

# There's No Time Like the Present (in Minkowski Spacetime)\*

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## Abstract

Mark Hinchliff concludes a recent paper, “The Puzzle of Change,” with a section entitled “Is the Presentist Refuted by the Special Theory of Relativity?” His answer is “no.”

I respond by arguing that presentists face great difficulties in merely stating their position in Minkowski spacetime. I round up some likely candidates for the job and exhibit their deficiencies.

## 1 Presentism and the Purported Refutation

The puzzle of change, according to Mark Hinchliff (1996)<sup>1</sup> can be traced to a view of time called eternalism:

On this view, which I will call *eternalism*, time is like space. There is nothing special about the things here; things at other places are just as real; no place is metaphysically distinguished. Similarly, for the eternalist, there is nothing special about the present; things at

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<sup>1</sup>Page references in the text will be to this paper.

other times are just as real; no time is metaphysically distinguished.

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One can solve the puzzle, according to Hinchliff, by exchanging eternalism for presentism.

*Presentism* is the denial of eternalism. According to the presentist, the way things are is the way things presently are. So the only things that exist are things that presently exist. . . . The presentist and the eternalist agree that Socrates does not presently exist and that he existed. They disagree about whether Socrates just plain exists. According to the eternalist, he does. According to the presentist, he does not. The spatial analogue of presentism is the view that the only things that exist are the things that exist here. On this analogous view, Mount Everest does not exist, which is extremely implausible. Things at other places are just as real as things here. However, presentism itself is not an implausible view. Time differs from space. According to the presentist, other times are not like other places. They are not just as real as the present. Only the present exists. (123)

While this characterization of presentism seems adequate for Hinchliff's (and my) purposes, one minor *caveat* must be noted. If one does not distinguish degrees of pastness and futurity but treats past and future as wholes, then there are eight possible ways to distribute reality amongst past, present, and future, ranging from the view that I call *eternalism* (past, present, and future are all real) to the view that none of them are. It is useful to distinguish a view between presentism and eternalism (as I characterize it) that I shall call *possibilism*, the view that that present and past things are real whereas future things are mere possibilia that are yet to come to be. According to possibilism, the present is still "metaphysically distinguished," for it is the time at which the

possibilia become actual. This view may well be the metaphysics of untutored common sense.<sup>2</sup>

Nevertheless, since Hinchliff's concern is to defend presentism solely and specifically, he uses the term *eternalism* simply to mean *non-presentism*. In his terms, the arguments that I present below will apply not just to presentism but also to any form of eternalism, like possibilism, that seeks to distinguish *the present* in Minkowski spacetime.

Though the adoption of presentism would, according to Hinchliff, help to resolve his puzzle regarding change, he sees a specter haunting presentism, a version of an argument once used by Putnam (1967) and by Rietdijk (1966, 1976) to show (allegedly) that the Special Theory of Relativity<sup>3</sup> (STR) entails a form of eternalism.<sup>4</sup> Consider two spacelike separated events  $O$  and  $E$  in a Minkowski spacetime  $\mathcal{M}$ .<sup>5</sup> There is a possible observer, Alice, at  $O$  for whom  $O$

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<sup>2</sup>Bigelow (1996) holds that until (roughly) the late nineteenth century, there were no non-presentists.

<sup>3</sup>To be definite I will take the Special Theory of Relativity to be that theory developed in Chapter 1, "The Geometry of Minkowski Spacetime" of Naber (1988). I use its notation, definitions and results freely in the footnotes to provide exact statements of ideas expressed less formally in the main text.

I hasten to add that there is nothing peculiar about the version of STR presented by Naber except the care with which the geometric structures underlying the physics of STR are developed. Any standard version of the theory could serve.

<sup>4</sup>One can deflate the metaphysical claims of any scientific theory wholesale by adopting an instrumentalist (Nagel 1960, Chapter 6) or constructive empiricist (Van Fraassen 1980) stance. The arguments of this paper will interest (or annoy) primarily those inclined towards scientific realism who can not also help feeling that there is something special about the present.

