Relativity, the Open Future, and the Passage of Time*

Oliver Pooley

14 August, 2013

Is the objective passage of time compatible with relativistic physics? There are two easy routes to an affirmative answer: (1) provide a deflationary analysis of passage compatible with the block universe or (2) argue that a privileged global present is compatible with relativity. (1) does not take passage seriously. (2) does not take relativity seriously. This paper is concerned with the viability of views that seek to take both passage and relativity seriously. The investigation proceeds by considering how traditional A-theoretic conceptions of passage might be generalised to relativistic spacetimes without incorporating a privileged global present. I argue that the most promising position marries the idea that open possibilities for the future are settled as time passes with a 'non-standard' interpretation of the relevant formal models.

I

The Project. This paper is concerned with the viability of a metaphysics of time that is both properly relativistic and which vindicates the objective passage of time. 'Properly relativistic' will be explained shortly. First, some remarks about what I take the objective passage of time to involve.

Time's alleged passage is notoriously difficult to pin down. There is, however, a rather straightforward idea that, if not fully capturing what is meant by the passing of time, is at least centrally associated with it. It figures prominently in the writing of both critics and fans of passage, including those of Arthur Prior, whose account of passage I review below. A perhaps more surprising recent source is the philosopher of physics John Norton, who writes:

> Time passes. Nothing fancy is meant by that. It is just the mundane fact known to us all that future events will become present and then drift off

*This is a draft of a Paper to be published in the *Proceedings of the Aristotelian Society*. Please cite the published version.

> into the past… Time really passes… Our sense of passage is our largely passive experience of a fact about the way time truly is, objectively. The fact of passage obtains independently of us. (Norton 2010, p. 24)[1]

There are two things to take away from this quotation. The first is that the passage of time involves what Prior (1968, pp. 1–2) called the 'becoming ever more past' of events: future events 'become present' and then 'drift off into the past.' The second is that this change in the degree of pastness of events is supposed not to be merely a function of our (changing) perspective on reality: it is a feature of the way 'time truly is… independently of us.' When I write of *real* or *objective* passage, I intend to highlight the second of these features.

So understood, the passage of time conflicts with relativistic physics. Responses to this conflict are usefully categorised in terms of attitudes to two alleged entailments. The first of these is that relativistic physics implies a 'B-theoretic' or 'block universe' view of time. The second is that the B Theory of time implies that there is no objective temporal passage. In these terms, there are three options open to the defender of real passage: reject relativity; or reject one of the two alleged entailments. This paper explores the option of denying the first supposed entailment, that is, denying that accepting relativity commits one to the block universe. Within this option there is a further, important distinction to be drawn. By far the most popular way to seek to reconcile relativity with an A-theoretic[2] view of time involves arguing that a privileged, spatially global present is compatible with relativity. My topic, in contrast, is the possibility of a 'properly relativistic' A-theoretic view that fully respects the symmetries of relativistic spacetime. Such a view will eschew a global Now.

Why seek after such a view? In the next section I summarise the B Theory, and endorse the second entailment; accepting the B Theory does commit one to denying that the 'becoming more past' of events is an objective feature of reality. This puts the B Theory in prima facie conflict with our ordinary, pre-theoretic conception of time, according to which the passage of time is a real, mind-independent phenomenon. I firmly believe that the B theorist can account for our mistaken belief that time really passes, but I also believe that a fully satisfactory explanation of the required type has yet to be given.[3] This motivates exploring whether the passage of time might,

[1] For similar descriptions by critics of passage, see, e.g., Smart (1949, p. 483) and Olson (2009).

[2] I am using the term 'A-theoretic' as a convenient label for any view of time according to which there is more to time than is captured by the B theorist's block universe.

[3] The parochial nature of our multiple, temporally-ordered perspectives on reality should feature centrally in any such story, as should the relationship between the causal and temporal structure of the world. Efforts by B theorists to account for our sense that time passes have been many and varied; see, for example, Grünbaum (1967); Mellor (2001); Falk (2003); Ismael (2011); Dainton (2011); Paul (2010); Prosser (2012); Deng (2013*b*). I side with Ismael and Deng, against Paul and Prosser, in that I do not believe that our mistaken view that time passes has its roots in experiential illusion.

after all, be compatible with relativity.

The investigation in the rest of the paper proceeds as follows. After discussion of the B Theory, four sections review non-relativistic views that seek to vindicate objective temporal passage. I start with presentism, for a grasp of how this view incorporates temporal passage is key to understanding the claims of the Moving Spotlight and the Growing Block theories, discussed next. I then consider what I call, following Fine (2005), 'non-standard' A Theories, before turning to views that link the passage of time to the idea that the future is open. This reasonably extensive survey provides the tools needed to identify an alternative to the B Theory that is properly relativistic. Relativistic generalisations of the Moving Spotlight view and the Growing Block view have recently been considered by Skow (2009) and by Earman (2008) respectively. Reviewing their efforts paves the way for consideration of 'non-standard' relativistic generalisations of views that link passage to the open future.

Finally, it is important to distinguish formal models from how these models are supposed to express the central commitments of the defender of real passage. In these terms, generalisation of A-theoretic views to relativity involves two stages: (1) identifying relativistic analogues of the classical models; and (2) explaining how such models articulate a non-B-theoretic view of time. The first step is relatively straightforward, and generically involves replacing a structure of totally ordered elements (intended, for example, to represent the tensed facts that hold as of some time) with a structure whose elements are only partially ordered. The harder task is to generalise to relativity the kind of stories that can be told about the pre-relativistic models.

II

Time Does not Pass in the Block Universe. As I am using the label, the B Theory of time can be characterised via the following question:

> Is an exhaustive catalogue of which events occur, and how they are temporally related, a complete account of temporal reality?

I define the B theorist as someone who answers this question in the affirmative. The imagined exhaustive description of the temporal relatedness of events is assumed to be tenseless: holding once and for all, from no temporal point of view. The fundamental temporal relations in question are those of the 'B series': relations of temporal precedence and, perhaps, temporal distance (duration).

The view is best elucidated via key spatial analogies. A description of reality that includes the spatial disposition of all objects and events relative to one another

Rather, it involves a mistaken way of thinking about experience that is in itself veridical.

('object *a* is five metres from object *b*, in the direction defined by the line joining objects *c* and *d*' etc.) leaves nothing out, spatially speaking.[4] One does not need to further specify that object *a* is *here*, or twenty metres *to the left*. Such information simply serves to locate objects spatially relative to ourselves, and (barring improbable symmetries) is anyway deducible: if the view-from-nowhere characterisation of reality is really complete, then one can in principle locate oneself spatially, and determine one's orientation in the world so described.

The B theorist likewise holds that to provide a complete account of temporal reality one does not need to specify which events are occurring *now*. Consider, for example, the present-tensed claim that you are reading. This is a true claim—you are, in fact, reading now. But it is also a fact that (as I write this) it is cloudy, i.e., cloudy *here*. The B theorist claims that such facts are strictly analogous. Their truth merely reflects our spatiotemporal perspective. Just as the fact that it is cloudy here is to be understood in terms of the spatially non-indexical fact that it is (on the relevant date) overcast at a latitude of 32.9°N and a longitude of 117.2°W, so too the fact that you are (now) reading is to be understood in terms of the tenseless claim that you are (in the tenseless sense of 'are') reading at . . . on . . . (look at your watch, and fill in the blanks).

On this picture, all times are on a par, fundamentally speaking. Consider the obvious spatial parallel. Almost no one believes that any particular spatial location is metaphysically privileged. Spatial places differ in all sorts of ways. One part of space currently contains me; another similarly-shaped part is completely filled with a portion of the Pacific Ocean. But these differences do not make any particular place special in the relevant metaphysical sense. Fundamentally speaking, they are all an equal part of reality. In particular, our immediate spatial location, the spatial analogue of the present time, is not metaphysically special, whether by virtue of the possession of some peculiar property or otherwise. Similarly, the B theorist does not regard the current time as in any way metaphysically privileged.

Since I am concerned with the compatibility of various views with relativistic physics, I should note that these time/space analogies involve relativistically suspect notions, namely, *times* and *spatial places*. According to relativity, at a fundamental level there simply are no such things. But note that my original characterisation of the B Theory, via an affirmative answer to the question at the start of this section, is not similarly problematic. Moreover, the relativistic generalisation of the claims of the preceding paragraphs is straightforward. It is the thesis that, fundamentally speaking, all regions of spacetime are on a par, regardless of the particularities of their extension in spatial, temporal and null directions.[5] The core of arguments

[4]Spatial points might be amongst the objects in question, so this characterisation is neutral between substantivalist and relationalist views of space.

[5]Eliminating time talk in order to provide a relativistically acceptable statement of the B Theory might be straightforward, but it leaves a substantive task for the relativistic B theorist to address. Even

from relativity to the B Theory is that the classical A-theoretic alternatives to the block universe do not generalise in this straightforward way.

This sketch of the B theory should have made it clear that the view implies that there is no objective passage of time. Relatively recently, however, several authors have insisted that time passes according to the B Theory, even independently of the perspectives of subjects embedded within time.[6] Dieks (2006), for example, equates 'temporal becoming' with the (non-perspectival) 'successive coming into being of events.' This sounds like it should be incompatible with the B Theory, according to which all events tenselessly exist, each at their particular spatiotemporal location. The block universe undergoes no change, so how can some part of it 'come into being'? Doesn't that require a change in the block, from a state in which it did not have that event as a part, to a state in which it does? Dieks, however, is not proposing any such thing. Instead, he holds that an event's coming into being is simply its happening ('what other coming into being could there be?'). He then notes that:

> Since everything that happens is recorded in the block universe diagram, 'coming into being' is also fully represented… This proposal boils down to a deflationary analysis of becoming: becoming is nothing but the happening of events, in their temporal order. (Dieks 2006, pp. 170–1)

If one wishes to label the successive occurrence of events 'temporal passage' then, yes, time passes according to the B Theory. John Earman rightly labels this a 'thin and yawn-inducing' sense of passage (Earman 2008, p. 159). Its advocates seem to be making heavy weather of facts that (almost) no one has ever denied. Worse than this, though, their claim to have successfully identified temporal passage in the block universe risks diverting attention from the key challenge that the B theory faces, namely, that of providing a B-theoretic explanation of why we are inclined to take the 'becoming more past' of events as an objective feature of reality. From here on in, the focus is on views that seek to vindicate this sense of passage, rather than, as the B-theorist must, explain it away.

---

those who do not take tense metaphysically seriously need to give an account of the truth conditions for tensed language (and of our ordinary talk of times) as used in a world that, fundamentally, does not contain times (see, e.g., Gibson and Pooley 2006, pp. 165–7).

[6] I have in mind, in particular, Dorato (2006), Savitt (2002) and Dieks (2006). Because they do not all self-identify as B theorists, perhaps because they are sceptical that there is a substantive dispute between A and B theorists, they might not characterise their efforts as arguing for the reality of passage on the B Theory. I should also mention Maudlin (2002; 2007, ch. 4), who styles himself as a defender of the block universe and yet believes in the objective passage of time in a more robust sense than allowed by Dieks *et al.* Whether he counts as a B-theorist in the sense of this section is not straightforward. The fact the he is a realist (and primitivist) about the passage of time suggests that he should view a description only of the temporal relatedness of all events as incomplete. However, he might also deny that it makes sense to say that one event stands in (e.g.) the 'earlier than' relation to another unless time passes (in his sense). I do not claim to understand Maudlin's view.

