of motion'. Instead of denying the second premise of the standard argument, he here appears to deny the first: he appears to say that the existence of absolute states of motion is compatible with relationalism about motion, since absolute states of motion are not kinds of motion.

On this second interpretation, the claim Sklar makes looks crazy. Isn't 'absolute motion is a kind of motion' analytic? But maybe Sklar just made a poor choice of name for his new basic intrinsic properties. Maybe we're supposed to think about his new properties the way we think about mass, or charge. To have a certain mass is not to be in any particular state of motion. But something's mass does have dynamical consequences. It does play a role in determining how that thing will move in the future.

It is a good question whether Sklar's primitive absolute accelerations deserve to be called 'states of motion', and if so, why. But nothing in the argument I give in this paper turns on the answers to these questions, so I will set them aside.

posed initial value problem. But even a relationalist who recognizes absolute accelerations in addition to interparticle distances and relative velocities cannot formulate such laws.

2 The Relationalist Initial Value Problem

There are two constraints an adequate relationalist formulation of Newtonian gravitational theory must meet: it must ‘capture the content’ of Newton’s theory, and it must have a well-posed initial value problem. In this section I describe and defend those constraints. I also explain why a ‘classically’ relationalist interpretation of Newton’s theory fails to meet those constraints. This will help set-up my argument that an interpretation based on Sklar’s proposal must also fail to meet them.

Roughly speaking, a relationalist theory captures the content of Newton’s theory just in case, for each model of Newton’s theory, there is a model of the relationalist theory to which it corresponds, and conversely.

What does ‘corresponds’ mean? To define it, I must first say something about the content of Newton’s theory. Newton’s theory tells us which histories of instantaneous states of the universe are physically possible, where (for Newton) an instantaneous state of the universe specifies the intrinsic properties of each material body and its position in space.[4] (Mass is the only relevant intrinsic property when gravity is the only force.) An adequate relationalist replacement for this theory won’t be in the business of giving us *that* kind of information, since it is partly information about space and time. Instead, it will be in the business of telling us which histories of relationalist instantaneous states are physically possible, where a relationalist instantaneous state specifies the intrinsic properties of each material body and the distance between each pair of bodies.[5]

To say when a relationalist and a Newtonian model correspond, I first de-

[4]From a spacetime point of view, Newton’s theory tell us, for each set of trajectories in Galilean spacetime, whether it is physically possible that some particles (with specified masses) follow those trajectories. But I will mostly take a ‘space + time’ point of view in this paper.

[5]Though see (Field [1989]) for arguments that one needs space even to define distances between material bodies.

fine ‘corresponds’ for instantaneous states: a Newtonian instantaneous state corresponds to a relationalist instantaneous state just in case they agree on the number of material bodies, on each body’s intrinsic properties, and on the distance between each pair of bodies. Then a relationalist and a Newtonian model correspond just in case they specify histories of corresponding instantaneous states. Since there are many Newtonian models that contain the same history of interparticle distances, this correspondence will be many-one.

I think it is obvious that a relationalist interpretation of Newton’s theory must meet this constraint. Meeting this constraint is part of what it is to be an *interpretation* of that theory.

Still, even in the context of classical mechanics, not all relationalists feel bound by this constraint. Recently, Julian Barbour ([1999]) has developed a replacement for (rather than an interpretation of) Newton’s theory that fails to meet this first constraint. (Pooley and Brown ([2002]) also defend this theory.) The theory is a replacement for Newton’s because it captures part, but not all, of the content of Newton’s theory: every one of its models corresponds to a Newtonian model, but not conversely.

At first, it may look like Barbour’s theory is irrelevant to the topic at hand. We want to know whether Newtonian mechanics and relationalism about ontology are compatable. What good is it to establish that some distinct theory (namely, Barbour’s) is compatable with relationalism about ontology?

But Barbour’s theory is relevant to the debate. Insofar as we want to know whether there is a relationalist interpretation of Newton’s theory, it is because we want to know whether the evidence available to Newton better supported substantivalism or relationalism, and we suppose that Newton’s physical theory is the theory that best fit his evidence. But (relationalists who defend Barbour’s theory contend) this last claim is false. And Barbour’s theory, which (they claim) better fits Newton’s evidence, is relationalistically acceptable.

I will have little to say in this paper about this strategy for defending relationalism in the context of classical mechanics. Let me just make two points. First, Sklar intended his theory to capture the entire content of Newton’s theory, and other relationalists still want a physical theory that does this, even given the availability of Barbour's theory. (Huggett [2006] is explicit about this.) It is worth exploring, therefore, whether such a theory exists. Second, I am interested in evaluating Sklar's proposal. And relationalists who do not feel bound by this first constraint will not be attracted to Sklar's proposal in the first place. If you abandon the first constraint, then Barbour's theory is much more appealing than Sklar's. That is, if there is no way to develop Sklar's proposal that satisfies the first constraint, then relationalists should consider Sklar's proposal a dead-end.

My second constraint is that a relationalist theory must have a well-posed initial value problem, in the following sense: the 'initial data', together with the theory's dynamical laws of motion, must determine the world's future evolution.

