Shedding Light on Time

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Throughout this century many philosophers and physicists have gone for the 'big kill' regarding tenses. They have tried to show via McTaggart's paradox and special relativity that tenses are logically and physically impossible, respectively. Neither attempt succeeds, though as I argue, both leave their mark. In the first two sections of the paper I introduce some conceptual difficulties for the tensed theory of time. The next section then discusses the standing of tenses in light of special relativity, especially recent work by Stein on the topic. I argue that, Stein's possibility theorem notwithstanding, special relativity is inconsistent with any *philosophically interesting* conception of tense. Finally, I search for help for tenses in the broader context of quantum theory, Lorentzian interpretations of time dilation/length contraction, and general relativistic spacetimes. I suggest that these avenues do not provide tenses the home for which some have hoped.

1. Introduction. Consider a four-dimensional manifold of point events, each having a unique spatial and temporal position. It will be useful to imagine each event carrying a lightbulb that we can switch on or off. For the moment, when a lightbulb is on we will say that the event *exists* and when it is off that it *doesn't exist*. The existing universe's size, duration, and topology will depend upon which lightbulbs are on. We will not yet worry about the particular form the metric takes on our manifold. In terms of our picture, the traditional tenseless view of time known as *eternalism* states that all the lights on our four-manifold are on—that is, they all exist. Temporal properties are relations among existing events. By contrast, the version of the tensed view of time known as *presentism* pictures the four-manifold as foliated via an equivalence relation, simultaneity, and time as the one-dimensional linearly ordered quotient set induced by simultaneity. Three-dimensional leaves of simultaneous events successively flash into and out of being according to this view, so that only present

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lights are ever on. A variant of this, which we might call historicism, holds that the past and present are real, i.e., that once lights are turned on they stay on.

Throughout this century many philosophers and physicists have gone for the 'big kill' regarding tenses. They have tried to show via McTaggart's paradox and special relativity that tenses are logically and physically impossible, respectively. Neither attempt succeeds, though as I'll argue, both leave their mark. Preoccupied with the big kill, philosophers have ignored plausibility arguments against the tense view. That is, they have ignored simply weighing the explanatory power of tenses as they would judge any other explanation of the phenomena. While going after smaller game may not be as thrilling as the previous exercises, it is, perhaps, more liable to produce lasting results. Here I cannot fully engage in this larger project, but I can set the stage for it by partially determining what conceptions of tense survive the tests of logic and physics. Whether the survivors are so damaged by these tests that they are unworthy of our belief—as I believe to be the case—is a question I will leave to another time.

In Sections 2 and 3 I introduce conceptual (non-empirical) difficulties for presentist and non-presentist versions of the tensed theory of time, respectively. Section 4 then discusses the standing of tenses in light of special relativity, especially recent work by Stein on the topic. Sections 5 and 6 embed this discussion within the broader context of quantum theory, the Lorentzian interpretation of special relativity and general relativitistic spacetimes.

2. Two Challenges for Presentism. Above I wrote as if it is clear exactly what the difference is between eternalism and presentism. But I should come clean and admit that I find it surprisingly difficult to understand exactly what presentism amounts to. It's not obvious that the two views differ over much. Clearly distinguishing presentism from eternalism is our first challenge for presentism.

One way to see the problem is by noticing where an analogy breaks down. Suppose time t_1 is the present. The question suggested by our metaphor is whether the lights at t_2 are on or not. Since we can only look at the lightbulbs at t_2 when at t_2, of course, we cannot go out and check. Our question is therefore a bit like the one asked by the skeptic in the kitchen, namely, does the refrigerator lightbulb go out when we shut the door? 'Refrigerator presentists' believe the light is off when the door is shut; 'refrigerator eternalists' believe the light remains on. Barring drilling a hole into the side of the refrigerator and other invasive moves, we can only check the light by opening the door. Yet this won't test either hypothesis. Now, if similarity to this debate were the problem, then we shouldn't worry about our philosophical debate's substance. Verificationist methodology to one side, the traditional debate would at least be over a genuine fact of the matter, namely, what lightbulbs (events) are on (exist) at different times.

