PRESENTISM, ETERNALISM AND RELATIVITY PHYSICS

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Eternalism, roughly, is the view that our most inclusive quantifiers range over past, present and future entities; its opposite is presentism, the view that our most inclusive quantifiers range only over present entities. Many have argued against presentism on the grounds that presentism is incompatible with the theory of relativity.[1] Relativity, goes the argument, is a paradigmatically successful scientific theory; presentism contravenes it; so much the worse for presentism. I shall urge in what follows that this line of reasoning is inconclusive at best. I grant that orthodox relativity theory favors an ontology of eternalism. But I shall draw on some recent work by Julian Barbour and collaborators to argue that there are presentist-friendly variations on orthodox relativity theory on all fours with the orthodox approach in terms of empirical adequacy and theoretical virtue. Current physics, I shall urge, gives us no good reason to prefer orthodoxy to these unorthodox variations. The upshot, I shall suggest, is that the incompatibility of presentism and orthodox relativity theory implies nothing very interesting about how to resolve the presentism/eternalism debate.

I begin by stating more precisely what I shall mean by ‘eternalism’ and ‘presentism’, then show why relativity theory is commonly thought to imply the former.

[1] For discussion, see Callender (2000: S587-S599); Godfrey-Smith (1979: 233-244); Hinchliff (1996: 119-136); Hinchliff (2000: S575-S586); Maxwell (1985: 23-43); Monton (*forthcoming*); Putnam (1967: 240-247); Rea (1998: 225-260); Rea (2003: 246-280); Rietdijk (1966: 341-344); Rietdijk (1976: 598-609); Savitt (1994: 463-474); Saunders (2002: 277-292); Savitt (2000: S563-S574); Sider (2001); Sklar (1974); Sklar (1981: 129-142); Stein (1968: 5-23); Stein (1970: 289-294); and Stein (1991: 147-167).

1. Presentism, Eternalism and Orthodox Relativity

Eternalists think of reality as spread out in time as well as space, comprising past, present and future entities. Presentists disagree, holding that every spatiotemporal thing whatsoever is a present thing. Less roughly, I shall think of eternalism as the thesis that the spatiotemporal world—the totality of spatiotemporal entities—is embedded in a four-dimensional manifold *M* of point-locations such that (a) *M* is structured by a primitive distance relation—the spacetime interval, and (b) *M* is isomorphic to at least one model of general relativity. And presentism, I shall say, is the thesis that the spatiotemporal world—the totality of spatiotemporal entities—is embedded in an enduring, *three*-dimensional manifold of point-locations structured by a primitive spatial distance relation.

So far, eternalism and presentism. We look next at why relativity theory is typically thought to imply the former. On their usual construals, special and general relativity are *spacetime* theories: roughly, theories that attempt to predict and explain physical phenomena in terms of the geometrical properties of a spacetime manifold, a four-dimensional, differentiable manifold on which geometrical objects are defined at every point. We can think of a spacetime theory *T* as having two parts: following van Fraassen (1987), its *theoretical structure* and its *theoretical hypotheses*. The theoretical structure of *T* is a family of mathematical spacetime models, where each model is an n-tuple $<M, \Phi_1, \ldots, \Phi_{n-1}>$ such that *M* is a four-dimensional, differentiable point manifold and $\Phi_1, \ldots, \Phi_{n-1}$ are *geometrical objects* defined everywhere on *M* (roughly, set-theoretical mappings defined on *M* representing its geometrical structure and matter-energy distribution). The theoretical hypotheses of *T* describe the relationship between its spacetime models and the empirical world. On the orthodox approach, special and general relativity include what we might call an *eternalist* theoretical hypothesis,[2] a proposition to the effect that one or more of the models of the theory is an isomorphic representation of *spacetime*, the four-dimensional space of locations-at-a-time in which all physical goings-on—past, present and future—are embedded.[3]

Plainly enough, then, orthodox relativity theory implies eternalism since it includes a theoretical hypothesis to the effect that eternalism is true. One might well wonder, though, whether there's any deep incompatibility between presentism and relativity theory. For can't we simply replace the eternalist theoretical hypothesis of orthodox formulations of the theory with a presentist alternative? As follows: Instead of thinking of some relativistic spacetime model as an isomorphic representation of a four-dimensional spatiotemporal world, we suppose that only a *part* of some model represents by isomorphism. We suppose a foliation or slicing of this model's manifold into a series of three-dimensional spacelike hypersurfaces. We then construe *one* member of this series as an isomorph of the *three*-dimensional world; other members of the series are construed as representations of past and future states of this 3-world. The entire series represents the evolution of the 3-world through time.