Why accept this second constraint? One defense appeals to scientific practice: (almost) all fundamental physical theories—including Newton's, the theory under discussion—take this form.[6] When physicists look for fundamental physical theories they are looking for theories that meet this constraint. For example, the physicist Julian Barbour, who is a relationalist for philosophical reasons, is explicit about seeking a relationalist replacement for Newton's theory that meets my second constraint ([1999], p. 76).

Another defense of the second constraint is more dialectical: a relationalist reformulation of Newton's theory that does not satisfy the second constraint is inferior to Newton's version. Because the relationalist theory is not deterministic and Newton's is, the relationalist theory lacks the predictive and explanatory power of Newton's theory. Proposing such a theory is not much of a defense of relationalism, then, if ordinary criteria for choosing scientific theories favor Newton's over the relationalist reformulation.

My second constraint is not much use until we specify what the relationalist initial data are. Usually we think that the possible initial data for a theory are just the possible instantaneous states of the world, according to that theory. But this is controversial. Newton's theory, for example, has a well-posed initial value

[6]Einstein's equation for general relativity doesn't look like a dynamical equation of motion, because it doesn't contain any time derivatives. But in well-behaved spacetimes the equation does determine the the values for the metric and stress-energy tensor throughout all of spacetime, given initial-data on a Cauchy surface.

problem. But the initial data include, in addition to each body's mass and position, its velocity. Some (like David Albert [2000], p. 17) deny that velocities are part of the instantaneous state of the world.

In light of this, we cannot just read off the initial data for a relationalist theory from that theory's characterization of the instantaneous states of the world. But it seems obvious—at first—what the relationalist initial data should be: they should include only each body's mass, the distance between each pair of bodies, and the rate at which those distances are changing. These are the 'classical' relationalist initial data.

It has been shown that these initial data are not enough to determine future evolution if a relationalist theory is to capture the content of Newton's theory.[7] Newton's theory permits distinct histories of interparticle distances that agree at a time on the distance between each pair of particles, and the rate at which those distances are changing. A relationalist theory that captures the content of Newton's theory must permit the corresponding histories of interparticle distances. But, again, these histories agree on the chosen initial data and disagree about future evolution.

What to do? Perhaps a relationalist could also include relative accelerations in his initial data—the rates at which the rates at which the interparticle distances are changing are changing. Few relationalists find this approach attractive.

3 Sklar's Maneuver

A theory based on Sklar's proposal adds facts about each body's state of absolute acceleration to the relationalist initial data. So, according to such a theory, the initial data (at a given time) are: (i) the distance between each pair of particles at that time; (ii) the rates at which those distances are changing; (iii) the intrinsic properties of each particle at that time, which now includes not just each particle's mass, but also its state of absolute acceleration. The hope is that with this richer set of initial data, Sklar's theory will succeed where classical relationalism failed.

[7] Barbour ([1999], p. 71) attributes to Poincaré the first careful treatment of this problem for relationalist theories.

One immediate objection to Sklar's proposal is that absolute accelerations are not relationalistically acceptable quantities. Absolute accelerations are the rates of change of absolute velocities (or, in Galilean spacetime, rates of change of 4-velocities); as reference to space and time appears in the definition of the latter, it also appears in the definition of the former.

Sklar denies that his absolute accelerations are defined as the rates of change of absolute velocities. He denies that they are defined in any way at all. He writes:

> Absolute acceleration is a property that a system has or does not have, *independently of the existence or state of anything else in the world.* Absolute acceleration is not a relation of a thing to some other material object, even the 'averaged-out mass of the universe'. It isn't a relation an object has to substantival space or spacetime itself, either. (Sklar [1974], p. 230)

So Sklar claims that the property of undergoing absolute acceleration is a fundamental intrinsic property—or, better, that for each direction and real number r, the property of accelerating in that direction at rate r is intrinsic. If these absolute acceleration properties are intrinsic, then they belong in the initial data just as much as bodies' masses do. (Unlike a body's mass, though, a body's absolute acceleration changes with time.)

Even though Sklar's intrinsic acceleration properties are not defined in the same way that absolute accelerations are defined in Newton's theory, the two kinds of acceleration are supposed to correspond. So for a model of Sklar's theory to correspond to a model of Newton's, it is not enough that they contain the same history of interparticle distances. They must also agree on the absolute acceleration of each particle at each time. As a result, Newtonian models that corresponded to the same relationalist model if masses are the only dynamically relevant intrinsic properties may in Sklar's theory correspond to distinct relationalist models. (I return to this point below.)

Philosophers have complained that it is mysterious how Sklar's intrinsic absolute accelerations are supposed to do their work (Earman ([1989], pp. 127-8) is one example). We know what the models of Sklar's theory look like, but what do the *dynamical laws* look like, that take this kind of initial data as input and give as output how the particles move in the future, as well as what each particle's absolute acceleration will be at later times? Sklar never wrote down any equations. Until we know just what Sklar's relationalist replacement for Newtonian gravitational theory looks like, we cannot evaluate whether it is a *better* theory than Newton's. So we should continue to be substantivalists until the details of Sklar's theory are filled in.

