*Relativity as Support for Presentism: A Modest Evidential Argument*[1]

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**Abstract:** Presentism is roughly the view that only the present exists. This view requires an absolute simultaneity relation. The special theory of relativity, however, is highly successful and does not account for absolute simultaneity. This is widely regarded as an evidential threat to presentism. In what follows, I propose a modest evidential argument in support of presentism on the basis of the physical evidence itself. A weak relativity postulate is shown to follow from a weak light-speed postulate. The weak light-speed postulate, in turn, is shown to be more probable on presentism than on its main rival doctrine, eternalism. Specifically, when one accounts for possible worlds in which the space-time metric is Euclidean (+,+,+,+) rather than Lorentzian (-,+,+,+), the empirical evidence turns out to be more probable on presentism than on eternalism. If successful, this argument provides modest evidential support for presentism and against eternalism. However, the support is drawn from an unexpected source: the physical evidence itself.

## *Introduction*

Presentism is roughly the view that only the present exists. Hilary Putnam suggests this is likely the view of the "man on the street."[2] To see why, note that events within time may be described individually as past, present, or future. This description involves individual tensed properties. Since events in daily life are commonly described using tensed language, one might take it for granted that time is tensed and that tensed language is appropriate. Events may also be



[2] Hilary Putnam, "Time and Physical Geometry," *The Journal of Philosophy* 64, no. 8 (April 27, 1967): 240.

described in relation to each other using terms like "before" and "after". This description makes no reference to the present moment and is therefore tenseless. McTaggart's paradox, however, demonstrates that events cannot be arranged in both tensed and tenseless series since "this would require of any event e that it is both present and future, and this is contradictory."[3] If one wishes to maintain that tense is real—the common sense view—then one simply denies that past and future events exist.[4] So it is that a common sense view of tenses (plus McTaggart's paradox) entails presentism. Of course, one could instead reject tenses. Rejecting tenses (plus McTaggart's paradox) entails eternalism, the view that all events are equally real and that tense is illusory.

Presentism faces several challenges despite this common sense support. Ned Markosian identifies four such challenges, three of which are conundrums involving non-present (and therefore non-existent) objects and times.[5] Markosian's remaining challenge follows from the Special Theory of Relativity (STR). Specifically,

> It is an apparently a consequence of that theory that there is no such thing as absolute simultaneity, and this suggests that which things are *present* is a relativistic matter that can vary from one reference frame to another. This in turn suggests that the Presentist is committed to the claim that what *exists* is a relativistic matter, so that it may well be the case that Socrates exists relative to your frame of reference but does not exist relative to my frame of reference. This would surely be an untenable consequence of the view. [6]

Markosian addresses the challenge from STR by asking, "Does STR have enough philosophical baggage built into it to make it either literally contain or at least entail that there is no such thing as absolute simultaneity?"[7] If so, then Markosian rejects the theory (calling it $STR^{+}$) on account of its philosophical baggage. If not, then the "philosophically austere" theory (called $STR^{-}$) does

[3] Craig Callender, "Shedding Light on Time," *Philosophy of Science* 67 (September 1, 2000): S590.
[4] Ibid.
[5] Ned Markosian, "A Defense of Presentism," in *Oxford Studies in Metaphysics*, ed. Dean W Zimmerman, vol. 1 (Oxford: Clarendon Press, 2004), 49–51.
[6] Ibid., 50–51.
[7] Ibid., 74.

not rule out presentism.[8] Notably, Markosian recognizes that any threat to presentism arises from the philosophical rather than physical-empirical component of STR. The strictly empirical evidence "is consistent with there being such a relation as absolute simultaneity."[9]

Accordingly, William Lane Craig (a defender of presentism) proposes an empirically adequate version of STR that is fully compatible with absolute simultaneity: neo-Lorentzian relativity.[10] Mere compatibility, however, does not impress the skeptic. Regarding Craig's proposal, Yuri Balashov and Michel Janssen suggest,

> the *physical* evidence militates *against* such a return to the days before Einstein … [T]he argument from physics against Craig's metaphysically-motivated proposal is on a par with the argument against proposals to return to the days before Darwin in biology or the days before Copernicus in astronomy.[11]

They then proceed to appeal to certain philosophical virtues of their preferred version of STR—the version normally articulated—that rule out absolute simultaneity.