To be sure, this isn't the usual way of proceeding, but is it a *substantive* departure from orthodox relativity? Many physicists, I think, would answer this question in the affirmative. Adding a presentist theoretical hypothesis to relativity requires privileging a

[2] This term comes from Monton (*forthcoming*).

[3] I am characterizing the orthodox approach to special and general relativity in terms of substantivalism about spacetime. I realize, however, that it's a matter of controversy whether relativity requires commitment to substantivalism, and if so, what sort of substantivalism it requires. Since, so far as I can tell, everything I say in the sequel can be re-cast in terms of some version or other of relationalism, I shall ignore this controversy and press on as if orthodox relativity was a theory about a substantival spacetime.

foliation of one or more of its models: for some one of its models, recall, we specify a particular slicing of the model into a series of spacelike hyperspaces and think of the resulting series of 3-spaces as uniquely representing the evolution of our 3-world through time. But many would say that adding a preferred foliation to relativity in this way means rejecting both the letter and the spirit of the theory. One of Einstein's most important insights, it is commonly thought, is the idea that there *is* no privileged foliation of spacetime (or our models thereof), no foliation such that it alone tells the correct story of how the cosmos evolves over time. Adding a presentist theoretical hypothesis to relativity means rejecting this central tenet of modern physics.

The upshot: presentism conflicts with both the letter and the spirit of orthodox relativity theory. Eternalism doesn't. Wherefore, says conventional wisdom, relativistic physics favors eternalism over presentism.

Well and good: relativistic physics, on its orthodox construal, favors eternalism over presentism. The interesting question is whether current physics gives us good reason to prefer the orthodox approach over the unorthodox, presentist-friendly approach sketched above. I shall argue that it doesn't. My tack will be to sketch a particular implementation of this unorthodox approach in the context of general relativity (GR) and then argue that current physics gives us no reason to prefer orthodox GR to this unorthodox variant. Though there are other ways of implementing a presentist approach to GR, I focus on one that is closely connected to some recent work on gravitation by Julian Barbour and collaborators. I'll close by saying something about the implications of my approach to GR for special relativity (SR).

2. A PRESENTIST-FRIENDLY VARIATION ON GR

As we've seen, a spacetime theory has two parts, its theoretical structure (some class of mathematical spacetime models) and its theoretical hypotheses (a set of propositions describing the relationship between the models of the theory and the empirical world). My presentist-friendly variation on general relativity—henceforth, presentist GR, 'PGR' for short—has the following theoretical structure: its models are all and only the CMC-foliable models of general relativity. (There is a large subclass of the class of general relativistic models whose members admit of a unique foliation into surfaces of constant mean curvature (CMC). For an introduction to the notion of CMC slicing, see Gordon Belot and John Earman [2001]: 239-240.)

PGR's theoretical hypotheses mimic those of orthodox GR except that it replaces orthodoxy's eternalist theoretical hypothesis[4] with a presentist theoretical hypothesis. The latter hypothesis consists of the following proposition:

> (**PTH**) At least one model of PGR represents the evolution of Space over time.

I shall now explain this proposition. To start with, it presupposes that the entirety of the physical world is embedded in Space, an enduring, three-dimensional object made up of enduring point-locations and structured by a primitive spatial distance relation. (It presupposes, then, that the spatiotemporal world is three- as opposed to four-dimensional.) It also presupposes that Space "evolves" over time. Something *x* evolves over time, let us say, iff there is some property *F* such that *x* bears the *having* or *instantiation* relation—which I suppose to be a two-term connection of things to their

[4] Where this, again, is a proposition to the effect that at least one general relativistic spacetime model is an isomorph of our four-dimensional world.

properties—to F, but *WAS*(x doesn't bear the *having* relation to F) or *WILL*(x doesn't bear the *having* relation to F).

(PTH) says that at least one model of PGR "represents" the evolution of Space over time. This claim may be understood as follows. At least one model of PGR represents the evolution of Space over time, we shall say, iff there is at least one model $<M, g, T>$ of PGR that admits of a CMC foliation into a sequence S^* of spacelike hypersurfaces such that there is a one-one map from a *history* H of Space onto S^* that takes each *instantaneous state* of H to a *corresponding* member of S^*. The key terms in the latter sentence may be explained as follows.