I claim that it is impossible to fill in these details in a way that meets the two constraints from section 2. Sklar's theory cannot be stated in the form of dynamical equations of motion with a well-posed initial value problem.

4 Sklar's Initial Value Problem is not Well-Posed

There are pairs of models of Newtonian gravitational theory in which, at some time, (i) the distances between corresponding pairs of particles are the same; (ii) the rates at which these distances are changing are the same; (iii) corresponding particles have the same mass and the same values for their absolute accelerations; but (iv) the future evolution of the particles in the first model differs from the future evolution of the particles in the second model.

The simplest examples are solutions to the two-body problem.

In one solution, two bodies of unit mass follow circular orbits around their common center of mass. At each time the bodies are (let us suppose) 10 light-seconds apart. So the rate at which the distance between them is changing is zero at each time. The absolute acceleration of each body is given by Newton's law, and depends only on the masses and positions of the bodies.

In another solution, two bodies of unit mass follow parabolic paths around their common center of mass as they slingshot past each other and off to infinity. At the moment of closest approach the bodies are 10 light-seconds apart, occupying just the same points of space as the two bodies in the first solution. Since this is the moment of closest approach, the rate at which the distance between them is changing is zero. The absolute acceleration of each body is given by Newton's law, and depends only on the masses and positions of the bodies. Since the masses and positions at this time are the same in this solution as in the first solution, their absolute accelerations are the same as in the first solution.

These two solutions, then, are the same at one time with respect to Sklar's initial data—masses, relative distances and velocities, and absolute accelerations—but differ in the future. So the initial value problem is not well-posed.

What has gone wrong? In Newtonian gravitational theory, the corresponding initial value problem is well-posed, because the initial data contain more information. They contain each particle's absolute velocity[8]; this information determines the total energy of the system, which determines its future evolution. (If the total energy is negative, then the particles orbit in circles; if it is zero, they move on parabolas.) Even though Sklar's initial data contains absolute accelerations in addition to interparticle distances and relative velocities, it still does not contain enough.

Does Sklar's proposal do *any* better than classical relationalism? The answer is 'no'. Let M_1 and M_2 be any two Newtonian models that witness classical relationalism's failure to have a well-posed initial value problem: the models agree at a time t on the mass of each particle, the distance between each pair of particles, and the rate at which these distances are changing; but they do not agree on these facts at all times. M_1 and M_2 may not also witness the failure of Sklar's theory, since they may not agree on the absolute acceleration of each particle at t. (The direction of a body's absolute acceleration depends on the orientation of the whole configuration of material bodies in space, and M_1 and M_2 may not agree on that at t.) But from M_1 we can generate a third model M_3 such that M_2 and M_3 *do* witness the failure of Sklar's theory. Here is the argument: since (time-independent) spatial isometries are symmetries of Newtonian mechanics, we can 're-orient' the configuration of material bodies in M_1 so that it also agrees with M_2 on each particle's absolute acceleration at t. That is, there is a third model M_3 that (1) differs from M_1 by a spatial isometry, and (2) agrees with M_2 at t on Sklar's initial data. It follows from (1) that M_2 and M_3 do not agree on interparticle distances at *all* times, which is what was to be shown. So every pair of Newtonian models that witnesses the failure of classical relationalism generates a pair of Newtonian models that witnesses the

[8]In Galilean spacetime, it contains its 4-velocity, which determines its 3-velocity relative to an inertial frame of reference.

failure of Sklar's theory.[9] Sklar's theory doesn't make any progress on the problem facing relationalist interpretations of Newtonian mechanics.

5 Concluding Remarks

I think it's obvious that Sklar's maneuver is a failure. Why do some relationalists continue to take it seriously? I think because they bring different criteria (in my view, the wrong criteria) to bear on the evaluation of the theory.

Nick Huggett ([1999]) defends a more explicit version of Sklar's theory. He (like Sklar) thinks that relationalist theories must meet a certain challenge, and that Sklar's theory does meet that challenge. But the challenge is not to meet the two constraints I gave in section 2.

Instead, the challenge is to explain, or account for, 'inertial effects'. Huggett uses Newton's globes thought experiment to explain the challenge. The tension in a rigid rod connecting two globes varies depending on the rate at which the globes rotate around their center of mass. This tension is an 'inertial effect'. But the tension in the rod does not supervene on the history of distances between the globes. A world in which the globes rotate and a world in which they are at rest have the same history of distances between the globes, but differ in the tension in the rod. Huggett concludes from this that a relationalist theory that is just a theory of interparticle distances fails to explain inertial effects.

To meet the challenge, then, Huggett thinks that all a relationalist needs is a theory in which supervenience is restored. They need to find some relationalistically acceptable difference between the two globe worlds that can help explain the different inertial effects in those worlds. Differences in Sklar's intrinsic absolute accelerations are supposed to be this difference.

I do not think that this is the correct way to understand the challenge classical relationalism faces. An adequate replacement for Newton's theory should contain dynamical laws of temporal evolution. But Sklar's proposal cannot be turned into a theory like that.

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