III

Presentism and the Passage of Time. Presentism is sometimes informally characterised as the view that only the present time exists.[7] It is true that the presentist, unlike the B theorist, does not believe that past and future times are distant parts of concrete reality. But this is not because they believe in the existence of only one of the B theorist's many times, a single 3-dimensional slice of the B theorist's block. According to the presentist, the material world is extended in only three spatial dimensions, and not extended in a temporal dimension. *The world* is not naturally characterised as *the present time*. A better characterisation of presentism starts with the observation that, for the presentist, truth *simpliciter* is tensed. Truth *simpliciter* is just what is presently true. The present truth about our three-dimensional world exhaustively characterises reality, and this includes how it was and how it will be, as well as how it presently is.

For the presentist, tensed facts are not reducible to how things tenselessly are at different parts of a temporally extended reality. In fact, the presentist holds that the opposite is true. How things 'tenselessly' are at past and future times is to be analysed in terms of present, tensed truth. Times, including the present, are logical constructs that allow for an elegant representation of the fundamental, tensed facts. With presentist times so understood, we are at liberty to use time talk again.[8] It follows that the block universe model, supplemented with an indication of which three dimensional subregion is the present (together, perhaps, with a future-pointing arrow), exactly encodes the presentist's commitments. One need only be careful not to misinterpret different parts of the block as corresponding to different parts of a tenselessly existing concrete reality. Instead they collectively represent all that is happening, has happened or will happen.

A natural thought at this point is that something crucial is still missing from the model. In what sense does it capture the passage of time? Doesn't the model need continual updating? Doesn't the region of the block representing the present need to move up the block, in the direction of the arrow? Perhaps the single block needs to be replaced by uncountably many copies, each with the present differently located, each representing the different sets of tensed facts that hold as time passes. Here is how Kit Fine expresses the worry:

> The passage of time requires that the moments of time be *successively* present and this appears to require more than the presentness of a single moment of time. The [presentist] at this point might appeal to

[7] A popular alternative, also in terms of existence, involves claims such as: necessarily, it is always true that only present objects exist (see, e.g., Markosian 2004). The characterisation of presentism advocated in the main text is intended to be compatible with this claim.

[8] A popular presentist move identifies times with maximal propositions of a certain kind. My characterisation of presentism is intended to be compatible with this ploy.

> the fact that any particular future time t^+ *will be* present and that any particular past time t^- *was* present. However, the future presentness of t^+ amounts to no more than t being present and t^+ being later than t…
>
> We naturally read more into the [presentist]'s tense-logical pronouncements than they actually convey. But his conception of temporal reality, once it is seen for what it is, is as static or block-like as the [B theorist]'s, the only difference lying in the fact that his block has a privileged centre. (Fine 2005, p. 287)

The worry is misplaced, as a review of Prior's account of presentist passage reveals.

Prior unpacks his first-pass characterisation of the passage of time, as the becoming ever more past of events, in tense-theoretic terms. Part of his story involves an eliminativism about events. Consider the recession into the past of Prior's falling out of a punt. According to Prior, to say that this event has so far receded 57 years into the past is to say nothing more than that Prior fell from a punt 57 years ago. Or, in semi-regimented language using metric tense-operators, WAS_{57y}(Prior is falling out of a punt).[9] Prior contends that this last sentence is not about any objects except him and the punt from which he fell: 'there is no real reason to believe in the existence either now or [57] years ago of a further object called "my falling out of a punt"' (Prior 1968, p. 10).

So far we have only considered how the Priorian presentist analyses apparent talk of events and their current pastness, or futurity. What about the *changes* in pastness and futurity that are constitutive of time's passage? Consider, again, Prior's fall from a punt. It was, just a year ago, only 56 years in the past. It is now no longer only 56 years in the past. In another year, it will be the case that Prior fell from a punt 58 years previously: the event will have receded a further year into the past. Letting 'P' stand for 'Prior is falling out of a punt,' in Prior's operator-theoretic regimentation, one has:

$$\mathrm{WAS}_{1y}(\mathrm{WAS}_{56y}(P)) \wedge \neg\mathrm{WAS}_{56y}(P) \wedge \mathrm{WAS}_{57y}(P) \wedge \mathrm{WILL}_{1y}(\mathrm{WAS}_{58y}(P)). \quad (1)$$

Can tense-theoretic claims like this really be all that the presentist needs to express the passage of time? Two reflections might help to assuage doubts. First, compare these tensed claims to the presentist's expression of everyday changes in ordinary objects, for example, my change in shape as I go from standing to sitting. For the presentist, this amounts to the fact that I am now sitting but that I was, a moment ago, standing, and so not sitting. In other words, change involves conjunctions of the form $P \wedge \mathrm{WAS}_n(\neg P)$. But, with a little redefinition, this is exactly what we have in the first two conjuncts in (1). The combination of the tensed facts (i) that I was standing but (ii) that I am not now standing amounts to real, objective

[9] '$\mathrm{WAS}_{57y}(P)$' is to be read as 'It was the case 57 years ago that P' etc.

change. Why should the same not be true of the combination of the tensed facts (i) that Prior's falling was 56 years ago and (ii) that this falling is not now 56 years ago?

The second reflection is this. If this second conjunction is genuine change, what kind of change is it? What is changing? We have seen that, for Prior, it is not the event of his falling, rather it is Prior himself.[10] Now, going from being such that one fell 56 years ago, to being such that one fell 57 years ago might seem to be a very anaemic kind of change. But this is exactly what one wants! It is exactly the change that is due to no more than time's passing. All robust intrinsic change could cease but, the defender of real passage thinks, things would continue to change merely by becoming older, for time continues to pass.

Let us return to Fine's charge that presentism is as static and block-like as the B Theory. One way to put the worry is that a block with a privileged centre represents only a proper sub-collection of the full set of tensed truths that obtain over time, as time passes. We have seen, however, that this set of present truths expresses genuine change. And, while some of these truths (like the facts that I'm now sitting but that I was standing) concern ordinary change in ordinary objects, others express the very change we are concerned with, namely, change in what is true. The present, tensed facts include, for example, facts to the effect that certain tensed propositions are not now true *but that they were or will be true*.[11] One simply cannot accept all the present, tensed truths without accepting that what is true undergoes genuine change.

Deng (2013*a*, pp. 29–31) provides a sympathetic application of Fine's criticism to presentist accounts of passage of the kind considered here. Her conclusion is not that time does not pass according to presentism, but that presentism is no better at capturing passage than the B Theory. However, what we have seen is that presentism vindicates, (i) events objectively becoming ever more past, (ii) an absolutely privileged time and (iii) genuine change in which time is privileged. Together these correspond to a sense in which there is real passage of a kind that is (rightly!) missing from the B Theory.

IV

The Moving Spotlight and the Growing Block. The Moving Spotlight and the Growing

[10]Save for the fact that he no longer exists. How to treat apparently singular propositions about things that no longer exist is a well known problem for presentism, but it is not *per se* a problem for their account of passage. Realistically, at any time there will always be numerous persisting things then existing to which passage-related change can be ascribed. But even in a maximally evanescent world that lacks persisting entities, one still has combinations of the form $\mathrm{WAS}(\exists x Fx) \wedge \neg Fx$. For Prior, this 'quasi change' (which does not require a presently existing entity that once was F but is so no longer) is sufficient for passage.

[11]See Markosian (2004, p. 78) for a Prior-like cashing out of passage in closely related terms.

Block views agree with the B Theory, against presentism, that past (and in the case of the Moving Spotlight view, future) times are as much a part of concrete reality as the present moment. They disagree with the B Theory in denying that a once-and-for-all description of the temporal relatedness of all parts of this temporally extended reality constitutes a complete account of time. These similarities justify discussing both theories together, for their main problems stem from this shared combination of commitments. I focus primarily on the Moving Spotlight view; some of the peculiarities of the Growing Block are discussed at the end of the section.

In a paper concerned with its potential relativistic generalisation, Brad Skow provides this nice summary of the Moving Spotlight theory:

> The theory combines eternalism—the doctrine that past, present, and future times all exist—with "objective becoming." The claim that there is objective becoming has two parts. First, facts about which time is present are nonrelative. That is, even if in some sense each time is present relative to itself, only one time is absolutely present… And second, which instant is absolutely present keeps changing. The NOW moves along the series of times from earlier times to later times. (Skow 2009, p. 666)

Clearly the claim that the NOW moves along the time series is central to the view's vindication of temporal passage. What sense can be made of it? A familiar 'two times' objection rears its head.[12] Movement is just change in location in some space with respect to time. But since the movement in question is that of the NOW's position in time, it seems that one needs to postulate an additional temporal dimension—*supertime*—with respect to which the NOW's position in ordinary time can be said to change. The smooth movement of the NOW, from past to future, is cashed out as the fact that, from the perspectives of ever Later[13] supertimes, the NOW is located at ever later times.

Skow thinks that the supertime picture is a useful aid to grasping the content of the theory rather than a *reductio* of it. He also insists that supertime is strictly a fiction. His official story is spelled out in terms of primitive tense operators: 'If it is NOW time t, then to say that the NOW moves from the past to the future is to say that *it was the case that* a time before t was NOW, and *it will be the case that* a time after t [will be] NOW' (Skow 2009, p. 668). Our review of presentism allows us to see that this move indeed gives us genuine change in which time is NOW. Moreover it is a type of change that can be combined with there being an absolute fact about which time is NOW.

[12] See, e.g., Broad (1923, p. 65) and, for the classic exposition, Smart (1949).

[13] I follow Skow's convention of distinguishing relations that order supertimes from those that order ordinary times by capitalising terms for the former.

So far, so good, but now consider how the official tense-theoretic story and the supertime metaphor are related. Suppose, again, that it is NOW time t and let how things are from the perspective of supertime T correspond to how things are *simpliciter*. What does it mean to say that WAS(a time earlier than t is NOW)? Skow suggests that this corresponds to the supertime claim that, from the perspective of some supertime T' Earlier than T, some time t' earlier than t is NOW.[14] This might surprise someone familiar with typical model-theoretic treatments of tense logic. After all, the meanings of tense operators are normally related to what is the case at ordinary times, not to what is the case at different points in supertime. But Skow is absolutely right to set things up as he does. It is the Moving Spotlighter's points of supertime, not the 'ordinary' times that they postulate as distinct parts of concrete reality, that play the role that ordinary times play for the presentist.

This points to a deeply problematic feature of the view, at least in this version. For the Moving Spotlighter, the eternalist thesis that past and future times exist on a par with the present is a tensed claim. 'Eternalism' is therefore apt, for the view involves the eternal persistence, in the presentist's sense of persistence, of all these times. They are taken to (always) be concrete parts of a (persisting) 4-dimensional reality. This reality changes (in the presentist's sense of change), but only by virtue of changes in which part of concrete reality is absolutely present.

Appeal to primitive tense does not, after all, avoid the two times problem. There *are* two times, it is just that one (ordinary time) is B-theoretic and the other (supertime) is A-theoretic. On the picture of reality being offered, I exist (somehow or other) at many 'temporal' locations along a thin tube-like region of a four-dimensional block and, moreover, I always was so located and will always continue to be so. I would like to think that I (or some temporal part of me) is located in a subregion of the block that is absolutely present. I would also like to think this privileged location is where I am typing this sentence. But with what right do I assume either of these things?[15] The Moving Spotlight theory is not a plausible view. It succeeds, like presentism, in securing an absolute yet changing fact of the matter about which time is present. In this context, however, its commitment to the equal reality of past and future times is a flaw not a feature.