An *instantaneous state* is a triple $<\Sigma, h_{ij}, \phi>$ such that Σ is a three-dimensional point manifold, h_{ij} is a Riemannian metric defined everywhere on Σ, and ϕ is a family of fields $\phi_1, \ldots, \phi_n$ such that $\phi_1, \ldots, \phi_n$ are scalar, vector and/or tensor fields defined everywhere on Σ that, intuitively, represent the distribution of matter and energy across Σ. $<\Sigma, h_{ij}, \phi>$ is an instantaneous state *of* Space, we shall say, if there is a one-one mapping Φ: Space $\rightarrow \Sigma$ such that (i) Φ maps spatial distances between space points p and q onto equal distances induced by h_{ij} between $\Phi(p)$ and $\Phi(q)$, and (ii), roughly, the quantity of mass-energy at a space point p is coded by the "values" of ϕ at $\Phi(p)$.

A *history* of Space, then, is any series S of instantaneous states such that (i) S is ordered by an irreflexive, asymmetric, and transitive relation R such that, for any $x,y \in S$, $R(x,y)$ iff *IS, WAS, OR WILL BE*(y is an instantaneous state of Space and *WAS*(x is an instantaneous state of Space)); and (ii) one member of S is presently an instantaneous state of Space.

Finally, an instantaneous state $\langle\Sigma, h_{ij}, \phi\rangle$ *corresponds* to a hypersurface Σ' of $\langle M, g, T\rangle$ iff there's a diffeomorphic embedding $\Phi: \Sigma \rightarrow M$ such that $\Phi(\Sigma) = \Sigma'$, $\Phi^*(h_{ij})$ is the Riemannian metric on Σ' induced by g, and $\Phi^*(\phi)$ codes the three-dimensional matter-energy distribution on Σ' induced by T.

In summary, according to (PTH), the physical world is embedded in an evolving three-space whose history is given isomorphic representation by at least one CMC-foliable general relativistic spacetime model. Such is our presentist-friendly variation on GR, roughly construed. The main difference between it and standard GR, the difference that matters for metaphysics anyway, is this: whereas the latter is typically construed as a theory describing the large-scale geometrical structure of a four-dimensional spacetime, our presentist variation is a dynamical theory describing the evolution over time of a curved, three-dimensional space and its contents.

This variation on GR is closely related to an approach to gravitation recently advocated by Julian Barbour and collaborators.[5] Their view takes its start from the so-called "3+1" approach to general relativity, also known as *geometrodynamics*.[6] On the standard formulation of GR, the basic equations of the theory are Einstein's field equations, which describe the distribution of metric and matter fields across a four-dimensional spacetime. With geometrodynamical GR, the basic equations are different. On Barbour's version, the basic equation is a Jacobi action principle that determines a class of geodesics through an infinite dimensional configuration space. Each point in the

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[5] See Anderson *et al* (2003: 1571-1604), Barbour (2003: 1543-1570), Barbour *et al* (1999), and Barbour *et al* (2002: 3217-3248). For an introduction to Barbour's approach to relativity, see Barbour (1994: 2853-2873) and Barbour (1999). For introduction and discussion of Barbour's approach aimed at philosophers rather than physicists, see Pooley (2001) and Butterfield (*forthcoming*).

[6] So-called "geometrodynamical" GR traces back to work in the late 1950s by Paul Dirac, Richard Arnowitt, Stanley Deser and Charles Misner. See, e.g., Arnowitt *et al* (1962).

configuration space is an instantaneous 3-geometry (and perhaps an instantaneous matter-energy distribution, though this is typically omitted for simplicity). The geodesics through the configuration space fixed by the action principle are sequences of 3-geometries and may be thought of as representing dynamically possible histories of an evolving three-space, each point on the curve being a instant of time in the three-space's history. The connection with the standard spacetime approach to GR is straightforward: the physically possible sequences of 3-spaces fixed by the action principle will each correspond to some sequence of spacelike hypersurfaces induced by some foliation of a general relativistic spacetime model.

Thus far the general contours of Barbour's approach to geometrodynamics. Recently, he and collaborators[7] have extended this basic approach to obtain a class of theories defined on a configuration space called *conformal* superspace, where this is the space one arrives at by quotienting the space of Riemannian metrics defined on some 3-manifold Σ—called *Riem*(Σ)—by the group of all diffeomorphisms of Σ and the group of all conformal transformations on *Riem*(Σ).[8] As above, the basic equation on their approach is an action principle that determines a class of geodesics through conformal superspace, each of which may be thought of as representing a dynamically possible history of an evolving 3-space. What's of interest to our project is that, on one of the theories they develop,[9] the class of curves through conformal superspace yielded by their

[7] See Anderson *et al* (2003); Barbour (2003) and Barbour *et al* (1999).

[8] Some of the theories they develop are defined on a slightly more complicated configuration space. I shall ignore this complication.