<sup>5</sup>"**Minkowski spacetime** is a 4-dimensional real vector space  $\mathcal{M}$  on which is defined a nondegenerate symmetric bilinear form  $g$  of index one; elements of  $\mathcal{M}$  will be called *events*." (Naber, page 1). Since  $g$  has index one,  $g(x, y) = x^1y^1 + x^2y^2 + x^3y^3 - x^4y^4$ , if  $x = (x^1, x^2, x^3, x^4)$  and  $y = (y^1, y^2, y^3, y^4)$ . If  $Q(x) \stackrel{\text{df}}{=} g(x, x)$ , then event  $E'$  is *spacelike separated* from event  $E$  if  $Q(E' - E) > 0$ .

and  $E$  are simultaneous.<sup>6</sup> There is, however, another possible observer, Bob, at  $O$  for whom  $E$  is not simultaneous with  $O$  but rather earlier than  $O$  because Bob is moving along the  $x^1$ -axis relative to Alice.<sup>7</sup> Bob is supposed to reason that since Alice is real (she is co-present with him at  $O$ ), then  $E$  must be real, since  $E$  is simultaneous with and hence real for the real Alice. But Bob also notes that  $E$  is past with respect to him and hence unreal according to presentism. We seem forced to conclude that presentism (in the context of STR) faces a *reductio*.

Since Putnam's argument seeks to refute presentism, Hinchliff seeks to undermine it. He notes (quite correctly) that the anti-presentist argument above relies on two assumptions. The first is a transitivity principle for reality: if  $E$  is real for  $A$  and  $A$  is real for us, then  $E$  is real for us too (130). There is, he says, "no compelling reason" (131) for a presentist to make this assumption. Transitivity is nevertheless a natural assumption to make for a dyadic relation like ' $x$  is real with respect to  $y$ ', where  $x$  and  $y$  are spacetime points or events, as Howard Stein showed in his dissection of the Putnam/Rietdijk argument.<sup>8</sup> A genuine problem with the argument, presented by Hinchliff, is that it seems to be committed to treating "observers" like Alice and Bob as both timelike vectors<sup>9</sup> or time axes<sup>10</sup> (in order for the assertion that  $O$  and  $E$  are simultaneous to make relativistic sense) *and* also as spacetime points (in order to apply the transitivity principle as formulated by Stein).

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<sup>6</sup>That is, there is an admissible basis for  $\mathcal{M}$  such that  $\Delta x^4 = 0$ . Without loss of generality we may assume that the various coordinate systems are in standard configuration. See Naber, page 20.

<sup>7</sup>That is, there is another admissible basis for  $\mathcal{M}$  such that  $\Delta \bar{x}^4 < 0$ .

<sup>8</sup>Stein (1968, 1991).

<sup>9</sup>The vector  $e_4$  in the admissible basis  $\{\epsilon_a\}$  in which (i.e., the "observer" for which)  $O$  and  $E$  are simultaneous.

<sup>10</sup>See Naber, p. 28.

Perhaps the Putnam/Rietdijk/Hinchliff argument can be reformulated to avoid this difficulty, but it is not my intent to pursue the matter here. Aside from limitations of space, I think that such an examination would involve minimal variations on Steinian themes. The point of this paper is to argue that, even if the anti-presentist argument cited by Hinchliff fails (as he and I believe it does), the presentist is by no means home free. There are grave difficulties in merely formulating a view in Minkowski spacetime that captures the metaphysical intuitions behind presentism. To begin to unearth these difficulties, let us turn to the second assumption that Hinchliff detected in the above anti-presentist argument.

## 2 From Presentism to Relativized Presentism

The other assumption is about what the doctrine of presentism is in a relativistic setting. Since in a prerelativistic setting the presentist says that the real events for an observer are the events simultaneous with that observer (and the simply real events are the events simultaneous with us now), the objection assumes that in a relativistic setting presentism is the view that the real events for an observer are the events simultaneous with the observer in the observer's frame of reference (and the simply real events are the events simultaneous with us now in our frame). Let us call this assumption about presentism in a relativistic setting *relativized presentism*. (130)

Since Hinchliff thinks that the presentist need not make this assumption, we might begin by examining the alternatives to relativized presentism that Hinchliff mentions. The first is a view suggested by William Godfrey-Smith (1979) that the present for an event  $E$  is the set of events on the past light cone of  $E$ . One advantage of this suggestion is that the present is defined in terms of a *bona fide* geometric structure in Minkowski spacetime, but it has

a number of consequences that should make a red-blooded presentist squirm.