However, the analogy is not good. The disputants about refrigerator lights agree that when the door is closed *there is* a lightbulb that *could be* on or off. Their debate is clearly over a genuine matter of fact. By contrast, presentists about time say lightbulbs that are off don't exist. If the bulb is off, *it ain't*. Only lightbulbs that are on exist, which is, unfortunately, precisely what eternalists maintain. Both theorists agree at t_{n+1} that the light was on at t_1, t_2 . . . t_n and that there was, is, and will be no time at which the light exists and is off. Where is the disputed fact of the matter?

One might argue that there is a genuine disagreement about whether it is *true* at t_1 that the lights at t_2 are on or off. Yet articulating the debate in these terms descends it into a squabble about the proper semantics of 'truth' and 'existence,' not a debate about time. Framed like this, the debate seems to turn merely on definitions. The presentist relies on a tensed theory of truth and a tensed reading of the existential quantifier. Truth and existence at t is only assigned to states of affairs at t. Not surprisingly, according to the presentist, it's not true at t_1 that the lights at t_2 are on. By contrast, the eternalist relies on a tenseless theory of truth and of the existential quantifier, where truth and existence at t is assigned to states of affairs omnitemporally. According to this rule, it is true at t_1 that the lights at t_2 are on. Since there are no convincing reasons to adopt one or another interpretation of truth and/or the existential quantifier (so far as I can see), there is no way to decide which rule is correct (Priest 1986). Left at this, the debate seems merely over whether we ought to use our predicate 'is true' to describe present events or whether we ought to extend it to non-present events too.

Once the first challenge has been successfully answered, a second challenge is for the presentist to explain apparent facts about the past (and future, if there are any). History books and other claims about the past are presumably not fictions. The NY Yankees, for instance, won the World Series in 1978. Presentists owe us an account of this fact, but their account can use only present facts. (Compare with the actualist modal realist's task of explaining truths about possible worlds using only propositions about the actual world.) Yet it is hard to see how they might accomplish this feat; the only proposal I know of, Hinchliff (1996), for instance, appears to be circular (see Oaklander 1998).

No doubt presentism faces more conceptual difficulties than merely those posed by the above challenges. Before evaluating presentism with respect to these difficulties, however, it seems to me that the bare bones of the presentist metaphysic first must be given some flesh by answering the above challenges. Of course whether this is worth the trouble depends in part on how tense theories in general fare when we turn to empirical matters.

3. Hybrid Theories and Conceptual Difficulties. There are many other species of tense theory besides presentism, e.g., historicism, and variants of presentism and historicism. Many of these views are what we might call 'hybrid theories', theories that in some sense combine the traditional A- and B-theories of time. Though not advertised as such, it is this hybrid theory that has attracted much attention in work on becoming in philosophy of science.

Hybrid views acknowledge that the world may be thought of as an existent four-dimensional entity, like B-theorists, but retain the idea that there is something special about present times, like A-theorists. Because hybrid theories accept that a four-manifold is the arena of world history, they cannot—on pain of coherency—analyze becoming in terms of the coming into existence of events. It simply doesn't make sense to say an existent event comes into being. Hybrid theorists therefore hold (or ought to hold) that the present but not the future possesses, for example, the property of determinacy or some primitive property of presentness, and that these properties do not bear on the (non)existence of events.

Here too we have problems, for interestingly, McTaggart's famous paradox seems to threaten *only* hybrid theories. McTaggart's paradox famously asserts that events cannot be arranged in an A-series, since that would require of any event e that it is both present and future, and this is contradictory. The friend of tenses' next move is to hold that e (say) *is* in the present, *was* in the future and *will be* in the past. This lands them in their notorious infinite regress since many of these second-order tenses are incompatible. But as some A-theorists point out, the paradox really affects only hybrid views. In order to get the paradox going one must initially ascribe to e mutually inconsistent monadic temporal properties. Eternalists avoid this ascription because they use only relational temporal properties. A-theorists, if they are presentists, escape by denying that *there are* past or future events. For presentists there simply is nothing to have contradictory properties. Hybrid views that combine tenseless time with *monadic* temporal properties, however, do seem to make the claims necessary to get McTaggart's paradox going, and so fall prey to McTaggart's infinite regress. Suppose the lightbulbs attached to our events look red when they are future and white when they are past. Understanding 'is red' and 'is white' as monadic properties, the future is a set of colored red lightbulbs and the past a set of colored white ones. We now struggle to make sense of red lightbulbs becoming white ones without the aid of another temporal dimension. The regress once again manifests itself.