I conclude this section with a few remarks the Growing Block theory. Prior's 'becoming more past' covers, as well movement from the near past to the far past, movement from the far future to the near future, and from the near future to the present. Unlike the Moving Spotlighter, the Growing Blocker treats these transitions very differently.

The central primitive notion of the theory corresponds to an event's passage

[14]Such supertime truth conditions for tensed statements are not meant as an analysis of tense. Rather, such claims are supposed to explicate supertime talk in terms of primitive tense.

[15]There is now a small literature on this 'how do I know that it is NOW now?' objection, originally pressed by Bourne (2002) and Braddon-Mitchell (2004).

from the future to the present. According to Broad (1923), an event's becoming present is exactly its coming into existence. Before it comes into being, the event simply does not exist. This means that, on the theory, there is no literal passage of events in the far future to the nearer future, for there are no future events around whose degree of futurity can be said to be changing. What about an event's passage from the present to the past? Broad held it to be a genuine change, but not one involving any intrinsic change in the event, and nor any change in the relations that the event bears to given other events. Rather, the change is constituted by the coming into existence of new events, to which the now past event thereby comes to be related. In Broad's words: 'Nothing has happened to the present by becoming past except that fresh slices of existence have been added to the total history of the world. The past is thus as real as the present' (Broad 1923, p. 66).

This last quotation highlights two aspects of the picture that deserve emphasis. First, unlike on the Moving Spotlight view, past times are held to be on a par with the present, ontologically *and metaphysically*. The present is distinguished only by its being the 'edge' of reality: the time beyond which there are no further times. Second, since the sum total of reality is forever increasing via becoming, the time slices of the Growing Block, just like the times of the Moving Spotlight view, *persist*. In fact, Broad seems to acknowledge this explicitly. He writes: 'there is no such thing as *ceasing* to exist; what has become exists *henceforth for ever*' (Broad 1923, p. 69, second emphasis mine).

The parallels with the Moving Spotlight theory are clear. The natural way to make sense of talk of the Block's growth in a way that avoids commitment to the existence of the points of a second time dimension is in terms of primitive tense. There is an absolute fact about the extent of the sum total of reality, but this fact changes. The sum total of reality *was* smaller; it *will be* larger. As with the Moving Spotlight theory, this manoeuvre does not avoid the postulation of two times. Just as in that case, we have one B-theoretic (truncated, but growing) dimension, and one A-theoretic 'dimension'. And as before, the picture appears to be guilty of 'spatializing' the former as a persisting dimension that, on closer analysis, does not connect directly with our ordinary tensed talk. Spelling out the growth of the block in terms of primitive tense gives rise to a coherent view, but it is one that is no more plausible than the Moving Spotlight view, for precisely parallel reasons.

V

Non-standard A Theories. On the views so far considered there are supposed be absolute facts of the matter about the way the world is. For the B theorist, the absolute facts concern how the world is from no temporal point of view. For the presentist, the absolute facts concern how the world is presently (understood to include how it was and how it will be). According to the Moving Spotlighter, there

is an absolute fact about which of the many existent times is NOW. *Non-standard A Theories* give up the idea that there are absolute facts of the matter about the way the world is. The resulting views resemble the B Theory in that they deny that any one time is absolutely privileged; they depart from the B Theory in upholding the non-reducibility of tense.

One route to such a non-standard A theory starts with the presentist view discussed above.[16] The presentist takes the present facts to be the absolute facts. They postulated no other facts, but in terms of the present facts, they are able to say what the facts *have been* and what they *are going to be*. On the corresponding non-standard view, the facts that the presentist takes as absolute are reinterpreted as holding only relative to some particular time. Further, what facts hold relative to past and future times is not taken to be reducible to what was and what will be the case *simpliciter*. The world is one way relative to one time; it is some other way relative to another time. There is no truth *simpliciter* to be had. Truth is taken to be essentially relative to times. The present time only counts as the present relative to the tensed facts we started with, the facts that hold relative to it. Every other time is equally present, relative to its own special collection of tensed facts.

Do non-standard views vindicate the passage of time? The first, obvious, point to make is that everything the presentist said was true absolutely remains true relative to a particular temporal perspective. And everything that the presentist maintained was always true remains true relative to every temporal perspective. Since time passes according to the presentist, the same holds true, as of any time, on the non-standard view. One of the view's many perspectives is supposed to be our perspective so we can truly say (now) that time passes.

This is to consider how things are from the perspective of each time. One might also consider how things vary across perspectives. Consider first the analogous variation in the B Theory, which can then serve as a useful contrast to the variation involved in non-standard A theories. On the B Theory, events do not literally become ever more past. But nevertheless one can consider the perspectives of a sequence of ever later times. In a sense, one can say of any given event that it becomes ever more past *relative to such a sequence*. But on the B Theory, all this amounts to is that the event is located at an ever greater temporal distance from each time in the sequence. This no more corresponds to the real passage of time than the analogous spatial truth that, relative to a sequence of locations ordered continuously by their mutual spatial distances, the first element of the sequence is an ever greater spatial distance from each subsequent member of the sequence.

Similarly, on the B Theory there is a sense in which each time counts as the present relative to itself. So even on the B Theory, 'the present' can be said to change

[16] I take the result to correspond to Fine's 'external relativist' version of non-standard realism about tense; see Fine (2005, pp. 278–80).

its position in time, relative to time. But again, the B-theoretic sense in which a time is present to itself is exactly analogous to the sense in which each spatial location counts as 'here' relative to itself. Being the centre of a perspectival representation is not *per se* to be represented as special by that representation. In fact, this seems to be a plausible way to think about the spatial origin of our visual representation of space. In one sense, vision represents our location differently from the other spatial locations that it represents.[17] But in another sense, even in visual experience, our spatial location is not represented as privileged. It is presented visually merely as the spatial location at which we happen to be. We understand the perspectival nature of our visual relationship to other places precisely in terms of our spatial relationship to those places. Moreover, our being so related to them is something that is itself represented in our spatially perspectival representation.

Consider, now, the analogous variations on the non-standard view. As one considers ever later temporal perspectives, a given event does, literally, become ever more past. Similarly, as one considers ever later perspectives, later and later times are distinguished as the present in a way that goes beyond the B-theoretic variation just reviewed. The way in which the tensed facts true relative to a particular time single out that time is supposed not to be reducible to tenseless relational facts about, e.g., the various B relations which events stand in to that time, so *a fortiori* the tensed facts cannot be facts about those relations.

Does this variation with temporal perspective provide us with a sense in which the non-standard view vindicates the passage of time? There is an apparent problem with the suggestion that it does. The variation is not itself a fact about how reality is. Our model of the view includes such variation but, as we saw earlier, features of the model that transcend what is true from each temporal perspective do not correspond to perspective-independent facts about reality. There are meant to be no such facts.[18] This issue recurs in the context of open future models of passage, so I postpone further discussion until the next section.

VI

Passage and the Open Future. So far I have assumed that vindicating the passage of time involves outlining a metaphysics according to which the becoming more past of events is a mind-independent, objective phenomenon. There is, however, another set of ideas that are naturally associated with the belief that time really passes.

The basic idea is crisply summarised by the cosmologist George Ellis:

[17] In some sense it is not represented at all except as a limit.

[18] A type of surrogate can be recovered in terms of time-relative facts. As of any time, I can consider what will be true from a sequence of ever later perspectives. And I can iterate this procedure by considering, for example, from the perspective of t_1 what is true, from the perspective of some earlier or later time t_2, about temporal perspectives ever later than t_2.

> Things could have been different, but second by second, one specific evolutionary history out of all the possibilities is chosen, takes place, and gets cast in stone. (Ellis 2006, 1812–3)

The view has two essential elements. First, there is the idea that the future is genuinely open: at any instant, there are several possible ways that the world might develop. Second, there is the idea that only one of these possibilities in fact happens: as time passes, exactly one of the many possibilities becomes actuality, and the rest become mere might-have-beens.

In order to pin down the view, one needs to clear about what is meant by the claim that the future is open.[19] Suppose that the laws of nature are indeterministic in the sense that specification of the world's history up to a certain time, together with those laws, does not fix all future facts.[20] To say that the future is open might only be to say that the future is not nomologically determined in this sense. But that the past and present, together with the laws, do not fix all future facts does not entail that there are no such facts. In tenseless terms, there can be a unique actual continuation of the world to the future of some time t, but this continuation need not be the only one compatible with the actual laws and the way the world is up to and including t.

Several advocates of the open future (e.g., Geach 1973; McCall 1976; Barnes and Cameron 2011) claim that true openness requires, not just that the future not be (nomologically) *determined*, but that it also be not fully *determinate*. And one popular way of cashing out what lack of determinateness means focuses on the status of future possibilities. When one has mere nomological openness of the future, there are, as of a time, many possible futures compatible with the indeterministic laws, but they are not all created equal. One amongst them corresponds to the actual future. The others are therefore ways the actual world *might have been* (consistent with its past and the laws), but not ways that it genuinely *might still be*. For example, it cannot both be true that there will not be a sea battle tomorrow but that there might be one (in the relevant, non-epistemic sense of might). The open future view now under consideration, therefore, insists that, for them all to be genuine possibilities, none from amongst them is now singled out as what will take place.[21] This leads naturally to 'branching time' models of reality: tree-like structures, the nodes of which correspond to spatially global instants. The branches are intended to represent the plurality of possibilities to the future of each of the nodes from which they branch.

[19]For a more comprehensive review of the options, see Torre (2011).

[20]The relevant sense of determinism is the model-theoretic one pioneered by Montague and refined and deployed by Lewis (1983) and Earman (1986).

[21]MacFarlane (2003, pp. 325–6) offers an argument of this kind against views that seek to uphold the bivalence of future contingents. For criticism, see Torre (2011, pp. 366-7).

Given such a structure, there are many ways to construct semantics for tensed (and modal) sentences relative to the structure's instants. The options most in accord with the intuitions that led us to this point are the ones that involve a failure of bivalence for future contingents. Suppose, that, as of now, it is an open possibility whether there will be a sea battle tomorrow: in some possible futures such a battle occurs, in others it does not. In such circumstances, the semantics should secure the truth of both of the following:

- There might be a sea battle tomorrow
- There might not be a sea battle tomorrow.

One might also reason that, whichever open possibility comes to pass, either there will be such a battle or there won't be. That is,

- Either there will be a sea battle tomorrow or there won't be

should also come out as true. However, since it is supposed to be genuinely unsettled, as of now, whether there will be a sea battle, neither of the following claims should count as true:

- There will be a sea battle tomorrow
- There will not be a sea battle tomorrow.

For similar reasons, it seems that neither should count as false either. The fact that it is not now settled that tomorrow there will *not* be a sea battle, for example, can be taken to be a reason for denying that 'there will be a sea battle tomorrow' is plain false. It turns out that there are relatively natural semantics for branching time that secure exactly these results.[22]

There is a popular line of argument against the branching-time model of the open future. The basic idea of the objection is that there is nothing unsettled about a branching reality. An omniscient being located at one of the nodes with branching to their future, should not be uncertain about, or think it unsettled whether, there will be a sea battle. There will be such a battle, for there is such a battle in at least one of the future branches. There are also future branches in which there won't be such a battle. If the claim 'the future contains a sea battle' does not come out as true (and is also not false), this is only because of a presupposition failure. 'The future' fails to refer because there are several futures (see, e.g., Lewis 1986, pp. 207–9).