First of all, we have been observing for about four decades the Cosmic Microwave Background Radiation (CMBR), which is thought to have originated about 300,000 years after the Big Bang, or about 15 billion years ago (give or take a few billion years). On Godfrey-Smith's view, the origin of this radiation counts as part of the present of the contemporary astrophysicists who observe it!

Second, Godfrey-Smith's suggestion seems to rest on the idea that events on the past light cone of  $E$  have a lightlike separation from  $E$  and hence the spacetime interval from  $E$  to (say)  $E'$  (on the past light cone of  $E$ ) is 0.<sup>11</sup> But then it seems arbitrary to exclude from the present events on the future light cone of  $E$ , which also are lightlike separated from  $E$ . It is hard to see, then, why the Big Crunch or the endless heat death of the universe should be excluded from the present. While I don't wish to quarrel over terms, it does seem desperate to define presentism in such a way that events virtually at the origin of our universe or in the remote future are included in the present.

One could make this complaint a little more formal. First, it seems reasonable to require that  $E$  itself be a member of any set  $S$  of events representing the present for  $E$  in  $\mathcal{M}$ . Second, it also seems reasonable to require that, if some set of events  $S$  represents the present for event  $E$ , then no events in  $S$  should be in each other's absolute past or absolute future (that is, it should not be the case that *all* observers at  $E$  agree that one of the events is, say, earlier than the other). Let us call this the requirement that any set of events representing the present in  $\mathcal{M}$  must be *achronal*.<sup>12</sup> Godfrey-Smith's suggested present is not achronal.

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<sup>11</sup>That is,  $Q(E' - E) = 0$ .

<sup>12</sup>That is, a set of events  $S$  is *achronal* iff, given that  $p \in S$  and  $q \in S$ , then the vector  $q - p$  is spacelike.

The second alternative to relativized presentism mentioned by Hinchliff (131) is that “the present can be identified with the here-now.” This view can be traced back at least to Robb (1921, page 13): “the present instant, properly speaking, does not extend beyond the here.” As Robb puts it alternatively (1921, page 13), “the only really simultaneous events are events which occur at the same place.” Given this characterization of the present, what are the prospects for presentism?

If the present for an event  $E$  in a Minkowski spacetime is just  $E$  itself, perhaps presentism is the view that only  $E$  itself is real. If presentism in the setting of classical spacetime is a form of “temporal solipsism,” then in Minkowski spacetime perhaps the natural expression of presentism is spatio-temporal solipsism.

This suggestion, as a way of reformulating presentism, clearly avoids the unpalatable consequences of Godfrey-Smith’s way while its characterization of the present for  $E$  clearly satisfies the two requirements proposed in the previous paragraph; nevertheless, the view seems unsatisfactory. If reformulated presentism distinguishes one point or event in Minkowski spacetime as *the* present, which one and why? Moreover, since it is central to presentism, as Hinchliff conceives of it, to connect existence to presentness, is it not at least a little discomfiting to the presentist to restrict reality to just one point of spacetime? Finally, this formulation of presentism is at odds with Hinchliff’s own metaphysical desideratum that for the presentist “other times are not like other places.” In this version of presentism events not at  $E$  spatially are just as unreal as events not at  $E$  temporally.

Consider an example. Suppose that Carol and Ted are two more observers who are relatively at rest,<sup>13</sup> with Carol’s worldline passing through the origin and Ted’s world line intersecting the  $x^1$ -axis at any point except the origin (but never, of course, intersecting Carol’s world line). We may suppose that they

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<sup>13</sup>That is, consider two coordinate systems with parallel  $x^4$ -axes.

exist from  $-t$  to  $+t$ . There can be no objection to saying that Carol's present at (say) time  $x^4 = 0$  is just the origin; but when one adds to that geometric characterization of the present the metaphysical view that "the only things that exist are things that presently exist," it seems that Carol can not acknowledge the existence of Ted then or ever (and vice versa). Ted is never present to Carol as world-line and, as far Carol as metaphysician is concerned, must therefore not exist. We, however, have no trouble in recognizing the above situation as one in which there are two individuals in spacetime. We are not here-now presentists.

It might be replied that the here-now idea is not that some one spacetime point is distinguished as present but that each point of spacetime is present with respect to itself. Then each point of spacetime is distinguished as real (with respect to itself), and the odd solipsism that looms on the first here-now alternative is supposedly avoided. But it seems to me that if each point of spacetime is distinguished, then no point of spacetime is metaphysically distinguished from any of the others with respect to presentness. As Don Alhambra del Bolero complains in Gilbert and Sullivan's *The Gondoliers*,

"When every one is somebody,  
Then no one's anybody!"