One quick way around this difficulty is to combine tenseless time with *relational* properties that aren't merely the ordinary B-relations of the tenseless theory. This seems to be the position adopted in current work in philosophy of science on becoming and relativity. Obviously this position is logically coherent. Event a can bear relation S to b but not bear S to c. In terms of our picture again, we can let Sxy mean 'lightbulb x looks red to y'. The lightbulb attached to the event of the Yankees losing the World Series in 1981 is red relative to their 1978 victory and white relative to their fantastic 1998 victory. This position in the logical geography regarding time hasn't proved to be very popular. This is probably because S, being a relation, falls squarely within the B-theory tradition, yet B-theorists have not found much need for becoming. Whether an event has become or not is traditionally a question about whether an event has acquired a special intrinsic property or not—a question that automatically disbars relational conceptions of becoming.

Furthermore, even if there were a perceived need for B-theoretic becoming, it's not clear that S has anything besides 'logical' legitimacy. As time passes, events are supposed to become __________. To be philosophically interesting, we must fill in the blank with something having clear ontological meaning, something besides 'existent'. Becoming ought not to be an epistemic notion arising from our ignorance of some events' properties. If becoming means 'becoming known', then it is trivialized. Yet it is far from clear that one can find a non-epistemic, satisfactory nature for becoming. When not analyzed in terms of existence, becoming is typically understood in terms of (in)determinacy. Indeterminate future events are sculpted into determinacy upon interaction with the present. One common way of making sense of this idea is through the claim that the future is branching, i.e., through the tree model of reality (McCall 1994, Dorato 1995). However, this idea runs into many troubles, not the least of which being how it makes sense of the present moving up the tree.

Since I haven't space to consider such analyses in detail, I will not linger over objections to this view. After all, one can always resort to the claim that becoming is a primitive and unanalyzable notion. Let us therefore grant the logical possibility of a determinacy relation defined over events on a spacetime four-manifold. Since it is a binary relation and not a monadic property it avoids McTaggart's paradox. But can it—or any other tense theory—circumvent the challenge from relativity?

4. Shedding Light on Becoming. As is well known, special relativity poses a threat to the tensed theory of time. The threat was enunciated by Putnam (1967) and others in the 1960s and attacked by Stein (1968). Later, papers in the 1980s, especially Maxwell (1985), provoked Stein again (1991). Since then there have been many papers, a book (Dorato 1995), and a few Ph.D. dissertations by philosophers of science keen to define a relation of objective becoming in relativistic spacetime. In particular quarters of this literature the idea that Stein conclusively refuted Putnam et al and made becoming relativistically respectable seems to have achieved the status of conventional wisdom.

What did Stein do? Stein proves that a binary partial ordering determinacy relation R can be defined consistently on Minkowski spacetime. He interprets Rxy as the point y being definite as of x. R satisfies several conditions Stein deems necessary for an adequate conception of becoming. It is first of all implicitly definable solely in terms of the time-oriented Minkowski metric, i.e., it 'commutes' with automorphisms of the time-oriented metric. R is also reflexive and transitive. Lastly, Stein stipulates that if xy is a past-pointing vector (from x to y), then Rxy holds. The idea is that at least all points in the causal past of x ($J^{-}(x)$) are definite for x. Stein's theorem demonstrates that Rxy can satisfy these conditions iff xy is a past-pointing vector (from x to y). Since the set of all past-pointing vectors from x constitutes its backward lightcone, the proof shows that the region of definiteness for any event is precisely its past lightcone. R is thus the relation of past causal connectedness.

Despite this proof, I must confess that, some quibbles aside, I've always found Putnam et al.'s argument eminently sensible. The idea is simply that any notion of becoming *remotely similar to that found among advocates of the tensed view of time* is not compatible with Minkowski spacetime. Stein is of course right that R can be consistently defined on (temporally oriented) Minkowski spacetime. The question, however, is whether R is a relation of serious philosophical interest to the philosophy of time.

Stein's argument crucially hangs on the acceptance or rejection of a 'non-uniqueness' condition that may be further imposed upon R. Using this condition one can very simply transform Stein's 'possibility' theorem into a 'no go' theorem for objective becoming in a Minkowski spacetime. The condition in question is very weak:

Non-uniqueness condition. $\exists x \exists y \exists R(Rxy \ \& \ Ryx \ \& \ x \neq y)$.