Rather than addressing these philosophical considerations directly, I would like to instead object to the claim that the *physical* evidence counts against presentist-friendly versions of STR. As I see it, the vast array of physical evidence supporting STR is reducible to confirmations of Einstein's two postulates: the relativity postulate ($R$) and the light-speed postulate ($L$). Supposing, with Markosian and Craig, that both presentism ($P$) and eternalism ($E$) are empirically compatible with Einstein's two postulates ($R$ and $L$), then the physical evidence must take a probabilistic form. Specifically, one may assess the evidence in Bayesian form allowing that R and L may not be independent of each other:

[8] Ibid., 75.

[9] Ibid.

[10] William Lane Craig, *Time and the Metaphysics of Relativity*, Philosophical Studies Series 84 (Dordrecht: Kluwer Academic, 2001).

[11] Yuri Balashov and Michel Janssen, "Critical Notice: Presentism and Relativity," *British Journal for the Philosophy of Science* 54 (2003): 330.

$$\frac{\Pr(P|R\&L)}{\Pr(E|R\&L)} = \frac{\Pr(R|P\&L)}{\Pr(R|E\&L)} \times \frac{\Pr(L|P)}{\Pr(L|E)} \times \frac{\Pr(P)}{\Pr(E)} \qquad (1)$$

Does physical evidence $R$ and $L$ lend support to philosophical view $P$ or to philosophical view $E$? To find out, one must evaluate the two Bayes factors on the right hand side of the equation. Provided that their product is valued greater than one, then one may say that $R$ and $L$ count as evidence in favor of $P$ and against $E$.[12]

In order to proceed, one must first ensure that propositions $R$ and $L$ represent the physical evidence without begging the question in favor of either $P$ or $E$. This requires careful reformulation of Einstein's postulates in the "philosophically austere" form suggested by Markosian so as to not rule out absolute simultaneity (and presentism $P$) *a priori*.[13] This will be the first task below. Following that, I will argue that $L$ entails $R$—the relativity postulate is a natural consequence of the finite speed of light. If so, then the first Bayes factor in Eq. (1) has a value of 1. It then follows that the relevant empirical evidence is given by $L$. I will then argue that $L$ is more probable on $P$ than on $E$. Specifically, when one considers possible worlds in which the space-time metric is Euclidean (+,+,+,+) rather than Minkowskian (-,+,+,+) it becomes clear that presentist Euclidean worlds are not possible. It follows from this that $L$ is somewhat more probable on $P$ than on $E$ and therefore that the second Bayes factor in Eq. (1) is greater than one. Given these two results, it follows that the strictly empirical evidence provides modest evidential support for presentism and against eternalism. Although the support is modest, its source is unexpected: the physical evidence itself.

### ***The Philosophical Austere Physical Evidence***

[12] The third factor represents the prior probability of P and E. Provided that they are non-zero, they need not be evaluated for the purpose of this argument.

[13] Markosian, "A Defense of Presentism," 75.

STR is built on two postulates: the relativity postulate R and the light-speed postulate L. The present task is to find empirically adequate versions of these postulates that do not rule out absolute simultaneity (and presentism) *a priori*. Using Markosian's terminology, I need to identify the two postulates of STR$^{-}$. These postulates are weaker versions of their counterparts in STR$^{+}$. They claim enough to predict the physical evidence that supports STR yet not enough to rule out absolute simultaneity. Therefore, anyone who accepts STR$^{+}$ must also accept the weak postulates of STR$^{-}$ along with other stronger beliefs they may hold about STR.

There are two elements of STR$^{+}$ (as it is normally articulated) that can be removed without any experimental consequences: the theoretical equivalence of all states of uniform motion[14] and the isotropy of the speed of light.[15] Let's begin with the first element of this pair. The relativity postulate generally includes a claim to the effect that one cannot experimentally distinguish between two states of uniform motion. Tim Budden coins this element "nautical relativity" in honor of Galileo's famous ship illustration. Below deck on Galileo's ship, "repetitions of isolated experiments performed in different states of inertial motion yield the same results."[16] It doesn't matter if the ship is sailing north, south, or standing still. There is no experimental way to distinguish between different states of uniform motion from below deck.

As mentioned above, STR$^{+}$ tends involves the additional claim that all states of uniform motion are also theoretically identical. Steven Savitt, for example, seems to understand the relativity postulate in this way. If one singles out one observer as being at absolute rest, one would "hold the principle of relativity to be false … [thereby] rejecting special relativity in favor

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[14] Craig, *Time and the Metaphysics of Relativity*, 26.

[15] Ibid., 29–30.