Presentism so reformulated collapses to eternalism.

There may be other ways to articulate the "here-now" option—ways to distinguish some proper subset of events in  $\mathcal{M}$  as present—but I do not see what they might be. The burden of reformulation at this point clearly rests with the presentist. Any of the above suggested views could, of course, be *called* presentism, but each fails to capture the fundamental metaphysical intuitions underlying presentism evoked so well in the quotes from Hinchliff at the beginning of this paper. Since we have now exhausted the alternatives to relativised presentism suggested by Hinchliff, I conclude, *for the moment*, that the presentist who takes STR seriously must take relativized presentism seriously.



### 3 From Relativized Presentism to Hyper-relativized Presentism

Consider an old but elegant argument given by Gödel (1949, page 558):

Change becomes possible only through the lapse of time. The existence of an objective lapse of time, however, means (or, at least, is equivalent to the fact) that reality consists of an infinity of layers of “now” which come into existence successively. But, if simultaneity is something relative in the sense just explained, reality cannot be split up into such layers in an objectively determined way. Each observer has his own set of “nows,” and none of these various systems of layers can claim the prerogative of representing the objective lapse of time.<sup>14</sup>

While this argument is aimed primarily at the idea the time is dynamic (another way of denying or opposing eternalism that has not been emphasized in this discussion), it also leads to problems for (relativized) presentism. At a given spacetime point  $E$  there are an infinite number of possible “observers” with their corresponding planes of simultaneity defining an infinite number of layers of “now.”<sup>15</sup> The Relativity Principle says, “All admissible frames of reference are completely equivalent for the formulation of the laws of physics.” (Naber, page 10). What the Relativity Principle means is that

there are no “distinguished” admissible observers, i.e., that none can claim to have a privileged view of the universe. In particular, no such observer can claim to be “at rest” while the others are

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<sup>14</sup>I would be grateful for pointers to older versions of this argument.

<sup>15</sup>See exercise 1.6.1 on page 37 of Naber.

moving; they are all simply in relative motion. We shall see that admissible observers can disagree about some rather startling things (e.g., whether or not two given events are “simultaneous”) and the relativity principle will prohibit us from preferring the judgement of one to any of the others. (Naber, page 10)

There is no way, according to the Relativity Principle, to distinguish physically any one of the layers or planes of “now” at a spacetime point from the infinity of others that can be defined there. No way has been suggested (or is even visible on the horizon) for distinguishing any one of these layers metaphysically. To be consistent with STR and the Relativity Principle the presentist must then either (i) hold that all events spacelike separated from  $O$  are present (and hence real) or (ii) hold that none of them are or (iii) relativize reality to “observers”.

The first suggestion (Weingard, 1972) runs afoul of the requirement that the set of events representing the present should be achronal. The second suggestion, without further embellishment, is just the identification of the present with the here-now, a proposal whose failings were noted in the previous section.

The third suggestion, relativized presentism, raises two problems. First, is the position intelligible? Gödel remarks, in footnote 5 of the paper from which I quoted above, that “The concept of existence, however, cannot be relativized without destroying its meaning completely.” I sympathize with this view. Suppose, for instance, reality is restricted to planes of simultaneity relative to an observer and suppose that some event  $E$  is assigned the coordinate  $x^4 = 0$  by Alice and  $\bar{x}^4 = 2$  by Bob. I think that I am expressing Gödel’s puzzlement by asking: what is added by saying that  $E$  is real for Alice but not real for Bob?

Secondly, Sklar bridles at the arbitrary nature of relativized presentism:

If we now associate the real (for an observer) with the simultaneous

for him, we must, accepting the conventionality of simultaneity, accept as well a conventionalist theory of 'reality for'. It is then merely a matter of arbitrary stipulation that one distant event rather than another is taken as real for an observer. Now there is nothing inconsistent or otherwise formally objectionable about such a relativized notion of 'reality for', but it does seem to take the metaphysical heart out of the old claim that the present had genuine reality and the past and future lacked it. For what counts as the present is only a matter of arbitrary choice, and so then is what is taken as real.<sup>16</sup>

Sklar bases his charge of arbitrariness on the controversial thesis that simultaneity is conventional.<sup>17</sup> It has not been recognized, I think, that even if one waives any claim that simultaneity is conventional, there is still a residual arbitrariness that attenuates the metaphysical significance of relativized presentism.