The objection presupposes a B-theoretic interpretation of branching-time models, in which the block universe is replaced by a 'block multiverse.' Whether such a

[22]The most well known are the supervaluationist semantics first proposed by Thomason (1970). For recent discussion, see Brogaard (2008), MacFarlane (2008), and, for an application of such semantics in the context of the Growing Block view, Briggs and Forbes (2012).

picture vindicates the intuition that the future is open is controversial. Many agree with Lewis that it does not.[23] The A-theorist, however, need not worry how this dispute is resolved, for, from their perspective, the objection gets things back-to-front. On the view we are exploring one *starts* with the intuition that, as of some time, the future is open. This is taken to mean that (i) there are several ways that thing might happen, and (ii) nothing in reality singles out (as of that time) one of these possibilities as the way things will actually be. On the intended interpretation, branching-time structures are introduced as a means to represent these purported facts, and to see whether a consistent formal theory incorporating them can be devised. Against this background, one is simply not permitted to reinterpret the branches relative to some time as several equally real futures, rather than as several equally real possible ways that the single future might turn out.[24]

It is time to confront an issue that has been lurking in the background. Recall that the view summarised in the quotation from Ellis has two components. The open future was the first. The second was the idea that, as time passes, just one of the several possibilities for each moment obtains. *As of now*, no future is distinguished but, with the passage of time, one will come to be. How is this idea to be incorporated into branching-time models?

At one level, what is required would seem to be straightforward. A path through a branching-time structure corresponds to a single determinate course of events. For the open-future A theorist, such a path corresponds to a possible view from the 'end of time': a possible way for the entire history of the world to have unfolded. Pick such a path through a given branching-time structure. Its linearly ordered instants define a linearly ordered sequence of subtrees of our original tree, with each member of the sequence a proper substructure of the preceding ones. Each instant from the chosen history is the privileged node of the corresponding subtree, where it features as the first instant of branching. With this machinery in place, the natural thought is

[23] The block multiverse picture was once routinely associated with the Everettian interpretation of quantum mechanics (EQM). Something like the Lewis objection lies behind the argument in Greaves (2004) that there can be no 'subjective uncertainty' in an Everettian world. Recently, there has been a subtle shift in the position of some advocates of subjective uncertainty in EQM. It is now claimed that the theory's fundamental ontology is equally consistent with a diverging (rather than branching) picture of quasi-classical worlds, and that this picture is to be preferred for precisely the kind of reasons alluded to above; see Saunders (2010) and Wilson (2011).

[24] Here are two possible sources of confusion. First, the defender of the open future is likely to insist both that (a) 'in reality' there are 'real' future possibilities and that (b) these future possibilities are all 'equally' real. As we have seen, the point of this insistence is to differentiate the view from advocacy of a merely nomologically open future. Second, the models represent all events in the possible futures as temporally related to the instant from which they branch. But of course events that might occur in the future are represented as temporally related to the present: *if* they occur, they will be some temporal distance from the present. It does not follow from this (for the A-theorist) that there (tenselessly) is both a sea battle 24 hours from now and (in some other realm of reality) an absence of such a battle 24 hours from now.

that the passage of time is to be represented, not within a single branching structure, but by a sequence of the kind just described. As time passes, successive elements of the sequence represent how reality is. Moving along the sequence corresponds to tracing an upward path through the original tree. Moment after moment, one of the many possibilities for each successive time is chosen. But there always remains branching to the future. No element of the sequence corresponds to the 'view from the end of time.' That exists only as the ideal limit of the sequence as a whole.[25]

Something very like this model of temporal passage has been defended by Storrs McCall (1976; 1984; 1994). The picture is very suggestive, but it invites the by now familiar two-times objection.[26] Time seems to be doubly represented, first by the sequence of ever shrinking trees and then by the temporal dimension within each tree. Thanks to our review of traditional A Theories, we are well placed to identify the most plausible A-theoretic responses, and to note some new twists that modelling the open future brings.

To my mind the least plausible option, which I take to be McCall's view, is the natural analogue of the Moving Spotlight and Growing Block views. As on the block multiverse view, reality as a whole is a branching entity whose individual branches are extended in four dimensions. As time passes, this reality changes. 'Branch attrition' occurs as more and more parts of it go out of existence. As on the Moving Spotlight view, future times are as real as past times. As on the Growing Block view, the present time is metaphysically on a par with other times. It is distinguished only in terms of its location relative to structurally definable features of reality. Rather than being the bleeding edge, it is the surface at which branching begins.[27]

What sense can be made of branch attrition? As on standard versions of the Growing Block and the Moving Spotlight, one can think of a single element of the sequence as corresponding to how things are absolutely. Change in branching is then understood in primitively tensed terms: other elements of the sequence represent how things were, and how they will be.

This is not a route that the open-future A theorist should take. Prior to our seeking to articulate the view in terms of an appropriate model, there seemed to be no incompatibility between insisting that, as of now, it is unsettled, and hence neither true nor false, that there will be a sea battle tomorrow, but that, as time passes, things get settled one way or the other. A sequence of ever smaller branching structures seems like an attempt to do justice to both features of the view. The parity of the branches in each element of the sequence respects the first; branch attrition

[25]Earman (2008) makes an analogous point concerning models of the Growing Block view.

[26]For related criticisms, see Nerlich (1998) and Farr (2012).

[27]This is to be faithful to McCall's view, and to interpret distinct branches as distinct realms of reality. There is also a linear time interpretation involving branching only at the level of courses of material events occurring within a four-dimensional block. The present time is then metaphysically distinguished, as the frontier between determinateness and indeterminateness in reality.

respects the second. However, we should reject the hybrid interpretation of the model. Concrete reality does not branch. The branching structures are simply ways of representing the particular pattern of tensed claims that the preferred semantics for such structures generates. The open-future A theorist should take such tensed claims as basic.

There are two kinds of such a view to consider: an analogue (or version) of presentism, and a non-standard view. The presentist variant claims that just one element of the sequence corresponds to a complete catalogue of the absolute facts. Strictly speaking, therefore, the other elements of the sequence cannot be required. This mirrors our earlier claim that, when modelling the presentist view in terms of a block universe with a privileged centre, one does not need additional blocks in order to show that the privileged centre moves forward in time. This fact is already encoded in the original block. Does this remain true once we have branching?

The key thing to note is that, while future elements of the sequence cannot be read off from earlier elements, that the future facts will correspond to one such element can. Amongst the tensed facts that a branching structure encodes is that exactly one amongst the possibilities open at that time will occur. Here is one way to visualise the point: while a given branching structure (absent a thin red line) does not encode a single sequence of the kind we have been considering, it does encode that the future tensed facts that hold at later and later times correspond to some such sequence. Given that it is not now determined how things will turn out, one might think that the lack of a preferred sequence is exactly as it should be. Passage is accommodated in this model just as it is in standard presentism. But the view adds the further feature that, as time passes, what once was unsettled becomes settled: there might be a sea battle or there might not, and either there will be one or there won't.

The model of the non-standard variant of the view *does* involve a particular sequence. Each element of it represents the irreducibly tensed facts that hold as of some time. This might seem to give us a more explicit representation of once open possibilities being settled by the passage of time: what is indeterminate as of t is settled in such-and-such a way as of t'. But care is needed: the sequence of trees does not represent how reality is absolutely, as conceived from no particular temporal point of view.

Just as the tensed facts that hold as of some time are not reducible to tenseless facts, there is no need for them to be deducible from the tensed facts that hold as of other times. As of t, it is neither true nor false that there will be a sea battle at t'. As of t', it is true that a sea battle is raging. This seems to be exactly what one needs if one is to capture the motivating idea with which we began this section. In fact, for exactly this reason, it might seem that this open-future version of non-standard A theory better captures the passage of time than a version in which the tensed facts as of one time can be read off from those that hold at another. In the latter case,

it is hard to see what the insistence that such facts are not reducible comes to, for there *is* a unique representation of reality—the block universe—from which the perspectival facts can be derived. This is no longer true of the open-future model. The primordial branching-structure captures only how things might turn out, not how they will turn out. The block universe history that constitutes the ideal limit of the sequence of the model's branching structures not only does not correspond to the facts as of any time (the end of time is never reached), it also, when interpreted as representing the absolute facts, misrepresents as determinate future facts that are genuinely unsettled.

I therefore take the combination of objective temporal passage and the branching-time conception of the open future to be a way that the A theorist can drive a wedge between their view and the B Theory. Of the various A-theoretic view surveyed up to this point, I take presentism, and some variant of non-standard A Theory to be the most attractive vehicles for this combination. In the face of relativity, only one of these views remains a going concern.

VII

Against a Preferred Now. Global instants play a fundamental role in the A Theories reviewed so far. Presentism takes the world to be extended in only three, spatial dimensions. In order to interpret a spacetime model as a representation of presentist reality, one needs to foliate it by a family of 3-dimensional instants and indicate which corresponds to the current time. The Moving Spotlight view embraces a 4-dimensional reality, but singles out a 3-dimensional subregion as metaphysically privileged. The Growing Block view's 4-dimensional reality is truncated to the future, bounded by a 3-dimensional, spatially extended surface. The nodes of the branching-time models represent 3-dimensional, spatially extended global instants.

Minkowski spacetime, the spacetime of special relativity, lacks such structure. While *some* models of general relativity come with physically preferred foliations by sequences of 3-dimensional spacelike hypersurfaces, the physical characteristics of such surfaces do not mark them out as obvious candidates for the privileged surfaces of a classical picture of temporal passage.[28] Moreover, the *local* physics (which, presumably, is the physics in terms of which we should seek to understand our temporal experience of the world) is as blind to these privileged surfaces as it is in special relativity. In fact, the local physics *just is* the physics of special relativity.

In the face of these facts, there would seem to be three distinct routes by which the passage of time might be reconciled with relativistic physics. The first, advocated, for example, by Dieks (2006) and Savitt (2009), is to offer a deflationary analysis of

[28]For a recent review of some of the obstacles to interpreting such foliations in presentist terms, see Wüthrich (2013, §5).

passage. As discussed in Section II, this simply ignores, rather than solves, the main explanatory challenge faced by the B Theory.

The second option is to argue that a model of passage that requires a preferred set of global Nows is compatible with relativity when the latter is correctly understood.[29] Here is not the place to review the sizeable literature on this possibility, but I want to highlight one cost of this route. Its advocates face a dilemma: either they interpret the spatiotemporal structure of relativistic spacetime at face value, or they are committed to spatiotemporal facts that go beyond this structure. Neither choice looks attractive.