[16] Tim Budden, "Galileo's Ship and Spacetime Symmetry," *The British Journal for the Philosophy of Science* 48, no. 4 (December 1, 1997): 484.

of presentism rather than accommodating presentism in Minkowski spacetime."[17] Within STR$^-$, however, one might instead follow Craig and suppose that different states of uniform motion have different absolute velocities.[18] Indeed, on Galileo's ship there is a fact of the matter as to whether the ship is sailing north, south, or standing still despite the ignorance of those below deck.

Of course, one could easily tell below deck if the ship is turning or otherwise accelerating. What accounts for this? Steven Weinberg identifies two possibilities. "Either we admit that there is a Newtonian absolute space-time, which defines the inertial frames and with respect to which typical galaxies happen to be at rest, or we must believe with Mach that inertia is due to an interaction with the average mass of the universe."[19] Weinberg recognizes that "the question of what determines these inertial frames was as mysterious after 1905 as in 1686."[20] While the latter explanation has proven more popular, Geoffrey Builder[21] and others have argued for the former explanation. Accordingly, one may reserve judgment as to whether experimentally indistinguishable states of motion ought to also be theoretically equivalent. Given that freedom, one may articulate the relativity postulate $R$ within STR$^-$ as follows:

> $R$: *Within a closed system there is no physical means to distinguish between two states of uniform motion.*

Let's now turn to the second empirically disposable element of STR$^+$: the isotropy of the speed of light. Normally, the light-speed postulate involves a claim to the effect that the speed of light is finite and independent of the motion of the light source. That the speed of light is finite is uncontroversial. That light behaves like a wave in a medium rather than like a projectile—its

[17] Steven Savitt, "There's No Time Like the Present (In Minkowski Spacetime)," *Philosophy of Science* 67 (September 2000): S570.

[18] Craig, *Time and the Metaphysics of Relativity*, 26.

[19] Steven Weinberg, *Gravitation and Cosmology: Principles and Applications of the General Theory of Relativity* (New York, NY: John Wiley & Sons, 1972), 17.

[20] Ibid., 19.

[21] G Builder, "Ether and Relativity," *Australian Journal of Physics* 11, no. 3 (September 1958): 279–297.

speed is independent of its source—has been well established by experimental comparison with emission theories of light, such as those of W. Ritz.[22] However, STR$^+$ proponents tend to further assert that the speed of light is also isotropic—light travels at the same speed in every direction.

The speed of light is intimately related to the question of distant simultaneity. Both are arguably conventional in nature. Ronald Anderson and Geoffrey Stedman explain this well.

> In order to synchronize spatially separated clocks, signals must be sent between them and the time of passage of such signals must be known … But we are caught in a circle here, as the time of passage for first signals can only be obtained by prior knowledge of the synchronization of clocks. The essence of the "conventionalist" position is that this circularity is inescapable and that no fact of nature permits a unique determination of either the simultaneity relation within an inertial frame or the speed of light in a given direction.[23]

Of course, if a signal is sent on a "round-trip" then only one clock is required to measure the time of the journey; no synchronization is required. The "one-way" speed of light, however, is always underdetermined by the experimental evidence.

Anderson and Stedman propose "the conventionality in the choice of the simultaneity, and thus the one-way speed of light, can be seen as a 'local gauge transformation'."[24] Suppose that the speed of light is isotropic with a value of $c$ in coordinate system $(\boldsymbol{x_0}, t_{\boldsymbol{0}})$. Anderson and Stedman show that under the following synchrony gauge transformation (where $\boldsymbol{\kappa}$ is a function of spatial position $\boldsymbol{x}$),

$$\boldsymbol{x_\kappa} = \boldsymbol{x_0}; \qquad t_{\boldsymbol{\kappa}} = t_{\boldsymbol{0}} - \frac{\boldsymbol{\kappa} \cdot \boldsymbol{x_0}}{c}; \tag{2}$$

the one-way speed of light in the direction $\boldsymbol{\hat{n}}$ at point $\boldsymbol{x}$ is given by,[25]

[22] W. Pauli, *Theory of relativity.*, trans. G. Field (New York, NY: Dover, 1981), 5–9.

[23] Ronald Anderson and Geoffrey E. Stedman, "Distance and the Conventionality of Simultaneity in Special Relativity," *Foundations of Physics Letters* 5, no. 3 (June 1992): 200.

[24] Ibid., 203.