[9] I'm speaking here of their "CS+V" theory. See Anderson *et al* (2003: 1586ff).

action principle is precisely the class of interest to the proponent of PGR: the class of curves corresponding to the CMC foliations of CMC foliable models of GR.

2.1 A Word about Presentism and Absolute Time

There are various ways of filling in the above sketch of our presentist variation on GR. For instance, I omitted from the above discussion any mention of a temporal metric. I suggested that the history of Space and its contents is given by a series of instantaneous states ordered by an analogue of the B-theoretic earlier/later relation. One might wonder what the metric structure of this series is. Pick any two "instants" in the series and there's this question: how much time elapses between them? Note that to suppose that there's a definite answer to this question is to suppose that time has an *absolute* metric, in the sense that, for any two past, present or future instantaneous states of Space, there's a well-defined temporal distance between them, an *amount* of time such that it is the amount of time that lapses between the states in question.

Now, one can certainly fill in the details of our sketch of a presentist theoretical hypothesis by adding an absolute temporal metric into the sketch. I want to suggest, though, that the presentist need not do so. I want to suggest, that is, that the presentist is free to view the temporal structure of her theory as metrically amorphous, or as it's sometimes (misleadingly) put, as "timeless".

Barbour has argued in a fascinating series of papers (and books) for what he calls a "timeless" view of physics.[10] For present purposes, we needn't go into the full details of his program. I want instead to focus on his claim that GR can be interpreted as a

[10] See Barbour (1999) for a popular exposition of the view.

timeless theory. As I'll try to show, presentism can be thought of as a timeless theory of time in just the same way that GR can be thought of as a timeless theory of gravity.

As we've already seen, Barbour's interpretation of GR takes its start from the so-called geometrodynamical approach to GR. What makes Barbour's version of geometrodynamics "timeless" is this.[11] The action principle at the heart of his theory—the principle that fixes the class of curves through superspace representing dynamically possible histories—has no time parameter. Points along the curves through superspace are labeled by an arbitrary parameter λ—arbitrary because any monotonically increasing parameterization will do—and the action principle describes the geodesic trajectories through superspace in terms of this arbitrary parameter. The dynamics of his theory, then, can be fully spelled out without mention of a time parameter and without postulating a primitive temporal metric. His approach is "timeless", then, in this sense: it postulates no primitive temporal metric.

(What then of GR's usual notion of proper time? Barbour shows, in effect, that it is definable from other quantities invoked by his dynamics. Very roughly, we can think of his action principle as yielding a set of equations that describe dynamically possible sequences of 3-geometries in terms of arbitrary, monotonically increasing parameterizations of the sequences. It turns out that certain ways of parameterizing a sequence *S* greatly simplify the equations describing it. Barbour shows that these simplifying parameterizations correspond to proper time along a special class of timelike curves through the general relativistic spacetime model corresponding to *S*. Proper time along all other timelike curves through the model is then definable in terms of the proper

[11] For discussion, see Barbour (1994), Pooley (2001), and Butterfield (*forthcoming*).

time along these curves. The upshot: GR's usual notion of proper time is definable from the dynamics of his theory, dynamics which invoke no primitive temporal metric.)

Now, it's no part of my project to comment on the merits of Barbour's approach. I bring it up because it suggests an analogous "timeless" approach to presentism, one I think will be attractive to some presentists. Go back to our series of instantaneous states representing the history of Space and its contents. We inquired above into the metric structure of the series. Pick any two "times" in the series and there's this question: how much time elapses between the instantiation of one time and the other? One might follow Barbour in denying that the question is well-formed. On this approach, our ersatz history of Space has no intrinsic temporal metric. We can arbitrarily specify a metric: e.g., we could say that the time lapse between times t_1 and t_2 is given by the number of times the earth goes round the sun in the interval between t_1 and t_2. Or we could say that it's given by the number of oscillations of some particle in that interval. Or we could refuse to specify a single metric, but give instead trajectory relative metrics, the ones suggested by Barbour, for instance, in the previous paragraph. Some choices, note, will yield simpler laws of motion than others. The ones that yield the simplest laws will likely be the ones we work with in physics. But in each case, we're merely *stipulating* a metric; the series in itself is metrically amorphous.

I find this sort of presentism-cum-conventionalism-about-time attractive. I shall think of our presentist theoretical hypothesis as postulating this sort of presentism.

I turn now to the main question of this paper: Does current physics give us some reason to prefer orthodox GR to the presentist variation on GR just sketched? Call this the Main Question.