According to typical versions of the second choice, the spacetime metric systematically misrepresents the true spatial and temporal distances between events. But it is the spatial and temporal distances of the spacetime metric that correspond to the measurements of physical rods and clocks. One variant of the second choice, for example, is the 'neo-Lorentzian' interpretation of special relativity. One can represent the commitments of this view in two stages. One first re-interprets the standard spacetime models of some special relativistic physics in terms of Newtonian spacetime structure. One then interprets the Newtonian structure in terms of one's favourite classical A-theoretic metaphysics.[30] On this picture, the Minkowski metric systematically misrepresents the spatial and temporal distances between events. For example, it might represent as some spatial distance apart and as standing in no temporal relation two events that are, from the point of view of the postulated Newtonian structure, some finite temporal distance apart and some other (derivative) spatial distance apart. It is, of course, the spatial and temporal distances of the Minkowski metric, not those of the hidden Newtonian structure, that correspond to the measurements of physical rods and clocks. Given this, it might seem preferable to adopt a literalistic attitude to the spacetime metric and simple superadd a metaphysically preferred foliation in terms of which passage is to be understood. But this choice also has its costs.

Suppose, for example, that some momentary event e is presently occurring and that some other event e' will occur. Suppose that the Minkowski metric represents the spatiotemporal distance between e and e' as being, say, two minutes. Now consider the set of events that will co-occur with e' according to the superadded

[29] For a systematic defence of this option, see Zimmerman (2011, §4).

[30] It is perhaps worth emphasising that this does not require revisionary physics. The standard geometrical machinery used to represent a Newtonian spacetime is an n-tuple $(M, h^{ab}, t_a, \sigma^a, \nabla)$. h^{ab} is a tensor field that defines the Euclidean spatial metric on simultaneity surfaces. t_a is a one-form field that defines these surfaces and the temporal distances between them. σ^a is a time-like vector field whose integral curves represent the worldlines of the points of absolute space. In terms of these objects one can define an effective (inverse) Minkowski metric $g^{ab} := \sigma^a\sigma^b - h^{ab}$, which is compatible with the derivative operator ∇. The 'Newtonian' representation of standard relativistic physics then simply couples matter fields (such as the electromagnetic field) to this object in the standard way (see, e.g., Trautman 1966, pp. 419–421).

foliation. Most of these will not occur two minutes after e according to the spacetime metric. Many will occur a much shorter temporal distance after e, for example, some small fraction of a second. That might seem strange, but it is perhaps a consequence that the A theorist can live with. Temporal distance, as measured by clocks and as encoded by the metric, is no longer a measure of a single distance between successive sets of co-occurring events. In short, it is no longer a measure of the passage of time. The situation, however, is worse than this. Not all events co-occurring with e' happen some temporal distance after e. There will be many events co-occurring with e', much further from it spatially, that, according to the metric, occur some *spatial* distance from e. That is, they happen after e (according to the A theorist's conception of passage) but they lie at no temporal distance from e (including the zero distance). The resulting view may not be incoherent, but it is very strange indeed. We have seen enough to motivate consideration of the third and final option: is it possible to generalise the models of the previous sections in order to obtain a genuinely A-theoretic view that does without global nows?

Something like this task has been undertaken recently by Earman (2008), for the Growing Block, and Skow (2009), for the Moving Spotlight. These were the views that looked least attractive in our review of classical models of passage, and their shortcomings carry over to the relativistic domain. Nonetheless, it is worth reviewing Earman's and Skow's efforts, for they can serve as a template for the generalisation of the branching-time models.

VIII

The Relativistic Growing Block. In order to appreciate Earman's generalisation of Growing Block models to relativistic physics one first needs to quickly rehearse his definition of classical models. He defines these as follows. Let $\mathcal{N} = \langle M, G_1, G_2, \ldots, P_1, P_2, \ldots \rangle$ be a spacetime model of some Newtonian theory. M is a four-dimensional manifold representing spacetime. $G_1, G_2, \ldots$ are fields defined on it representing the standard spatiotemporal structures of Galilean spacetime. $P_1, P_2, \ldots$ are fields representing the material content of the model. One can define a time function $T : M \to \mathbb{R}$ that encodes the simultaneity structure and temporal metric of the model. In terms of $\mathcal{N}$, Earman defines *future-truncated models*, $\mathcal{N}_{T \leq \Delta}$, by deleting from the spacetime manifold of $\mathcal{N}$ all the points p such that $T(p) > \Delta$, $-\infty < \Delta < +\infty$, and then restricting the geometric and matter fields G_i and P_j of $\mathcal{N}$ to the truncated manifold (Earman 2008, p. 139). One can then characterise a model of the Growing Block view as a pair $\mathcal{B} = \langle \mathfrak{N}, \precsim \rangle$. $\mathfrak{N}$ is a set such that, for some $\mathcal{N}$, each element is isomorphic to $\mathcal{N}_{T \leq \Delta}$ for some Δ. The relation $\precsim$ is defined via the condition that for any $\mathbf{n}, \mathbf{n}' \in \mathfrak{N}$, $\mathbf{n} \precsim \mathbf{n}'$ iff $\mathbf{n}$ can be isomorphically embedded as a submodel of $\mathbf{n}'$. For $\mathcal{B}$ to be an allowed model, $\precsim$ should be a total order. It is to be interpreted as 'contains at least as much existence as.'

$\mathfrak{N}$, ordered by $\precsim$, thus provides us with a sequence of the kind familiar from our earlier discussion. In principle, there are two ways of interpreting it as representing an A-theoretic reality. The 'standard' way interprets one of the elements of $\mathfrak{N}$ as corresponding to how reality is, absolutely speaking. 'Earlier' and 'later' elements of the sequence then represent how reality *was* and how it *will be*. The 'non-standard' way seeks to interpret each element as a representation of how reality is *as of some time*, where the time-relative facts are held to be not further reducible to facts that hold absolutely.

So much for the Newtonian case. At some level of abstraction, the possible generalisations to relativistic physics are straightforward. One replaces $\mathcal{N}$ with a (non-extendible, orientable) spacetime model $\mathcal{R} = \langle M, g_{ab}, P_1, P_2, \ldots \rangle$ of some relativistic theory. Earman then considers two options, which he labels *hypersurface becoming* and *worldline becoming*.

Hypersurface becoming requires that $\mathcal{R}$ admit a global time function; a function $t : M \to \mathbb{R}$ such that for any $p, q \in M$ where p is in the chronological past of q according to the spacetime metric g_{ab}, $t(p) < t(q)$. The construction of a model of 'hypersurface becoming' then parallels the Newtonian case. One considers pairs of the form $\mathcal{B}(\mathcal{R}, t) = \langle \{\mathcal{R}_{t\leq\delta} : l < \delta < u\}, \precsim \rangle$. As before, $\mathcal{R}_{t\leq\delta}$ is the future-truncated model one obtains from $\mathcal{R}$ be deleting all points p of M such that $t(p) > \delta$ and then restricting the fields of $\mathcal{R}$ to result. l and u are the lower and upper bounds of the range of t. The relation $\precsim$ is defined via the condition: $\mathcal{R}_{t\leq\delta} \precsim \mathcal{R}_{t\leq\delta'}$ iff $\delta \leq \delta'$.

So far the construction parallels the Newtonian case too closely. The elements of $\{\mathcal{R}_{t\leq\delta} : l < \delta < u\}$ are totally ordered by the relation $\precsim$. As a result, the A theorist can apply whichever was their preferred interpretation of the classical growing block model directly to the relativistic model, but they face the thorny issue of which of the uncountably many time functions compatible with a given spacetime $\mathcal{R}$ corresponds to the surfaces of real becoming. This is a variant of the (disavowed) second route to reconciling passage with relativity. We need, instead, to generalise the model to one that does not single out a preferred family of global Nows. The natural move is to consider the set $\mathfrak{R}$ of all possible future-truncations of $\mathcal{R}$ associated with every possible time function on $\mathcal{R}$. We can then define a relation $\precsim$ on this set in an obvious way. The required conditions is that, for all $\mathbf{r}, \mathbf{r}' \in \mathfrak{R}$, $\mathbf{r} \precsim \mathbf{r}'$ iff there is *some* time function t on $\mathcal{R}$ such that $\mathbf{r}$ is isomorphic to $\mathcal{R}_{t\leq\delta}$, $\mathbf{r}'$ is isomorphic to $\mathcal{R}_{t\leq\delta'}$, and $\delta \leq \delta'$.[31]

We now confront an instance of the defining feature of the type of relativistic models to be considered in the remainder of this paper. The relation $\precsim$ is a *partial order*, not a total order. How does this key difference with the pre-relativistic case affect the type of interpretation that the A theorist is able to give of the model?

[31]The result is similar (but not identical) to what Earman calls a 'super Broad hypersurface Becoming model' (Earman 2008, p. 150).

In the pre-relativistic context there were two options. The standard option takes a single element of the relevant set as a representation of how reality is absolutely speaking; the non-standard option treats every element of the set as on a par, each corresponding to a representation of how reality is relative to some time.

The first of these looks like a non-starter. Suppose one took an element $\mathbf{r} \in \mathfrak{R}$ isomorphic to $\mathcal{R}_{t \leq \delta}$, for some value δ of some time function t, as corresponding to how reality is absolutely.[32] This might seem already to give up on our aim of an A-theoretic view without global Nows. But, so far we only have one global Now, not a whole sequence, so let us bracket this objection and move on. With this choice of $\mathbf{r}$ as representing the absolute facts, it might seem as if one can straightforwardly interpret any $\mathbf{r}' \gtrsim \mathbf{r}$ as corresponding to how reality *will* be. But even this much is not straightforward, for we have to decide what to say about two elements $\mathbf{r}_1$ and $\mathbf{r}_2$ of $\mathfrak{R}$ that both correspond to extensions of $\mathbf{r}$ but which are not comparable by $\lesssim$. Can one maintain that reality will be both as $\mathbf{r}_1$ represents it as being *and* as $\mathbf{r}_2$ represents it as being? Essentially the same problem becomes far more acute when one considers elements of $\mathfrak{R}$ that are incomparable (according to $\lesssim$) with $\mathbf{r}$ itself. Let $\mathbf{r}'$ be such an element that does not include the here and now (which, I assume, is part of the futuremost boundary of $\mathbf{r}$). $\mathbf{r}'$ cannot represent how things will be unless the existence of what is happening right here and now can come to cease to be. But nor can it represent how things were unless something that had come to be has now come to cease to be.

The moral is that, if one maintains that a unique element of $\mathfrak{R}$ corresponds to how things are absolutely, there does not seem to be an appropriate way to treat *all* the other elements of the set. Can non-standard A theory do any better? On such a view, the problem of what to make of two incomparable elements of the $\mathfrak{R}$ from the perspective of a third does not arise (at least officially), for, on the non-standard view, one does not look to other elements of the model in order to deduce the tensed facts that hold relative to a given element. Such facts are supposed to be represented by the element itself. Even so, the prospects for the view are not much better. One problem concerns the nature of the perspective relative to which the irreducibly perspectival facts are supposed to obtain. Spacelike hypersurfaces of relativistic spacetimes simply are not naturally interpreted as things with respect to which reality might be a certain way. Our here and now is a subregion of uncountably many such surfaces if it is a subregion of any. *We* enjoy a particular spatiotemporal perspective on reality, but it is not a perspective that naturally extends to any one of the encompassing hypersurfaces.[33]

[32] Presumably one would like the here and now (i.e., your reading this sentence) to be located in a region of spacetime somewhere on the surface $t = \delta$.