[25] Ibid., 204–207.

$$\boldsymbol{c}_{\hat{\boldsymbol{n}}}(\boldsymbol{x},\boldsymbol{\kappa}) = \frac{c\hat{\boldsymbol{n}}}{1 - \hat{\boldsymbol{n}} \cdot \nabla(\boldsymbol{\kappa} \cdot \boldsymbol{x})}. \tag{3}$$

From the form of this equation, it is clear that "the average of the one-way speeds of light in opposite directions is simply equal to $c$."[26] Anderson and Stedman further demonstrate that the average speed of light traveling around any closed loop with the anisotropic velocity given by Eq. (3) will always be $c$.[27] This gauge freedom is further explored by E. Minguzzi who writes,

> Both [simultaneity and electrodynamics] have the mathematical structure of a gauge theory over a one-dimensional group … Other analogies, like that between the Sagnac effect and the Aharonov-Bohm effect, or like that between magnetic forces and the Coriolis forces, become self evident in light of the gauge interpretation.[28]

In summary, the one-way speed of light is a function of clock synchronization and vice-versa—both are gauge dependent. As such, one cannot directly test for the one-way speed of light any more than one can "test for the absolute zero voltage in seawater" since the one-way speed of light—like electric potential—is gauge dependent.[29] Accordingly, we may adopt the following light-speed postulate as part of STR$^{-}$:

> *L*: *There exists a frame of reference in which the speed of light has a finite round-trip average speed of $c$, independent of the motion of its source.*

### *The Relevant Evidence: Light-speed*

We have articulated $R$ and $L$ within STR$^{-}$ in a manner that does not rule out absolute simultaneity *a priori*. The next task is to evaluate the first Bayes factor in Eq. (1). We need to compare the values of $\Pr(R|P\&L)$ to $\Pr(R|E\&L)$. Namely, what is the probability that the relativity postulate would be true given the light-speed postulate plus presentism (or plus

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[26] Ibid., 207.

[27] Ibid., 210.

[28] E Minguzzi, "Simultaneity and Generalized Connections in General Relativity," *Classical and Quantum Gravity* 20, no. 11 (June 7, 2003): 2443–2456, arXiv:gr-qc/0204063v2.

[29] R. Anderson, I. Vetharaniam, and G.E. Stedman, "Conventionality of Synchronisation, Gauge Dependence and Test Theories of Relativity," *Physics Reports* 295, no. 3–4 (March 1998): 99.

eternalism)? I will argue that the light-speed postulate entails the relativity postulate, namely $\Pr(R|L) = 1$. Since $P$ and $E$ are compatible with $L$ and $R$, given their philosophically austere formulation, it then follows that $\Pr(R|P\&L) = \Pr(R|E\&L) = 1$. Therefore the first Bayes factor in Eq. (1) is also equal to one.

The view that $L$ entails $R$ is not new. Simon J. Prokhovnik argues the relativistic effects of length contraction and time dilation "are by no means independent and that both may in fact be consequential on a single more fundamental concept."[30] For Prokhovnik, the fundamental concept of interest is the postulated existence of "a basic inertial system … relative to which electromagnetic propagation is isotropic with velocity c."[31] Prokhovnik calls this system an "aether", although the philosophical and historical baggage associated with that term need not detain us here. It turns out that $L$ as articulated above entails the existence of at least one such system. Although $L$ does not require isotropic light propagation, Ettore Minguzzi and Alan Macdonald demonstrate that the truth of $L$ is sufficient for one to synchronize clocks such that light propagates isotropically.[32] As such, we may regard $L$ as practically equivalent to Prokhovnik's "fundamental concept" from which length contraction and time-dilation may be derived.

Prokhovnik begins by showing that if one assumes both $L$ and the relativistic length contraction of moving bodies, then simple clocks will run slower by the precise amount expected for time-dilation. Therefore, "It is the measurement of time which is effected by motion, the effect resulting from the interplay of two phenomena—the Fitzgerald [length] contraction and

[30] S. J. Prokhovnik, "The Case for an Aether," *The British Journal for the Philosophy of Science* 14, no. 55 (November 1, 1963): 195.

[31] Ibid.