3. Clarifying the Main Question

What we're looking for, then, is some reason to prefer orthodox GR over the unorthodox variation sketched above. Some will have broadly philosophical reasons for preferring orthodoxy. So, for example, some will argue that presentism is metaphysically impossible or somehow incoherent; others will argue that metaphysics must always start with what scientists believe and since scientists aren't presentists, presentistic GR is a non-starter. But I wish to bracket these kinds of considerations. (I shall assume that presentism isn't obviously impossible or incoherent and that one can sensibly do metaphysics without starting from the deliverances of current science.) Instead, I want to focus on a set of narrower questions: Is there some *empirical* reason to prefer orthodox GR? Does PGR conflict with some deliverance of experimental physics? If not, then is there some *theoretical* reason to prefer orthodox GR—some truth-indicating theoretical virtue or set thereof displayed by orthodoxy and not by our presentist-friendly variant? So, for instance, if our presentist GR involved elaborate conspiracy on the part of nature to hide her true structure, a conspiracy not found in the orthodox picture, this would count against it. Or if presentist GR involved a myriad of unexplained coincidences not found in its orthodox cousin, or if it postulated explanatorily superfluous entities in a way that its orthodox cousin didn't, these would be theoretical costs not shared by orthodox GR and would constitute theoretical grounds for preferring the latter. So the Main Question comes to this: are there either empirical or truth-indicating theoretical grounds of the sort displayed in the last few sentences for preferring orthodoxy?

4. Empirical reason to prefer orthodoxy?

Here we're wondering whether there is observational evidence inconsistent with presentist GR. So is there some deliverance of astronomy, say, or some branch of experimental physics that conflicts with presentist GR? The answer to this question would be 'yes' if we knew from astronomical observations, say, that the spacetime models isomorphic to our universe aren't CMC foliable. It'd also be 'yes' if we knew of observable phenomena which couldn't be *embedded* into a CMC foliable model of GR. In very general terms, an observable phenomenon is embeddable into a model of GR if it can be represented by an n-tuple $\langle M, \Phi_1, \ldots, \Phi_{n-1} \rangle$ such that (a) M is a point manifold representing some bit of spacetime, or some bit of space through time, and $\Phi_1 \ldots \Phi_{n-1}$ are geometrical objects representing M's geometry and, e.g., observable particle trajectories or patterns of field intensity, and (b) $\langle M, \Phi_1, \ldots, \Phi_{n-1} \rangle$ is a *submodel* of some general relativistic spacetime model.

So what's to say? Is there some deliverance of astronomy or experimental physics that conflicts in one of these ways with presentist GR? Perhaps so: the deliverances of quantum physics would seem not to be embeddable into the models of classical GR—so the search for a quantum theory of gravity. But set this problem aside: this is as much a problem for orthodoxy as it is for presentist GR. Is there some deliverance of observational astronomy or experimental physics—*modulo* the deliverances of quantum physics—that conflicts in one of these ways with presentist GR? The answer here, I think most would agree, is 'no'.

5. Theoretical Reasons to Prefer Orthodoxy?

5.1 Presentist GR violates a central tenet of modern physics: no priveleged foliations

Presentist GR, unlike its orthodox cousin, postulates a preferred foliation on its spacetime models. On presentist GR, one way of foliating spacetime is physically significant in a way that other ways of foliating aren't: it alone carves our spacetime models into a sequence of 3-slices that accurately represents the evolution of Space over time; other ways of foliating induce sequences of 3-slices that *mis*represent the history of Space. But this violates a central tenet of modern physics according to which there is no preferred foliation of spacetime (or our models thereof), no one correct way of carving spacetime into spaces and times so that it and it alone tells the story of how the cosmos evolves over time.

True enough, presentist GR violates this tenet of modern physics. But in the present dialectical context, this doesn't amount to much of an objection since the question we're considering is whether we've some reason for preferring theories that comport with this tenet over theories that don't.

5.2 Egalitarianism about reference frames has led to some highly successful physics

Classical relativistic physics, one of the most successful research programs in physics to date, was built on the assumption that there are no privileged reference frames. Doesn't this strongly suggest that there aren't any?

No. An equally plausible explanation for the success of classical relativistic physics is that the world is housed in a three-space whose evolution is described as above.

5.3 Orthodox GR is simpler than Presentist GR

Like orthodox GR (and for that matter, most any spacetime theory), presentist GR can be formulated in generally covariant form. But its generally covariant formulation will be slightly more complicated than orthodoxy's on account of its more restrictive class of models. Some might take this as indication that orthodoxy is a simpler theory and thus more likely to be true.

But this strikes me as misguided. The class of PGR models isn't in any obvious sense more miscellaneous or gerrymandered than the full class of general relativistic spacetime models, nor are the theoretical hypotheses of PGR in any obvious sense more complicated than those of orthodoxy. Since, on the view of theories we're working with—the so-called semantic view—a theory just *is* a class of models and a class of theoretical hypotheses, the claim that orthodoxy is a simpler theory looks wrong to me.