[33] One of Fine's own reasons for advocating a version of non-standard A theory is that he believes that, unlike standard A-theoretic views, it does not need a privileged spacetime foliation (Fine 2005, 305–7). However, his preferred 'frame-theoretic' non-standard view still conceives of tense in terms

A desire to do better justice to the local nature of our spatiotemporal perspective can be used to motivate the second of Earman's two options: worldline becoming. One starts again with an inextentible relativistic spacetime model $\mathcal{R}$.[34] One then considers a past and future endless timelike curve γ in $\mathcal{R}$. In now familiar notation, one can represent a corresponding Growing Block model based on this curve as $\mathcal{B}(\mathcal{R}, \gamma) = \langle \{\mathcal{R}_{J^-(p)} : p \in \gamma\}, \precsim \rangle$. $\mathcal{R}_{J^-(p)}$ is obtained by deleting all the points of $\mathcal{R}$ not in the causal past of the point p and restricting the fields of $\mathcal{R}$ to the result. The relation $\precsim$ is defined via the condition: $\mathcal{R}_{J^-(p)} \precsim \mathcal{R}_{J^-(r)}$ iff $J^-(p) \subseteq J^-(r)$. Once again, the elements of $\{\mathcal{R}_{J^-(p)} : p \in \gamma\}$ are totally ordered by the relation $\precsim$. The properly relativistic model we desire considers all possible worldlines or, more simply, all points of $\mathcal{R}$. The resulting model is $\mathfrak{B}(\mathcal{R}) = \langle \{\mathcal{R}_{J^-(p)} : p \in M\}, \precsim \rangle$, with $\precsim$ still defined via $\mathcal{R}_{J^-(p)} \precsim \mathcal{R}_{J^-(r)}$ iff $J^-(p) \subseteq J^-(r)$.[35] It is a partial order on $\{\mathcal{R}_{J^-(p)} : p \in M\}$.

As before, one can consider standard and non-standard A-theoretic interpretations of this model. The standard variant suffers from the problems that afflicted the standard interpretation of the hypersurface-based model. In addition, it displays a further peculiarity that looks decisively problematic. Suppose one takes $\mathcal{R}_{J^-(p)}$ as representative of how reality is absolutely. What's so special about p? Presumably you hope that p is (roughly speaking) the (i.e., your) here and now. What's so special about *you*? We therefore do better to consider the viability of a non-standard A-theoretic interpretation. Here we face the general unsuitability of the Growing Block model as something that might underpin a non-standard view. $\mathcal{R}_{J^-(p)}$ looks adequate to representing irreducible past-tensed facts that hold as of spacetime point p, but what do we want to say about tensed claims, made as of p concerning the future, or the elsewhere?[36] It is hard to avoid looking to other elements of the model as encoding these, but that way lies many of the problems that plague the standard interpretation.

IX

The Relativistic Moving Spotlight. Properly relativistic Growing Block models are not promising materials for the would-be A theorist. Let us turn, instead, to Skow's suggested generalisation of the Moving Spotlight view. Skow motivates his proposal

of global spacelike surfaces. The criticisms of this paragraph thus apply to it. 'Frame-theoretic' views also do not generalise naturally to the variably curved spacetimes of general relativity, which lack the relevant (global) frames.

[34]One no longer requires that $\mathcal{R}$ admit a time function. It is enough for the construction to work that $\mathcal{R}$ be causal-past distinguishing. See Earman (2008, pp. 151-2) for the relevant definitions.

[35]The model is closely related (though not identical) to what Earman calls a 'super worldline becoming model' (Earman 2008, p. 152).

[36]The *elsewhere* of a point in a relativistic spacetime is the set of points spacelike related to it. I.e., the set of points neither in nor on either its past or future lightcones.

via the supertime representation of the pre-relativistic view. The following is a natural 'constraint law' describing how supertime intervals and time intervals should mesh:

> If p and q are points in supertime, and p is r units Later than q, then the time that is NOW from the perspective of p is r units later than the time that is NOW from the perspective of q. (Skow 2009, pp. 671–2)

Skow asks how this should be generalised when one replaces Galilean spacetime, with its unique family of global instants, with Minkowski spacetime. With supertime still in place, one is after something of the form:

> If p and q are points in supertime, and p is r units Later than q, then the BLANK-1 from the perspective of p is BLANK-2 than the BLANK-1 from the perspective of q.

Where 'BLANK-1 holds the place for the kind of region that is "lit up" from perspectives in supertime, and BLANK-2 holds the place for the relation that those regions stand in' (Skow 2009, p. 672). As Skow notes, the structure of relativistic spacetimes provide us with no natural way to fill in these blanks. His 'solution' is to replace the perspectives of the points of supertime with those of the points of 'Minkowski superspacetime'. From each such perspective, just one point of ordinary spacetime is 'lit up' as PRESENT. One can then state natural constraint laws, including, for example:

> If p and q are points in superspacetime that are Timelike related, and p is to the Future of q (that is, lies in the Future Light Cone of q), then the point that is PRESENT from the perspective of p is timelike related to and to the future of the point that is PRESENT from the perspective of q. (Skow 2009, p. 673)

Skow claims that this relativistic model vindicates passage, for the relativistic PRESENT can be said to move just as much as the NOW of the pre-relativistic theory:

> Just as, as one moved from Earlier to Later points in supertime, one saw the NOW move from earlier to later times, so as one moves from Earlier to Later points along any Timelike curve in superspacetime, one will see the PRESENT move from earlier to later points along a corresponding timelike curve in spacetime. (Skow 2009, p. 675)

At this point, the reader is likely to recall Skow's insistence, when discussing the pre-relativistic model, that supertime was just a metaphor. According to the official theory, the perspective of exactly one point in supertime corresponds to the absolute facts. The perspectives of other points in supertime are representations

of facts officially spelled out in terms of primitive tense operators. It is really these tensed facts, understood as absolute facts, that secure the 'movement' of the NOW. One therefore wants to know: what is the official story for which Minkowski superspacetime provides a metaphor? Skow declines to answer. After speculating that it might be possible to spell it out in terms of 'primitive tense-like operators that are adapted to the structure of relativistic spacetime,' he excuses himself from doing so by suggesting that the result would not be worth the effort because 'the presentation of the theory using superspacetime is easier to understand' (Skow 2009, 673–4).

This does not seem adequate. The issue is not whether a story in terms of relativistic tense operators might be more perspicuous than the superspacetime metaphor. The issue is whether a coherent story in terms of relativistic tense operators can even be told. Can we maintain that the facts associated with a particular perspective in superspacetime (however these are to be rendered in terms of relativistic tense operators) correspond to the absolute facts? The absolute privileging of (not just the now but) the here and now that this involves seems unacceptable. While it might be natural to think of ourselves as (momentarily) metaphysically special compared to the contents of past regions of spacetime, we do not think of ourselves as metaphysically special compared to, say, the inhabitants of the other side of the Earth. The non-relativistic A theorist can further play down the lack of egalitarianism by insisting that past times *have been* NOW and future times *will be* NOW. On the most obvious ways of reconciling tensed claims with relativistic spacetime structure, the relativistic Moving Spotlighter cannot even claim this of spacetime regions in our elsewhere. These *never have been and never will be* PRESENT. The best one can say of them is that it will be the case that they have been PRESENT (*cf.* Putnam 1967, p. 246).[37]

The supertime metaphor and (presumably) the superspacetime metaphor are supposed to explicate versions of the Moving Spotlight view conceived of as variants of standard A Theories that involve absolute (tensed) facts. The difficulties just reviewed suggest that embracing the non-standard route is the relativistic A theorist's best option.[38] Rather than explore the consequences of this move in the unattractive framework of the Moving Spotlight, I wish to introduce the natural relativistic generalisations of the classical branching-time models of passage.

X

Branching Spacetimes and the Passage of Time. Recall the distinction, central to differentiating a merely nomologically open future from the notion modelled by

[37]Primitive 'spatial' tenses would provide extra resources to describe the elsewhere, but only at the risk of introducing an unwanted moving HERE, and the passage space.

[38]In more recent work, this is also Skow's view.

branching-time structures, between facts being *undetermined* and their being *indeterminate*. This contrast has featured in discussion of the compatibility of becoming and relativistic physics. Nicholas Maxwell distinguishes what he calls 'predicative probabilism' from 'ontological probabilism.' The former is essentially the Montague–Lewis–Earman notion of indeterminism, combined with a unique actual history. The latter asserts that 'the basic laws are probabilistic *and that the future is now in reality open with many ontologically real alternative possibilities*' (Maxwell 1985, 25, original emphasis). It therefore involves a commitment to the open future in the sense of Section VI. Maxwell's central contention is that relativity and ontological probabilism are incompatible. His arguments are the main target of a well-known paper by Howard Stein (Stein 1991), which defends the viability of a notion of becoming that Stein first articulated in response to Putnam's and Rietdijk's relativity-based arguments for the block universe (Rietdijk 1966; Putnam 1967; Stein 1968).

In a nutshell, Stein's relativistic notion of becoming is this: all and only those events on or in the past lightcone of a spacetime point p have become determinate as of p (see, e.g., Stein 1968, p. 14). It is might not be evident from this characterisation alone that Stein is offering something that goes beyond a Dieks-style deflationary notion of becoming.[39] However, it is clear elsewhere that Stein takes himself to be outlining a position that is distinct from the block universe view. For example, deliberately quoting Maxwell's terminology, he claims to have argued that 'special relativity is perfectly compatible (in general) with "ontological probabilism"' (Stein 1991, 164). How does the idea that an event has become as of p if and only if it is in the past lightcone of p achieve this?

On the open-future view of passage of Section VI, to say that an event has become determinate is to say that it is no longer one of several equally real alternative possibilities. So, to say that all and only events in the past lightcone have become, as of some spacetime point p, is to say that, while there is a unique matter of fact concerning what has occurred in all regions to the past of p, there are (as of p) a plurality of possibilities open for regions of spacetime to the absolute future of p *and in its elsewhere*. This suggests that a first step towards a relativistic version of the open-future view of passage should be a relativistic generalisation of branching-time models to structures that encodes this pattern of relational indeterminacy.

One type of generalisation of branching-time structures has been pioneered by Nuel Belnap, who calls the result *branching space-times*.[40] Branching-time (BT)

[39]For example, Stein claims that 'the leading principle' that justifies the use of 'becoming' in a relativistic setting is: 'At a space-time point *a* there can be cognizance of—or information or influence propagated from—only such events as occur at points in the past of *a*' (Stein 1968, 16). This principle is one that B theorists can easily accept.

[40]The seminal work is Belnap (1992), which, incidentally, cites Stein (1991) in its opening remarks. It exists in a slightly updated form as Belnap (2003). Belnap (2012) contains concise references to more recent literature.

models involve a set of global instants (or, better, spatially global, instantaneous possibilities) partially ordered by a relation <, which one can read as 'is in the causal past of.' Belnap's generalisation involves replacing global instantaneous possibilities with possible point events. A branching space-times (BST) model is a set OW of such possible point events partially ordered by a relation <, which retains the meaning 'is in the causal past of.' ('OW' stands for 'Our World.')