[32] Ettore Minguzzi and Alan Macdonald, "Universal One-Way Light Speed from a Universal Light Speed Over Closed Paths," *Foundations of Physics Letters* 16, no. 6 (December 1, 2003): 593.

the anisotropy of light propagation relative to a moving body."[33] He then goes on to discuss an argument by J. Bastin that inverse-square force laws, such as gravitation and electromagnetism, are modified by motion so that "a moving system of particles would require a clustering of the particles in the direction of motion in order to maintain the equilibrium state of the forces within the system."[34] An object boosted into motion smoothly (rather than merely observed by different observers) will therefore experience a real Lorentz contraction. This point is also described very well by Carlos Barceló and Gil Jannes. They demonstrate using condensed matter systems how an observer internal to the system cannot detect absolute motion with respect to the medium through which they travel.[35]

Given the fact that $L$ entails length contraction and the slowing of physical clocks, it is a simple task to show that $R$ also holds. Herman Erlichson, for example, identifies two alternative derivations of STR: the Lorentz Theory A (LTA) and the Lorentz Theory B (LTB).[36] On the LTA, one assumes an ether, length contraction, and time dilation and then derives the Lorentz transformation equations and the relativity principle. We have seen above that $L$ may be construed (for practical purposes) as an ether hypothesis and that it entails length contraction and time dilation. It follows that $L$ entails $R$.

It is also fruitful to consider Erlichson's LTB.[37] In this case, an ether is hypothesized and the covariance of Maxwell's equations is assumed. One then derives the Lorentz transformations and in turn the relativistic effects of length contraction and clock retardation. It turns out that $L$ is sufficient to support an LTB-style approach to $R$. We have seen that if $L$ is true then one can

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[33] Prokhovnik, "The Case for an Aether," 198.

[34] Ibid., 203.

[35] Carlos Barceló and Gil Jannes, "A Real Lorentz-FitzGerald Contraction," *Foundations of Physics* 38, no. 2 (February 1, 2008): 191–199.

[36] See in particular Table I in Herman Erlichson, "The Rod Contraction-Clock Retardation Ether Theory and the Special Theory of Relativity," *American Journal of Physics* 41, no. 9 (1973): 1069.

[37] Ibid.

additionally render the speed of light isotropic through a careful choice of simultaneity gauge.[38] However, $L$ virtually entails that light signals must obey a wave-equation given their independent isotropic propagation. The wave-equation, however, is necessarily covariant under Lorentz transformations. The Lorentz transformations and relativity principle therefore also follow from $L$ via Erlichson's LTB. Therefore, since $\Pr(R|L) = 1$, Eq. (1) simplifies as follows:

$$\frac{\Pr(P|R\&L)}{\Pr(E|R\&L)} = \frac{\Pr(L|P)}{\Pr(L|E)} \times \frac{\Pr(P)}{\Pr(E)} \tag{4}$$

### ***Light-speed and the Space-time Metric***

The remaining task is to show that $\Pr(L|P) > \Pr(L|E)$, namely that the philosophically austere light-speed postulate $L$ is more likely to be true given presentism than given eternalism. In order to estimate these two probabilities, let's consider three classes of possible worlds potentially available to presentism and eternalism: Minkowski space-time, Galilean space-time, and Euclidean space-time. These space-times have different metrics and therefore different—yet analogous—electrodynamics. One may formulate electrodynamics on all three types of space-time without inconsistency. Of course, electrodynamics as we observe it clearly indicates that the actual world is Minkowskian—the space time metric has the signature (-,+,+,+). We, however, are interested in what sort of world we should expect given the truth of presentism or eternalism, not immediately in what sort of world we actually inhabit. Let's discuss these three classes of possible worlds in turn.

First, we see that a Minkowskian world, such as our own, is compatible with both presentism and eternalism—hence the need for evidential arguments. In such a world L holds since Minkowskian electromagnetic waves travel with a finite velocity independent of the

[38] Minguzzi and Macdonald, "Universal One-Way Light Speed from a Universal Light Speed Over Closed Paths."

motion of their source. The round-trip light-speed is constant since it is possible to choose coordinates such that the metric is made diagonal and the one-way speed of light is set to $c$.