Maybe the suggestion, rather, is that, *ceteris paribus*, spacetime theories that admit of simpler generally covariant formulation are more likely to be true. But why think this? One main reason for thinking this is that simplicity of generally covariant formulation often goes together with economy of postulated spacetime structure (in general, the more structure you postulate, the more complicated your field equations get), and thus economy of postulated ontology. Since economy of the latter sort is arguably a truth-indicating theoretical virtue, to the extent that it explains the simplicity of a theory's generally covariant formulation, the latter will also be a truth-indicating theoretical virtue.

This all seems plausible enough, but in the present case, it's not clear that orthodoxy's simpler generally covariant formulation is a function of its postulating less ontology than presentist GR. This because orthodoxy in fact postulates *more* ontology than presentist GR: it postulates a vast realm of past and future entities not postulated by the presentist.

Are there other reasons for thinking that orthodoxy's simpler generally covariant formulation is truth-indicating? Not any obvious ones.

5.4 PRESENTIST GR IS *AD HOC* IN A WAY THAT ORTHODOXY ISN'T

Presentist GR arbitrarily restricts the class of general relativistic models to the CMC foliable models. Since there's no physical motivation for this restriction, presentist GR has a whiff of *ad hocness* about it: it looks as if the only motivation for the restriction is the desire to produce a theory friendly to presentism.

A few points in reply. First, it is notoriously difficult to spell out what the charge of *ad hocness* comes to exactly. I rather suspect that accusing a theory of *ad hocery* has more to do with expressing one's distaste for the theory than with substantive criticism. Be that as it may, secondly, it's not true that there's no physical motivation for restricting the class of general relativistic models to the CMC foliable models. For instance, Barbour and collaborators have recently argued that (a) there are good reasons for thinking the evolution of the cosmos over time to be governed by a variational principle like that at the heart of their theory, and (b), that, if it is, then CMC evolution of 3-geometry over time follows as a consequence.[12] It's an open question, I gather, whether they're right about this, but this much seems clear: it's going too far to say there's no

[12] See Anderson *et al* (2003) and Barbour *et al* (2002).

physical motivation for thinking CMC slicing fundamental. Some very good physicists seem to think there's physical motivation for it.[13]

Thirdly, and most importantly, the objection presupposes that a physical theory is somehow untoward if a motivation for introducing certain of its features is the desire to produce a theory that comports well with one's background metaphysic. But this is surely wrong. General relativity, I take it, wasn't objectionably *ad hoc* when first put forward by Einstein, though many of its features were motivated by his background metaphysical assumptions (e.g., his assumptions about Leibnizian relationalism and Machian accounts of inertial effects).

5.5 Presentist GR postulates a conspiracy on the part of nature to conceal her true structure

This sort of complaint is sometimes lodged against the so-called "neo-Lorentzian" approach to special relativity (*see*, e.g., Balashov *et al* [2003]: 327-346). On this approach, instead of postulating a Minkowski manifold and analyzing the usual special relativistic effects (length contraction, time dilation, relativity of simultaneity, etc.) in terms of the Lorentzian geometry of this manifold, one postulates Newtonian spacetime and classical electrodynamics and tries to account for the special relativistic effects by appeal to motion induced deformations in our measuring equipment. The idea here is that, though the underlying metrical structure of space and time is the classical Newtonian structure—replete with absolute spatial and temporal distances, absolute velocity and absolute rest—systematic deformations in our measuring equipment hide this structure from us.

[13] For discussion of other motivations, see Qadir *et al* (1985), Tipler (1988: 222), and Valentini (1996: 45-66).

Given this sort of theory, one can see why one might complain of conspiracy.[14] But in the case of presentist GR, it's harder to see how the objection would go. PGR does not postulate an absolute temporal metric hidden from observation by slowing clocks: it postulates, rather, that there is no temporal metric intrinsic to the world. It does not postulate a Euclidean spatial metric hidden from us by distorted measuring equipment, and it does not imply that any object has a well-defined absolute velocity: it says that for any two instants of time, there's no one correct answer to the question how much time elapses between them. Thus it implies that there's no one right answer to the question how fast an object moves with respect to Space.

Still, one might complain, it *is* committed to absolute simultaneity and rest. First, it's committed to a well-defined simultaneity relation that holds independently of reference frame. That relation may be defined as follows:

> events x and y are absolutely simultaneous $=_{df.}$ for some events u and v, u=x and v=y.