In a classical BT model, histories are simply maximal totally ordered subsets of the model. In contrast, maximal totally ordered subsets of OW are something like inextendible wordlines: maximal chains of causally-related point events lying *within* histories. Since histories can be equated with maximal sets of *compatible* events, the key to identifying the histories of a BST model is isolating the relevant notion of compatibility. In the case of BT models, two events are compatible if they are part of the same global instant, or are parts of causally related instants. With the generalisation from instants to point events, we need to allow that distinct events can be compatible even though they are not comparable by the relation <. Belnap's solution is to classify two events as compatible if there is some event which includes both of them in its past.[41] One therefore has a distinction amongst pairs of events incomparable by < between those that are 'spacelike related' (jointly occur in some histories) and those that are incompatible (jointly occur in no history). The histories of OW can then be defined as *maximal directed subsets* of OW. (A subset E of OW is directed iff, for any elements $e_1, e_2 \in E$, there is some element e_3 of E such that $e_1 \leq e_3$ and $e_2 \leq e_3$.) One can therefore think of both BT and BST models as certain kinds of sets of overlapping histories. They differ in terms of the pattern of overlap. In the former, histories branch at global instants. In the latter, histories branch at one or more space-like related point events.

In order to make contact with Stein's constraint on relativistic becoming, we need to be able to say when two incompatible possible events count as different possibilities for one and the same location in spacetime. Whether two incompatible events are collocated is not, in general, defined in Belnap's BST framework, but it is something that can be defined for specific classes of models. From here on, my discussion is implicitly restricted to BST models of this type. In particular, Placek and Belnap (2012) have recently described a class of BST models the histories of which are isomorphic to Minkowski spacetime, for which a colocation relation is easily defined.[42] If one considers an element of such a model, i.e., a possible event e, occurring at some particular spacetime point p, then all the histories in which e occurs overlap in the past of p. However, for spacetime locations q to the future or in the elsewhere of p, one will, in general, have two or more incompatible

[41] This move only works because branching spacetimes theory rules out the possibility of 'backward branching' by fiat.

[42] Other examples of 'Minkowskian Branching Structures' had previously been constructed by Müller (2002) and by Wroński and Placek (2009).

events located at q that share a history with e. In other words, amongst the models of Belnap's BST theory, there are structures that would appear to give a precise expression to the kind of relativistic 'ontological probabilism' that Stein seems to have had in mind.

Relativistic ontological probabilism, however, does not by itself constitute a relativistic theory of becoming. Recall that the view discussed in Section VI had two elements: (i) genuine openness that (ii) was settled with the passage of time. So far we have considered only the relativistic generalisation of (i). Just as classical BT models have a natural 'block multiverse' interpretation, so do BST models. In fact, it is because of the possibility of such a 'relativistic block multiverse' that Everettian quantum mechanics can evade the troubles that plague other realist interpretations of quantum theory (such as collapse theories or Bohmian mechanics), and secure a straightforward reconciliation between quantum mechanics and relativity. Whether or not this essentially B-theoretic interpretation of BST models can underwrite genuine relational indeterminateness, it no more involves the objective passage of time than its pre-relativistic analogue. In order to vindicate real temporal passage, one needs to provide an A-theoretic interpretation of the model according to which, as time passes, what was indeterminate becomes determinate.

In the classical case, this was achieved by considering the sequence of ever smaller branching structures that one obtains from a given BT structure, W, by selecting from it a single history, h. One obtains a unique set of sets of histories in W, namely, $\{H_{(m)} : m \in h\}$, that are totally ordered by the relation of subsethood. ($H_{(m)}$ labels the set of histories in W that contain instant m.)[43] One can do the exactly parallel thing to a BST model $\langle OW, <\rangle$, i.e., one can consider the set $\{H_{(e)} : e \in h\}$ defined by some history h in OW.[44] As the previous discussion might have led one to expect, $\subseteq$ is only a partial order on this set. Its elements are natural relativistic analogues of the elements of a classical branching-time model of passage. Adapting Earman's notation, one might write $\mathcal{B}(OW, h) = \langle \{H_{(e)} : e \in h\}, \precsim \rangle$, where $\precsim$ is now defined via: $H_{(e)} \precsim H_{(e')}$ iff $H_{(e')} \subseteq H_{(e)}$.

[43] This set of histories is not, strictly, a substructure of the original. That is obtained by considering the union of such a set of histories, structured by the restriction of the original $<$.

[44] There has been surprisingly little discussion of this kind of construction in the context of branching spacetimes. As far as I am aware, something similar has only been considered by Placek (2002). Švarný (2012), for example, in considering whether the 'flow of time' can be accommodated in a range of branching models, including BST models, does not seek to incorporate 'branch attrition'. I therefore take his approach to be a variant of the deflationary account rejected in Section II. McCall intended his branch-attrition model of temporal passage to be compatible with relativity and, in Appendix 2 to McCall (1994), he provides a 'frame-invariant' characterisation of a relativistic branching structure in a manner that owes much to Belnap's. However, his characterisation of branch attrition is always in frame-relative terms. How distinct frame-relative descriptions might be understood as different descriptions of a single underlying objective process is not explicitly addressed.

Note that variant models can be constructed by choosing different types of subregions in h. The set $\{H_{(e)} : e \in h\}$ embodies the choice of individual spacetime points as the relativistic heirs to the present. The model is therefore the BST analogue of (the generalisation of) Earman's worldline becoming models, and of Skow's relativistic moving spotlight. One could, instead, focus on 'slices' of h: maximal sets of spacelike related events in h. The resulting set of subsets of OW is $\{H_{(E)} : E \text{ is a slice of } h\}$. It too will be partially ordered by the relation of subsethood. It is a natural analogue of (the generalisation) of Earman's hypersurface becoming models.

We can now consider whether such models admit of a plausible A-theoretic interpretation, and thereby allow for the possibility of time's really passing in a relativistic world without global Nows. As before we have two options to consider: the analogues of the standard and non-standard classical views. The former takes exactly one element of the model—a set of histories defined in terms of their inclusion of some particular event e—as representative of the absolute facts. In other words, the facts as of some particular event e are taken as the absolute facts.

The non-relativistic analogue of the view relied on a variant of the presentist account of passage. In spelling this out, we had to deal with a delicate issue: future indeterminacy meant that what the absolute facts were going to be could not be read-off from the (current) absolute facts. Therefore a particular choice of 'future' elements in the original model was not justified. Ultimately this was not problematic, because amongst the current facts were facts to the effect that future indeterminacy was later going to be resolved (one way or another). One can do justice to the idea that, as time passes, open possibilities are going to be settled without a model that includes *how* they are going to be settled.

In order for a similar story to be viable in the context of the relativistic model, at least two things are required. First, the tensed facts as of a spacetime point, interpreted as absolute facts, should underwrite a relativistic analogue of the presentist's account of passage. Second, these tensed facts must include facts to the effect that 'as time passes' the current openness concerning the future (and the elsewhere) will be (or will have been) settled one way or the other.

I propose to leave unresolved these intriguing issues because, even if successful on this front, the view is untenable, for the same reason that the corresponding interpretations of Earman's and Skow's models founder. It is simply not plausible to take as absolute, facts that correspond to the perspective of a spacetime region that is both spatially as well as temporally local. I therefore take a *non-standard* A-theoretic interpretation of our BST-based models to be the most promising way to reconcile becoming with relativity. I finish by outlining such a view.

Consider the model $\mathcal{B}(OW, h) = \langle \{H_{(e)} : e \in h\}, \precsim \rangle$. According to a non-standard A-theoretic interpretation of this model each element of $\{H_{(e)} : e \in h\}$ represents the facts that hold as of some spacetime point. $H_{(e)}$, for example, encodes

the facts that hold as of the spacetime location of the event e. Even though such facts are the facts that hold as of some spacetime point, they are not supposed to be reducible to further facts that hold absolutely. These facts display a particular pattern of indeterminacy. As of some point p, what happens outside of p's casual past is indeterminate. But, as of every point, including all points outside of p's causal past, what happens at that point is determinate. Despite not being inter-deducible, the sets of perspectival facts in this network mesh in the obvious ways. What is happening at q, as of q, will be among the things that might happen (or might later have happened) as of points not in the causal future of q.

The model is inequivalent to a single BST model. Facts that are indeterminate as of earlier points in spacetime are settled as of later points. The model is also inequivalent to the preferred history it encodes, or to a BST model that includes a 'thin red line,' at least as the latter is normally understood. In both of these models, non-past indeterminate facts are misrepresented as determinate. The particular pattern of perspective-relative facts that the model encodes *cannot* be understood as reducible to a B-theoretic reality corresponding to either a block universe or a block multiverse. The model therefore constitutes an apparently coherent, thoroughly relativistic A-theoretic alternative to the B Theory.

Does this mean that it vindicates the objective passage of time? In the classical analogue of the model, one could trace through a unique, totally ordered sequence of temporal perspectives, and see facts once open become settled. The spatiotemporal perspectives of the relativistic model are only partially ordered. One can consider a maximal totally ordered subset of them, corresponding to a maximal chain of events in the model's preferred history. According to such a sequence, the tide of becoming has the shape of a past lightcone that moves up the privileged worldline. Does *some* aspect of such 'worldline-dependent becoming' correspond to something objective? Can one see different such sequences obtained from one and the same model as 'gauge equivalent'? Are they just different ways of representing the same underlying passage of time?

It is standard in cases where gauge equivalence is postulated to demand some kind of characterisation of the gauge-invariant reality that gauge-related descriptions differently represent. The prospects for providing something of this sort look better if we change the model, from one based on spacetime points, to one based on slices through our preferred history. Ironically, it is a model involving the analogue of *global* spacelike hypersurfaces that best represents *local* becoming, conceived of as *transition from the indeterminate to the determinate*. The reason is that, as one shifts from 'perspective' to 'perspective' along some maximal totally ordered sequence of elements from the set $\{H_{(E)} : E \text{ is a slice of } h\}$, the resulting change in what is determinate is not spread out over a past lightcone, but is spatiotemporally local.[45]

[45]For those familiar with them, models of causal set dynamics (see Rideout and Sorkin 1999) might

Let S_1 and S_2 be two arbitrary, maximal totally ordered subsets of $\{H_{(E)} : E \text{ is a slice of } h\}$. One might seek to characterise their gauge-invariant content as follows. Very crudely, maximality ensures that for any event e in h, one can find short enough stages of both sequences S_1 and S_2 where pretty much all that happens is a transition from e's potentiality to its actuality. Transitions like this are obvious candidates for the objective local becoming that both sequences represent. Such sequences can differ over whether this transition (which is just the occurrence of e) is 'before' or 'after' the becoming definite of some other event spacelike related to e. But since the events are spacelike related, there is no fact of the matter concerning which occurred first.[46]

Oriel College
Oriel Square
Oxford OX1 4EW
UK
oliver.pooley@philosophy.ox.ac.uk

References.

Barnes, Elizabeth and Ross Cameron 2011: 'Back To The Open Future'. *Philosophical Perspectives*, 25, pp. 1–26.

Belnap, Nuel 1992: 'Branching Space-Time'. *Synthese*, 92, pp. 385–434.

——— 2003: 'Branching Space-Time, Postprint January, 2003'. `http://philsci-archive.pitt.edu/id/eprint/1003`.

be a helpful parallel. BST-based models obtained from slices (rather than points) of the preferred history are something like continuous analogues of the partially ordered sets of discrete structures generated by the classical sequential growth (CSG) of causal sets. In particular, it is standard within the causal set community to understand different sequences of causal sets generated by a growth dynamics as gauge equivalent if they terminate in the same set. Sorkin (2007) has argued that CSG models provide a way to reconcile becoming and relativity without a preferred Now. From the current perspective, Sorkin's proposal should be understood as a version of non-standard A theory. It is a discrete version of the Growing Block view, and so subject to the criticisms of Growing Block views made above. It is, however, possible to recast and reinterpret causal set models along the lines of the branching-time models advocated in this paper.