Second, a Galilean world is one in which the speed of light is instantaneous and therefore $L$ does not hold. In such a world Maxwell's equations become invariant under the Galilean rather than Lorentz transformations.[39] Of course, $R$ holds in Galilean electrodynamics although one is able to clearly identify relations of absolute simultaneity—recall Galileo's ship. Absolute simultaneity is necessary but not sufficient to establish presentism. Therefore, such a world is compatible with both presentism and eternalism.[40]

Third, a Euclidean world is one in which the space-time metric is (+,+,+,+) rather than the (-,+,+,+) that we in fact observe. Euclidean space-time is rarely discussed since our world is demonstrably not a Euclidean one. Nevertheless, electrodynamics may be formulated in Euclidean space-time analogously to the formulation in Minkowski or Galilean space-time.[41] In a Euclidean world, the interaction between electric charges and currents is not mediated by signals travelling with a finite velocity and therefore $L$ is does not hold. Rather, every event is causally connected to every other event.[42] Euclidean electrodynamics is essentially a four-dimensional analog of three-dimensional electrostatics and magnetostatics—the wave equation takes an elliptical form.[43] Once again, $R$ is satisfied without $L$ in Euclidean space-time since the equations are invariant under rotations in Euclidean four-space.[44]

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[39] José A. Heras, "The Galilean Limits of Maxwell's Equations," *American Journal of Physics* 78, no. 10 (2010): 1052.

[40] William Lane Craig and Quentin Smith, eds., *Einstein, relativity and absolute simultaneity* (New York, NY: Routledge, 2008), 7.

[41] E. Zampino, "A Brief Study on the Transformation of Maxwell Equations in Euclidean Four-space," *Journal of Mathematical Physics* 27, no. 5 (1986): 1315–1318; José A. Heras, "Electromagnetism in Euclidean Four Space: A Discussion Between God and the Devil," *American Journal of Physics* 62, no. 10 (1994): 914–916.

[42] Zampino, "A Brief Study on the Transformation of Maxwell Equations in Euclidean Four-space," 1317.

[43] Heras, "Electromagnetism in Euclidean Four Space," 915.

[44] Zampino, "A Brief Study on the Transformation of Maxwell Equations in Euclidean Four-space," 1315.

Euclidean space-time differs from Galilean and Minkowskian space time is one important respect: *it is incompatible with presentism*. In a presentist Euclidean space-time, present events that exist stand in symmetric causal relations with future events that do not yet exist (and with past events that no longer exist). One may contrast this situation with a Galilean world in which any two present events mutually influence each other by virtue of instantaneous electromagnetic interactions. In the Galilean presentist case, both events exist. Not so in the Euclidean case where all events influence all other events symmetrically without any regard for which events exist. Of course, in a presentist Minkowski space-time presently existing events stand in causal relations with non-existent events on their past and future light-cones. However, these relations are not symmetrical: two events cannot both lie on the others' future light cone (or both on the others' past light cone). The causal symmetry between existing and non-existing events is the root of the problem for presentist Euclidean space-time. On this basis, I take it that there are no possible worlds in which presentism and Euclidean space-time both are true.

Let $m$, $g$, and $e$ represent the propositions that the world is Minkowskian, Galilean, and Euclidean respectively. Based on the considerations above, we may write $\Pr(L|m) = 1$, $\Pr(L|g) = 0$, $\Pr(L|e) = 0$, and $\Pr(e|P) = 0$. It follows that,

$$\begin{aligned}\Pr(L|P) &= \Pr(L|m\&P)\Pr(m|P) + \Pr(L|g\&P)\Pr(g|P) \\ &\quad + \Pr(L|e\&P)\Pr(e|P) \\ &= \Pr(m|P).\end{aligned} \tag{5}$$

In the case of eternalism,

$$\begin{aligned}\Pr(L|E) &= \Pr(L|m\&E)\Pr(m|E) + \Pr(L|g\&E)\Pr(g|E) \\ &\quad + \Pr(L|e\&E)\Pr(e|E) \\ &= \Pr(m|E).\end{aligned} \tag{6}$$

If we take the possible worlds to be Minkowskian, Galilean, or Euclidean then we may write,

$$1 = \Pr(m|P) + \Pr(g|P), \tag{7}$$

and also,

$$1 = \Pr(m|E) + \Pr(g|E) + \Pr(e|E). \tag{8}$$

As such,

$$\frac{\Pr(L|P)}{\Pr(L|E)} = \frac{\Pr(m|P)}{\Pr(m|E)} = \frac{1 - \Pr(g|P)}{1 - \Pr(g|E) - \Pr(e|E)}. \tag{9}$$

The question here becomes, "how likely are Minkowskian, Galilean, and Euclidean space-times on presentism and eternalism?" Here we must be careful to avoid introducing further background knowledge from the actual world. Supposing that the possible space-times are equally probable on $P$ or $E$, with the exception of Euclidean presentist worlds, then we have:

$$\frac{\Pr(L|P)}{\Pr(L|E)} = \frac{3}{2}. \tag{10}$$

More conservatively, it is clear that any probability $\Pr(e|E)$ of a Euclidean eternalist space-time detracts somewhat from the likelihood of eternalism given the experimental evidence. Given a four-dimensional eternalist world, why think that such a world is not likely to be Euclidean? I can't think of a comparable reason to the one offered above against the possibility of presentist Euclidean worlds.