And second, it's committed to a well-defined notion of absolute rest or sameness of place that holds independently of reference frame: roughly, an object exhibits absolute sameness of place over an interval of time if, over the course of that interval, it overlaps one and the same region of Space.

And, goes the complaint, insofar as it's committed to these, it's committed to an untoward conspiracy. After more than a century of trying, no one has been able to detect a preferred simultaneity frame or distinguished state of rest. If there are such things, nature is doing a good job hiding them.

[14] Though for an extended defense of the neo-Lorentzian approach, see Craig (2001).

Supposing there are such things, though, what is the sense, exactly, in which nature is "hiding" them? Let the skeptic speak: "Well, there's the fact that, where the effects of gravity can be ignored, relative to local Lorentz frames, the laws governing non-gravitational interactions appear to be Lorentz invariant. And doesn't this fact constitute a kind of conspiracy on the part of nature to hide absolute rest and simultaneity from us if there are such things?" No, not in any obvious sense. Is there some reason to *expect* that, were presentism true, the local laws governing non-gravitational interactions—the laws holding on a small neighborhood of any space point—would single out the rest frames? Not that I can see. Consequently, I can't see any reason for thinking that the defender of PGR who grants that the local laws governing non-gravitational interactions are locally Lorentz invariant is *ipso facto* committed to an untoward conspiracy to hide what we would otherwise expect to see.

Maybe the worry is this. Whereas the proponent of orthodoxy has an *explanation* for the fact that local Lorentz invariance holds—viz., the local approximate Minkowski geometry of spacetime—the presentist must chalk this up to unexplained coincidence. So Michelle Jannsen and Yuri Balashov:

> In the neo-Lorentzian interpretation it is, in the final analysis, an unexplained coincidence that the laws effectively governing different sorts of matter all share the property of Lorentz invariance, which originally appeared to be nothing but a peculiarity of the laws governing electromagnetic fields. In the space-time interpretation this coincidence is explained by tracing the Lorentz invariance of all these different laws to a common origin: the space-time structure posited in this interpretation (Balashov and Janssen [2003]: 341-342).

In brief: defenders of orthodoxy can appeal to the local Minkowski geometry of spacetime to explain why the laws governing different sorts of non-gravitational interactions are all locally Lorentz invariant; PGR must chalk this up to fantastic luck. This looks bad for PGR.

But, by way of reply, it's very difficult to see why the local Minkowski geometry of spacetime postulated by orthodox GR should count as an *explanation* of the fact that the laws governing non-gravitational interactions are locally Lorentz invariant. (Here I follow recent arguments to this effect by Harvey Brown and Oliver Pooley [2001]: 270-271). It certainly seems *possible*—in the broadly logical sense—that matter and energy should be spread across a spacetime whose background geometry is Minkowskian, but the laws governing the matter and energy don't satisfy the Lorentzian symmetries. (The scenario envisaged is analogous to the scenario envisaged by the neo-Lorentzian in which one has matter and energy spread across a spacetime whose background geometry is Newtonian, but the laws governing the matter and energy don't satisfy the Galilean symmetries.) Since a Minkowskian background geometry would seem to be compatible with non-Lorentz-invariant laws, it's hard to see why the existence of local Minkowski geometry counts as an *explanation* of local Lorentz invariance.

Brown and Pooley argue that local Lorentz invariance is not something that can be derived from GR's postulation of local Minkowski geometry, but must be independently *assumed* (Brown and Pooley [2001]: 270). If they're right, then the proponent of orthodoxy and the proponent of PGR look to be in the same boat: each postulates local Lorentz invariance; neither proposes to explain it.

(Before I move on, a recent claim by Barbour and collaborators is relevant here (Barbour, Forster, and Ó Murchadha [2002]). They claim to be able to derive local Lorentz invariance from the action principle at the heart of the so-called BSW approach to geometrodynamics. If they're right, then they've shown that local Lorentz invariance isn't among the fundamental postulates of GR, but a consequence of them. What's interesting about this for our purposes is that, if they're right, the presentist and the proponent of orthodoxy are still in the same boat: for the presentist can grant with equanimity that the dynamical evolution of Space and its contents over time is governed by Barbour's BSW Lagrangian.)

5.6 What about unfoliable spacetimes?

It's well known that not all models of GR can be foliated into global spacelike hypersurfaces. (Gödel (1949), for instance, proposed a widely-discussed model of general relativity that cannot be foliated.) Doesn't this make trouble for the foregoing presentist variation on GR?

No. Why would it? If PGR is right, the physically possible models of GR are just the CMC-foliable ones, and unfoliable spacetimes like Gödel's represent interesting but physically impossible scenarios.