This condition says merely that at least one event in the universe shares its present with another event's present. This seems the thinnest requirement one might put on becoming. Readers familiar with Putnam's original paper will recognize this as essentially his second assumption, one that Stein drops to prove his theorem. However, *all* versions of the traditional tensed theory hold this meager assumption. Yet, as weak as it is, with it we can prove the following simple 'no go' theorem, which is implicit in Clifton and Hogarth (1995):

'No Go' Theorem. For any binary relation R on time-oriented Minkowski spacetime, if R is i) implicitly definable from time-oriented

metrical relations, ii) transitive, iii) such that, if $y \subseteq J^{-}(x)$, then Rxy, and iv) satisfies non-uniqueness, then R is the universal relation, U.

Because the proof of this theorem is a trivial extension of the argument behind Stein's theorem or Clifton and Hogarth's Theorem 2, I leave it to the reader. Note that the addition of condition iv rules out R being the past causal connectibility relation. Coupled with Clifton and Hogarth's Theorem 2, this proves the theorem. Intuitively put, Stein's theorem shows that given conditions i–iii, if there is a becoming relation, it must be past causal connectibility R. R is an ordering relation, and as such, is anti-symmetric (Rxy & Ryx → x≡y). But non-uniqueness stipulates that for at least one pair of events R is not anti-symmetric, and this is enough to turn the existence proof into a no-go proof.

Stein and some of his defenders (Clifton and Hogarth 1995, Dickson 1998) would probably reply that the non-uniqueness assumption begs the question, that the notion of a spatially extended present is not relativistically acceptable. But that is precisely the point of Putnam's argument and the 'no go' theorem. The logical structure of the argument, *pace* Dickson (1998), couldn't be more clear or plausible: it is a simple reductio against the idea of importing traditional becoming into Minkowski spacetime. Traditional conceptions of time all accept the non-uniqueness assumption. It is therefore legitimate to use it in a reductio of the idea.

The debate between Putnam et al. and Stein et al. is not, or shouldn't be, over the logic or physics of the above two theorems, for this is straightforward and uncontroversial. If there is a debate, it is therefore over which becoming relation, defined via the conditions of these theorems, ought to count as Becoming (and which theorem, correspondingly, ought to be the relevant one). Let's continue to refer to Stein's relation as R, and let's refer to the traditional conception of becoming (the one the proverbial man-in-the-street allegedly has, the one traditional analytic philosophers discussed, etc.) as R*. R* is a much richer a concept, I take it, than merely R + non-uniqueness; but R* is *at least* R + non-uniqueness.

We can see very quickly that R is very different from R*. Recall that due to R's anti-symmetry, event x is present with y iff x≡y. From the traditional standpoint, this consequence trivializes becoming.[1] According to this definition, only a single point is present for you, namely, your here-now. But this is true for *each* point. At my here-now I am present according to myself as I speak to you; you are present with respect to yourself as you speak to me. But we do not (and no one does) share a present.

1. Anti-symmetry does not trivialize becoming in Newtonian spacetime because it admits a binary total ordering relation on equivalence classes of events. The equivalence relation 'simultaneous with' partitions the set of all events into disjoint subsets, upon which an ordering relation can then be defined.

Furthermore, one's past is not the union of one's former nows on this view. Consider the Yankees winning the World Series in NY in 1998. Since I wasn't in NY at that time, and yet the event is now in my backward lightcone, the Yankees' win determinately happened for me but at no time was it present for me. Another consequence is that what past events are determinate (for me) depends crucially on how fast I walked to my computer. Untold numbers of stars now exist determinately thanks to my detour to the kitchen for a snack. Finally, and perhaps worse, the becoming relation is *maximally* observer-dependent, for no two observers agree on what is determinate.

That Stein's R is not remotely close to the traditional becoming relation R* is abundantly clear. The conditions defining R are perhaps necessary, but far from sufficient, for traditional becoming. The traditional becoming relation makes becoming observer-independent. Contrary to R, the traditional theory also gives the present spatial extent and makes the past the union of one's former presents. It is important to point out that the traditional theory makes these assumptions *not* merely based on the assumption that spacetime is classical. It makes these assumptions because they are thought to be part and parcel of our ordinary concept of time.