Concerning the probability of a Galilean world, it would be a mistake to think that $\Pr(g|E)$ is particularly low or that $\Pr(g|P)$ is particularly high in order to escape this evidential argument. William Craig and Quentin Smith note that the absolute simultaneity of Galilean space-time poses no threat to eternalist interpretations of that space-time.[45] Galilean space-time is not necessarily more likely on presentism than eternalism. Rather, it is the perceived evidential weight of Minkowski space-time in favor of eternalism that may lead one to suppose that Galilean space-time is the *de facto* ally of the presentist. The purpose of this argument has been to challenge and correct that perception. Therefore, if the argument above is successful,

[45] Craig and Smith, *Einstein, relativity and absolute simultaneity*, 7.

then we have good reason to take the second Bayes factor in Eq. (1) to be greater than one. It then follows that physical evidence lends modest support to presentism rather than eternalism.

### ***Application: Potential Responses to Four Objections***

The evidential argument presented above sheds light on various objections to presentism motivated by STR. In what remains I will offer brief (non-rigorous) responses to four such objections. The first is the so called "conspiracy of nature objection" to presentism. On this objection, the objector recognizes both that absolute simultaneity is a necessary condition for presentism and that nature does not permit the detection of absolute simultaneity relations. The presentist likely agrees with this. The objector then offers a dilemma. Either nature is fine-tuned to hide absolute simultaneity relations[46] or they don't exist. The former is implausible, hence the distain for a natural conspiracy, so the latter must be true. Given the discussion above, however, it ought to be clear that absolute simultaneity relations are hidden as a consequence of the light-speed postulate. However, the light-speed postulate is highly qualitative and does not exhibit the typical features of fine-tuning. The presentist is therefore free to reject the dilemma. Indeed, on presentism instantaneous signals are a privilege, not a right. As it happens, $L$ ensures that simultaneity is gauge dependent. No conspiracy of nature is necessary to hide absolute simultaneity; one merely needs $L$ to be true.

The second objection is that absolute simultaneity is "otiose"—a "free rider in the theory"—and should therefore be removed from any reasonable interpretation of STR.[47] This may also be construed as an appeal to the supposed ontological parsimony of $STR^+$. Thomas

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[46] cf. Tim Maudlin, "Non-local Correlations in Quantum Theory: How the Trick Might Be Done," in *Einstein, Relativity and Absolute Simultaneity*, ed. William Lane Craig and Quentin Smith (New York, NY: Routledge, 2008), 164.

[47] Ibid.

Crisp points out, however, that the eternalist "postulates a vast realm of past and future entities not postulated by the presentist."[48] Perhaps these entities, rather than absolute simultaneity, ought to be shaved off of the theory. Which entities hold greater explanatory power over the physical evidence? In the argument presented above we have seen that the empirical evidence $R$ and $L$ is more probable on presentism than on eternalism. Furthermore, since explanatory power can also be expressed in Bayesian terms, one may restate the results above in terms of explanatory power.[49] Specifically, since $L$ entails $R$, $L$ explains $R$. Furthermore, since $L$ is more probable on $P$ than on $E$, $L$ is better explained by $P$ than by $E$. Since presentism holds greater explanatory power over $R$ and $L$, perhaps it is the "vast realm of past and future entities"[50] rather than absolute simultaneity that deserves to be described as otiose.

An alternate form of this objection is pressed by those who deny the conventionality of simultaneity, often citing David Malament's famous result.[51] It is important to realize that the significance of Malament's result within the conventionality debate is both contested[52] and irrelevant to the argument presented above. Suppose that Malament does succeed in arguing that only one simultaneity relation per observer is definable in terms of the causal structure of space-time—a point not conceded by Adolf Grünbaum.[53] The argument above merely uses the uncontroversial, demonstrable gauge freedom of simultaneity to formulate weak versions of the relativity and light-speed postulates. No prior commitment is required to the significance of this

[48] Thomas M. Crisp, "Presentism, Eternalism and Relativity Physics," in *Einstein, Relativity and Absolute Simultaneity*, ed. William Lane Craig and Quentin Smith (New York, NY: Routledge, 2008), 270.