[46]Related material was previously presented in St Andrews, Chicago, London (England), London (Ontario), Bristol, Warwick, Oxford, Birmingham, Bonn, Nottingham, Florence, Dubrovnik, Dublin, Geneva and San Diego. I am grateful to numerous members of those audiences for useful comments. The passage of time has, unfortunately, loosened my grip on who deserves to be individually thanked. A proper subset includes: Richard Arthur, Andrew Bacon, Imogen Dickie, Antony Eagle, Matt Farr, Carl Hoefer, Mike Martin, Thomas Müller, John Norton, Tomasz Placek, Steven Savitt, Clinton Tolley and, for comments on earlier drafts, Craig Callender, Natalja Deng, Brad Skow, Stephan Torre and Chris Wüthrich. Work for this paper was supported during 2008–10 by a Philip Leverhulme Prize. Support from the Spanish MINECO grant FFI2011-29834-C03-03 is also gratefully acknowledged.

——— 2012: 'Newtonian Determinism to Branching Space-Times Indeterminism in Two Moves'. *Synthese*, 188, pp. 5–21.

Bourne, Craig 2002: 'When Am I? A Tense Time for Some Tense Theorists?' *Australasian Journal of Philosophy*, 80, pp. 359–371.

Braddon-Mitchell, David 2004: 'How Do We Know it is Now Now?' *Analysis*, 64, pp. 199–203.

Briggs, Rachael and Graeme A. Forbes 2012: 'The Real Truth About the Unreal Future'. In Karen Bennett and Dean Zimmerman (eds.), *Oxford Studies in Metaphysics*, Volume 7, pp. 257–304. Oxford: Oxford University Press.

Broad, C. D. 1923: *Scientific Thought*. London: Kegan Paul.

Brogaard, Berit 2008: 'Sea Battle Semantics'. *The Philosophical Quarterly*, 58, pp. 326–335.

Dainton, Barry 2011: 'Time, Passage, and Immediate Experience'. In Craig Callender (ed.), *The Oxford Handbook of Philosophy of Time*, pp. 382–419. Oxford: Oxford University Press.

Deng, Natalja 2013*a*: 'Fine's McTaggart, Temporal Passage, and The A Versus B-Debate'. *Ratio*, 26, pp. 19–34.

——— 2013*b*: 'Our Experience of Passage on the B-Theory'. *Erkenntnis*, pp. 1–14. URL `http://dx.doi.org/10.1007/s10670-013-9489-5`.

Dieks, Dennis 2006: 'Becoming, Relativity and Locality'. In Dennis Dieks (ed.), *The Ontology of Spacetime*, pp. 157–76. Elsevier.

Dorato, Mauro 2006: 'Absolute Becoming, Relational Becoming and the Arrow of Time: Some Non-conventional Remarks on the Relationship Between Physics and Metaphysics'. *Studies in History and Philosophy of Modern Physics*, 37, pp. 559–76.

Earman, John 1986: *A Primer on Determinism*. Dordrecht: D. Riedel.

——— 2008: 'Reassessing the Prospects for a Growing Block Model of the Universe'. *International Studies in the Philosophy of Science*, 22, pp. 135–64.

Ellis, George F. R. 2006: 'Physics in the Real Universe: Time and Spacetime'. *General Relativity and Gravitation*, 38, pp. 1797–1824.

Falk, Arthur 2003: 'Time Plus the Whoosh and Whiz'. In Aleksandar Jokić and Quentin Smith (eds.), *Time, Tense and Reference*, pp. 211–250. MIT Press.

Farr, Matt 2012: 'On A-and B-Theoretic Elements of Branching Spacetimes'. *Synthese*, 188, pp. 85–116.

Fine, Kit 2005: 'Tense and Reality'. In *Modality and Tense*, pp. 259–320. Oxford: Oxford University Press.

Geach, P. T. 1973: 'The Future'. *New Blackfriars*, 54, pp. 208–218.

Gibson, Ian and Oliver Pooley 2006: 'Relativistic Persistence'. *Philosophical Perspectives*, 20, pp. 157–198.

Greaves, Hilary 2004: 'Understanding Deutsch's Probability in a Deterministic Multiverse'. *Studies In History and Philosophy of Science Part B: Studies In History and Philosophy of Modern Physics*, 35, pp. 423–456.

Grünbaum, Adolf 1967: 'The Status Of Temporal Becoming'. *Annals of the New York Academy of Sciences*, 138, pp. 374–395.

Ismael, Jenann 2011: 'Decision and the Open Future'. In Adrian Bardon (ed.), *The Future of the Philosophy of Time*, pp. 149–168. New York: Routledge.

Lewis, David 1983: 'New Work for a Theory of Universals'. *Australasian Journal of Philosophy*, 61, pp. 343–77.

——— 1986: *On the Plurality of Worlds*. Oxford: Blackwell.

MacFarlane, John 2003: 'Future Contingents and Relative Truth'. *The Philosophical Quarterly*, 53, pp. 321–336.

——— 2008: 'Truth in the Garden of Forking Paths'. In Manuel García-Carpintero and Max Kölbel (eds.), *Relative Truth*, pp. 81–102. Oxford University Press.

Markosian, Ned 2004: 'A Defense of Presentism'. In Dean Zimmerman (ed.), *Oxford Studies in Metaphysics*, Volume 1, pp. 47–82. Oxford: Oxford University Press.

Maudlin, Tim 2002: 'Remarks on the Passing of Time'. *Proceedings of the Aristotelian Society*, 102, pp. 237–252.

——— 2007: *The Metaphysics within Physics*. Oxford: Oxford University Press.

Maxwell, Nicholas 1985: 'Are Probabilism and Special Relativity Incompatible?' *Philosophy of Science*, 52, pp. 23–43.

McCall, Storrs 1976: 'Objective Time Flow'. *Philosophy of Science*, 43, pp. 337–362.

——— 1984: 'A Dynamical Model of Temporal Becoming'. *Analysis*, 44, pp. 172–6.

——— 1994: *A Model of the Universe*. Oxford: Oxford University Press.

Mellor, D. H. 2001: 'The Time of Our Lives'. *Royal Institute of Philosophy Supplement*, 48, pp. 45–59.

Müller, Thomas 2002: 'Branching space-time, modal logic and the counterfactual conditional'. In Thomasz Placek and Jeremy Butterfield (eds.), *Non-locality and modality*, NATO Science Series, pp. 273–291. Dordrecht: Kluwer.

Nerlich, Graham 1998: 'Falling Branches and the Flow of Time'. *Australasian Journal of Philosophy*, 76, pp. 309–316.

Norton, John D. 2010: 'Time Really Passes'. *Humanae.Mente*, 13, pp. 23–34.

Olson, Eric 2009: 'The Passage of Time'. In Robin Le Poidevin, Peter Simons, Andrew McGonigal, and Ross Cameron (eds.), *The Routledge Companion to Metaphysics*, Abingdon: Routledge.

Paul, L. A. 2010: 'Temporal experience'. *The Journal of Philosophy*, 107, pp. 333–359.

Placek, Tomasz 2002: 'Branching for a Transient Time'. In Helena Eilstein (ed.), *A Collection of Polish Works on Philosophical Problems of Time and Spacetime*, pp. 73–92. Dordrecht: Kluwer.

Placek, Tomasz and Nuel Belnap 2012: 'Indeterminism is a modal notion: branching spacetimes and Earman's pruning'. *Synthese*, 187, pp. 441–469.

Prior, Arthur 1968: 'Changes in Events and Changes in Things'. In *Papers on Time and Tense*, pp. 1–14. Oxford: Oxford University Press.

Prosser, Simon 2012: 'Why Does Time Seem to Pass?' *Philosophy and Phenomenological Research*, 85, pp. 92–116.

Putnam, Hilary 1967: 'Time and Physical Geometry'. *Journal of Philosophy*, 64, pp. 240–7.

Rideout, David and Raphael Sorkin 1999: 'Classical Sequential Growth Dynamics for Causal Sets'. *Physical Review D*, 61, p. 024002.

Rietdijk, C. W. 1966: 'A Rigorous Proof of Determinism Derived from the Special Theory of Relativity'. *Philosophy of Science*, 33, pp. 341–4.

Saunders, Simon 2010: 'Chance in the Everett Interpretation'. In Simon Saunders, Jonathan Barrett, Adrian Kent, and David Wallace (eds.), *Many Worlds? Everett, Quantum Theory, and Reality*, pp. 181–205. Oxford: Oxford University Press.

Savitt, Steven 2002: 'On Absolute Becoming and the Myth of Passage'. In Craig Callender (ed.), 'Time, Reality and Experience', , *Royal Institute of Philosophy Supplement*, Volume 50, pp. 153–67. Cambridge: Cambridge University Press.

——— 2009: 'The Transient Nows'. In Wayne Myrvold and Joy Christian (eds.), *Quantum Reality, Relativistic Causality, and Closing the Epistemic Circle: Essays in Honour of Abner Shimony*, The Western Ontario Series In Philosophy of Science, Volume 73, pp. 349–362. Berlin: Springer.

Skow, Bradford 2009: 'Relativity and the Moving Spotlight'. *Journal of Philosophy*, 106, pp. 666–78.

Smart, J. J. C. 1949: 'The River of Time'. *Mind*, 58, pp. 483–494.

Sorkin, Raphael 2007: 'Relativity Theory Does Not Imply that the Future Already Exists: A Counterexample'. In V. Petkov (ed.), *Relativity and the Dimensionality of the World*, pp. 153–61. Berlin: Springer.

Stein, Howard 1968: 'On Einstein–Minkowski Space–Time'. *Journal of Philosophy*, 65, pp. 5–23.

——— 1991: 'On Relativity Theory and Openness of the Future'. *Philosophy of Science*, 58, pp. 147–67.

Švarný, Petr 2012: 'Flow of Time In BST/Bcont Models And Related Semantical Observations'. Available at: `http://philsci-archive.pitt.edu/id/eprint/9194`.

Thomason, Richmond H. 1970: 'Indeterminist time and truth-value gaps'. *Theoria*, 36, pp. 264–281.

Torre, Stephan 2011: 'The Open Future'. *Philosophy Compass*, 6, pp. 360–373.

Trautman, Andrzej 1966: 'Comparison of Newtonian And Relativistic Theories of Space-Time.' In Banesh Hoffmann (ed.), *Perspectives in Geometry and Relativity: Essays in Honor of Václav Hlavatý*, pp. 413–425. Bloomington: Indiana University Press.

Wilson, Alastair 2011: 'Everettian quantum mechanics without branching time'. *Synthese*, 188, pp. 67–84.

Wroński, Leszek and Tomasz Placek 2009: 'On Minkowskian Branching Structures'. *Studies In History and Philosophy of Modern Physics*, 40, pp. 251–258.

Wüthrich, Christian 2013: 'The Fate of Presentism in Modern Physics'. In Roberto Ciuni, Kristie Miller, and Giuliano Torrengo (eds.), *New Papers on the Present*, Munich: Philosophia Verlag.

Zimmerman, Dean 2011: 'Presentism and the Space-Time Manifold'. In Craig Callender (ed.), *The Oxford Handbook of Time*, pp. 163–244. Oxford: Oxford University Press.