Recall Carol and Ted, our two observers who are relatively at rest, with Carol at the origin and Ted anywhere along the  $x^1$ -axis (this time possibly including the origin) but also at  $x^4 = 0$ . Carol and Ted, then, agree as to what events are present, what events occur at  $x^4 = 0$ . Suppose that Carol maintains that the events that are real for her are precisely the events with coordinates  $(x^1, x^2, x^3, 0)$ , the events on her plane (or hypersurface) of simultaneity. Suppose Ted disagrees. The events that are real for him, he claims, are pretty much those that are real for Carol, except that around  $x^2 = 3,455$  there is a little bulge of (spacelike separated) points that he insists are real for him. There is no physical reason, as far as I can see, that would underwrite a preference for reality-for-Carol to reality-for Ted. I believe that the presentist can provide no metaphysical reason to prefer one to the other. If this is so, then even

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<sup>16</sup>1981, page 297 of reprinted version.

<sup>17</sup>Which, of course, is not to be confused with the thesis that simultaneity is relative. The latter is non-controversially a feature of STR.

if (*pace* the Relativity Principle cited above) one hyperplane of simultaneity could somehow be singled out as representing *the* present, the presentist still has no way to adjudicate a non-denumerably infinite set of claims that distinct achronal surfaces represent the real at that present.

If this argument is correct, relativized presentism collapses to a position that one might call *hyper-relativized presentism*. Relativized presentism, itself a weak view of dubious intelligibility, seems almost robust when compared to hyper-relativized presentism.

In classical spacetime presentism is a radical doctrine arising from a compelling metaphysical intuition. While it is hard to shake that intuition, the above arguments lead me to the conclusion that it can not even be expressed in Minkowski spacetime. This puzzling predicament raises questions about the relation between metaphysical intuitions and modern physics, between common-sense (or, if you will, manifest) and scientific pictures of the world.

Perhaps ‘refutation’ is not the right word to describe this impasse; but my argument is that, whichever way you prefer to place your bets, there is, at this stage of the dialectic, an intractable incompatibility.

## 4 From STR to GTR

To the above argument one might respond that there is some metaphysically distinguished or absolute simultaneity but that STR is incapable of marking it (and so much the worse for STR). Hinchliff cites a short paper by Arthur Prior (1970) in which Prior writes, “One possible reaction to this situation, which to my mind is perfectly respectable though it isn’t very fashionable, is to insist that all that physics has shown to be true or likely is that in some cases we can never *know*, we can never *physically find out*, whether something is actually happening

or merely has happened or will happen.”<sup>18</sup> Presumably Prior means us to infer that, whether or not we can know it, there is some (physical or metaphysical) fact of the matter as to whether a spacelike separated event has happened, will happen, or is going on right now—a fact of the matter unfortunately beyond the ken of the relativist.

Taken at face value, Prior’s objection really should not be respectable in the least. It trades on readily exploitable pre-relativistic intuitions about time and combines them with (I would conjecture) the sort of anthropomorphized popular presentation of STR that emphasizes “observers” and what they can “see.” These popular presentations are helpful and (as far as they go) accurate, but they often leave the misimpression that STR is as much epistemology as physics, that it is in some way an incomplete view (as it is hoped that quantum mechanics will turn out to be an incomplete view) of reality. A careful presentation of the geometric structures in Minkowski spacetime underlying the physics of STR (such as Naber’s, which underlay my argument) shows that the assumption of the existence of a distinguished plane of simultaneity is incompatible with STR (and its Relativity Principle as cited above) whatever an “observer” can *or cannot* “see” or measure.

But let us take Prior’s suggestion at somewhat more than face value, for there is a sense (though not the one he hoped for) in which STR *is* an incomplete theory. As Misner, Thorne and Wheeler (1973, page 187) note: “the existence of the gravitational redshift shows that a consistent theory of gravity cannot be constructed within the framework of special relativity.” For a relativistic theory of gravitation one must turn to the General Theory of Relativity (GTR).

Indeed, Gödel immediately dismisses the argument I quoted above by noting that certain physicists had suggested a way to reintroduce distinguished layers of now in certain general relativistic spacetimes, and he replies to this move in

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<sup>18</sup>The quotation appears on page 323 of the reprinted version.

a remarkable fashion.<sup>19</sup> If my argument is correct, the presentist should throw in the towel *with respect to STR* but need not admit defeat, for there is GTR and beyond yet to be examined.