5.7 The leading candidates for a theory of Quantum Gravity don't involve a fixed foliation

Because it has proven impossible to marry classical general relativity to quantum theory, it is generally assumed that classical general relativity is, strictly speaking, false, and that the true theory of gravity is some yet-to-be-worked-out quantum theory of gravity.

So far, there is no consensus about exactly how this theory will go, but at present, the leading approaches make no use of a preferred foliation.[15] Does this give us reason to prefer orthodoxy? (Here we wouldn't be thinking of orthodoxy as preferable to PGR in

[15] For discussion, see Monton (*forthcoming*).

the sense that the former but not the latter is *true*. Rather, we'd be thinking that the former is a better approximation to reality than the latter.)

I don't think it gives us any reason at all. For this to constitute reason to prefer orthodoxy, we'd also need reason to think that, even if we were to eventually settle on a theory lacking a preferred foliation, there wouldn't be an alternative, empirically adequate fixed foliation theory of comparable theoretical virtue. But, I submit, we've currently no reason to think the latter.

I'm out of ideas now about why orthodoxy might be theoretically preferable to our unorthodox, presentist-friendly variant. I take the upshot of this discussion to be that the answer to the Main Question is 'no': at present, anyway, we've no good reason (from physics) for thinking that orthodox GR is more likely to be true than the above-sketched presentist-friendly variant. Note that I do *not* claim that we've reason for thinking that the latter is more likely to be true than the former. I claim only that current physics gives no reason to prefer one over the other. If I'm right about this, my argument leads us to this conclusion: presentism's incompatibility with orthodox general relativity tells us very little about whether we should or shouldn't be presentists.

6. On Presentism and Special Relativity

Thus far, my discussion has focused exclusively on general relativity. If what I've said is on target, presentism's incompatibility with orthodox GR sheds little light on the presentism/eternalism debate. But most discussion in the literature on presentism and relativity physics focuses on the incompatibility of presentism with *special* relativity

(SR). I close, then, by considering the question whether presentism's incompatibility with SR sheds any further light on the presentism/eternalism debate.

One thing to note here is that the above sort of strategy for formulating a presentist-friendly variation on GR doesn't carry over to SR. My approach to GR took its start from the fact that there is a large class of general relativistic spacetime models—viz., the class of CMC-foliable models—for which there is a natural definition of a global time function. For obvious reasons, this sort of approach isn't available in the case of SR: Minkowski spacetime admits of no non-arbitrary partitioning into spacelike slices. So, you might object, even if I'm right that there are physically viable variations on GR friendly to presentism, the same can't be said of SR. So much the worse for presentism, then, since SR is a paradigmatically successful physical theory.

But this sort of argument strikes me as misguided. Suppose I'm a proponent of PGR. You point out that my theory conflicts with SR. (Perhaps as follows: my theory implies presentism; presentism conflicts with SR; so my theory conflicts with SR.) True enough, I reply, my theory conflicts with SR, but then again, so does orthodox general relativity: SR says that spacetime is flat; orthodox GR, together with the fact that the universe contains matter, implies that it isn't. So PGR conflicts with SR, but so does orthodox GR. So far, anyway, my theory is no worse off than orthodox GR.

Reply: well, given orthodox GR, SR is at least locally correct: where the effects of gravity can be ignored, relative to local Lorentz frames, the laws governing non-gravitational interactions take their special relativistic forms. But so too with PGR: the proponent of PGR grants that, where the effects of gravity can be ignored, the laws governing non-gravitational interactions take their standard special relativistic forms.

Reply: yes, but it's a fundamental principle of SR that there are no preferred slicings of spacetime. PGR conflicts with this principle and thereby incurs a steep cost. True enough, PGR conflicts with SR's "no priveleged slicing" principle. But why think this a steep cost? Is this it? Is it that failure to comport with the principle costs PGR in empirical adequacy or truth-indicating theoretical virtue? It doesn't seem so. If the above arguments are on target, PGR and orthodox GR are on par in these respects. Since orthodox GR is about as good as it gets when it comes to empirical adequacy and theoretical virtue, it would seem that PGR pays no steep price in either for failing to comport with SR's "no priveleged slicing" principle. Are there other reasons for thinking that PGR's failure to comport with the principle tells against the theory? No obvious ones.

Now I'm out of ideas about why we should think PGR's conflict with SR makes trouble for it. As best I can tell, SR gives us no good reason at all for thinking PGR false. But PGR entails presentism. So SR gives us no good reason for thinking presentism false.

I take the upshot of all of this to be that presentism's incompatibility with SR and GR implies nothing very interesting about how to resolve the presentism/eternalism debate.[16]

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