[49] cf. Jonah N. Schupbach and Jan Sprenger, "The Logic of Explanatory Power," *Philosophy of Science* 78 (January 2011): 105–127.

[50] Crisp, "Presentism, Eternalism and Relativity Physics," 270.

[51] David Malament, "Causal Theories of Time and the Conventionality of Simultaneity," *Noûs* 11, no. 3 (September 1, 1977): 293.

[52] Anderson, Vetharaniam, and Stedman, "Conventionality of Synchronisation, Gauge Dependence and Test Theories of Relativity," 121–126.

[53] Adolf Grünbaum, "David Malament and the Conventionality of Simultaneity: A Reply," *Foundations of Physics* 40, no. 9–10 (October 1, 2010): 1285–1297.

gauge freedom or as to whether any one simultaneity gauge is metaphysically preferred. Once the argument goes through, however, one obtains evidential support for presentism and the absolute simultaneity that it entails. This physical support counts as a reason to consider the possibility of simultaneity relations not defined by the causal structure of space-time.

The third objection may be called the "coordination problem." Craig Callender argues that potential absolute simultaneity relations "preferred by quantum mechanics may not be [those] preferred by metaphysics."[54] Specifically, why think that any given physical absolute simultaneity relation is the same as the metaphysical relation entailed by presentism? In the argument presented above, however, there is no need to identify any given physical simultaneity relation with the present of the presentist. Rather, one may show that R entails L without either positing or ruling out absolute simultaneity of any sort. Next, one may show that presentist Euclidean worlds are not possible by merely considering the presentist simultaneity relation of what exists "now". As such, the argument does not depend on a physical example of absolute simultaneity. Therefore, Callender's coordination problem may be left unsolved without undercutting this argument.

The last objection may be called the "common origins objection." Balashov and Janssen suggests that on presentist interpretations of STR, such as Craig's,[55]

> it is, in the final analysis, an unexplained coincidence that the laws 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 [eternalist] 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 [eternalist] interpretation.[56]

[54] Craig Callender, "Finding 'Real' Time in Quantum Mechanics," in *Einstein, Relativity and Absolute Simultaneity*, ed. William Lane Craig and Quentin Smith (New York, NY: Routledge, 2008), 65.
[55] Craig, *Time and the Metaphysics of Relativity*.
[56] Balashov and Janssen, "Critical Notice: Presentism and Relativity," 341–342.

Put simply, "there are brute facts in [Craig's] neo-Lorentzian interpretation that are explained in the [eternalist] space-time interpretation."[57] Balashov and Janssen therefore argue—counter to my claims above—that eternalism best explains the physical evidence and is therefore more probable on that evidence than presentism. Among other things, our arguments differ over whether $L$ entails $R$. This is a critical difference since if $L$ entails $R$ then it is $L$—rather than $R$—that is the relevant *explanandum*. In order to generalize the argument presented above to account more clearly for non-electromagnetic systems one also would need to generalize the light-speed postulate. In principle, this involves discussing non-Abelian gauge theories. One must then argue that $R$ also follows from a generalized $L$. I propose doing so as follows.[58]

Physical field theories involve interactions between locally conserved source currents through intermediary fields. Supposing that no field interaction between sources is instantaneous (generalized $L$), then observers will enjoy a conventionality/gauge freedom of simultaneity similar to that discussed above. Via Noether's theorem, an observer will be able to formulate a field theory describing the interactions between conserved source currents. This is possible in any coordinate system in which the sources are observed to be locally conserved. However, source conservation—like Doppler shift and aberration—is independent of what simultaneity gauge one chooses. Therefore, observers in relative motion who agree that a given source current is conserved may use Noether's theorem to formulate the same physical field theory in different coordinates. Specifically, one cannot expect a breakdown of the Lorentz invariance of physical laws without a corresponding observed breakdown of the conservation of the source currents. The finite speed of source interaction permits multiple equivalent formulations of the

[57] Ibid., 342.
[58] Benjamin B. Nasmith, "Presentism in a World Denied Instantaneous Signals," (2011): [Preprint] URL: http://philsci-archive.pitt.edu/id/eprint/8836 (accessed 2013-03-02).

same field theory in different coordinates. Therefore, a generalized $L$ also entails $R$. If this approach succeeds, the generalized $L$ (rather than $R$) becomes the proper *explanandum* of presentism and eternalism. In light of the discussion above, a generalized $L$ is also better explained by presentism than by eternalism. Accordingly, the common origins objection need not trouble the presentist.

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