On these further fronts, there is some preliminary good news and bad news. The good news is that there are a remarkable variety of spacetime structures in GTR. Some may indeed provide a congenial home for the present. The bad news is that every general relativistic model  $(M, g)$  is required locally to have the structure of Minkowski spacetime.<sup>20</sup> Even in GTR, then, the problems raised for presentism by the above arguments may continue to be relevant, if only tangentially.

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<sup>19</sup>This topic is, of course, beyond the scope of this paper, but a recent paper by Savitt (1994) examines Gödel's argument and contains references to current literature on the topic. Earman examines Gödel's argument more skeptically in the Appendix to chapter 6 of his (1995).

<sup>20</sup>That is, for each  $p \in \mathcal{M}$ , the tangent space to  $p$  is required to have the structure of Minkowski spacetime. See (Naber, pp. 82-3.)

REFERENCES

- Bigelow, J. (1996), "Presentism and Properties" in James E. Tomberlin, ed., *Philosophical Perspectives 10: Metaphysics, 1996* (Cambridge, MA and Oxford, UK; Blackwell Publishers).
- Earman, J. (1995). *Bangs, Crunches, Whimpers, and Shrieks: Singularities and Acausalities in Relativistic Spacetimes* (New York and Oxford: Oxford University Press).
- Gödel, K. (1949), "A Remark About the Relationship Between Relativity Theory and Idealistic Philosophy" in Schilpp, P., ed. *Albert Einstein: Philosopher-Scientist* (LaSalle, IL: Open Court). Reprinted with additions and corrections in Gödel, K. (1990), *Collected Works*, Vol II. Edited by S. Feferman et al. (New York and Oxford: Oxford University Press).
- Godfrey-Smith, W. (1979), "Special Relativity and the Present", *Philosophical Studies* 36: 233-244).
- Hinchliff, M. (1996), "The Puzzle of Change" in James E. Tomberlin, ed., *Philosophical Perspectives 10: Metaphysics, 1996* (Cambridge, MA and Oxford, UK; Blackwell Publishers).
- Misner, C., K. Thorne, and J. Wheeler (1973), *Gravitation* (San Francisco; W. H. Freeman and Company).
- Naber, G. (1988), *Spacetime and Singularities: An Introduction* (Cambridge; Cambridge University Press).
- Nagel, E. (1961), *The Structure of Science: Problems in the Logic of Scientific Explanation* (Burlingame: Harcourt, Brace & World).
- Prior, A. (1970), "The Notion of the Present", *Studia Generale* 23: 245-238. Reprinted in Fraser, J. T., F. C. Haber, and G. H. Miller, eds. (1972), *The Study of Time*, (Berlin, Heidelberg, and New York: Springer-Verlag).
- Putnam, H. (1967), "Time and Physical Geometry", *Journal of Philosophy*

64: 240-247. Reprinted in Putnam's *Collected Papers*, vol. I (Cambridge: Cambridge University Press, 1975).

Rietdijk, C. W. (1966), "A Rigorous Proof of Determinism Derived from the Special Theory of Relativity", *Philosophy of Science* 33: 341-344.

———. (1976), "Special Relativity and Determinism" *Philosophy of Science* 43: 598-609.

Robb, A. A. (1921), *The Absolute Relations of Time and Space* (Cambridge; Cambridge University Press).

Savitt, S. (1994) "The Replacement of Time", *Australasian Journal of Philosophy* 72: 463-74.

Sklar, L. (1981), "Time, Reality, and Relativity" in Richard Healy, ed., *Reduction, Time, and Reality* (Cambridge: Cambridge University Press); Reprinted in Sklar (1985), *Philosophy and Spacetime Physics* (Berkeley: University of California Press).

Stein, H. (1968), "On Einstein-Minkowski Space-time", *Journal of Philosophy* 65: 5-23.

———. (1991), "On Relativity Theory and Openness of the Future", *Philosophy of Science* 58: 147-167.

Van Fraassen, B. (1980), *The Scientific Image* (Oxford; Clarendon Press).

Weingard, R. (1972), "Relativity and the Reality of Past and Future Events", *British Journal for the Philosophy of Science* 23: 119-21.