Perhaps one doesn't care about our ordinary concept of time? Fine—you have no quarrel with me. But then the new concept of becoming needs to be independently motivated. Stein and his defenders claim that we must accept the above bizarre consequences if relativistic becoming is to have a chance. They point out that there is no contradiction in a becoming relation with such properties. However, Putnam et al never pretended to argue that logic and relativity alone prevents a becoming relation from being defined in Minkowski spacetime. Of course one can define *some* relation on Minkowski spacetime and *call* it becoming. The interesting question is whether one can define on Minkowski spacetime a relation that is philosophically well motivated. Without such a motivation, the new becoming relation R remains a philosophically empty technical result.

The traditional reasons for R* derive from their alleged status as the best explanation of tensed language and behavior, our psychological experience, and the phenomenon of change. I personally do not believe these grounds confer sufficient weight to warrant positing R*. Even if they did, however, they could not be used in support of Stein's R. One certainly cannot find support from ordinary language for believing that spatially distant events don't exist, for example (Stein's observation of the double—temporal and spatial—meaning of 'present' notwithstanding). Nor can one see how R would help explain change or the psychology of time flow in a manner that added anything significant to the ordinary eternalist's explanation. The question is then whether there are instead reasons from theory and science to posit Stein's becoming. I'm not sure there are. Nothing like Stein's becoming relation is posited in the physics that I know, nor can I think of any genuine problem in physics that positing R will answer. The bulk of Stein's article tries to motivate the idea that the appropriate sense of the present in special relativity is a single point. Even granting this,[2] nowhere does one find a positive reason to believe Stein's becoming obtains in the world. Absent such an argument, there is little reason to be so interested in R's possibility. There is certainly no reason to conceive of his theorem as 'refuting' Putnam et al. The two becoming relations are defined differently. The traditional one, R*, which arguably has independent interest due to common sense views about time, is provably inconsistent with Minkowski spacetime. The non-traditional conception, R, by contrast, is compatible with Minkowski spacetime but appears to be philosophically idle.

5. Preferred Frames. Does the no-go result and subsequent discussion mean that the tensed theory is dead, once and for all? No, for there is always the option of differently interpreting the data supporting special relativity. Specifically, one could adopt the empirically adequate Lorentzian interpretation or one might add extra structure to Minkowski spacetime, i.e., a foliation. According to the first interpretation, the background spacetime is not Minkowskian but Newtonian. The effects of Maxwell's equations on clocks and rods imply that we will never experimentally determine the true states of motion or of rest (as explained nicely by Bell 1987). But still the Newtonian spacetime would provide a foliation of spacetime via equivalence classes of simultaneous events. We could maintain the picture of equivalence classes of simultaneity planes not tied to inertial observers successively flashing into and out of existence, while granting that we cannot experimentally determine which frame is the one that becomes. Such a conspiratorial interpretation of nature is not desirable, ceteris paribus, but such an interpretation is not contradicted by observational facts. The reason for the nearly universal adoption of the Minkowskian interpretation is that it (arguably) enjoys many methodological advantages compared with those of its competitor. But were the case for tenses sufficiently strong, it might outweigh these methodological advantages and force us to choose differently. Alternatively, we might keep the Minkowski metric but add more structure to spacetime. We might

2. Weingard (1972), addressing Stein (1968), argues that the most natural expression of Newtonian simultaneity in Minkowski spacetime is the set of all events that *can* be considered simultaneous with an event e, i.e., all those events spacelike to e. Assuming that becoming is transitive, one can prove that all events in the spacetime have become on this reading of simultaneity. Savitt (this volume) notes that this proposal violates his achronality requirement, so if this requirement is accepted, Weingard's 'present' is unacceptable.

add a foliation, i.e., a preferred stacking of spacelike hypersurfaces that divides the spacetime manifold. Becoming, then, could occur with respect to this preferred stacking (see Rakic 1997 for an interesting result in this direction).

As it happens, there may be good reason from quantum theory to adopt one of these views. Non-relativistic and relativistic quantum mechanics alike suffer from the notorious measurement problem. Few treatments of this problem describe a world wherein Minkowski spacetime could remain the background arena in which physical systems evolve. In the non-relativistic case, if one maintains that our experiences of determinate measurement outcomes are in fact illusory (as in Everettian interpretations), then one ends up telling the story of physical evolution on N-dimensional configuration space, not Minkowski spacetime. If one solves the problem by providing a realistic collapse mechanism (as in GRW), then the collapses pick out a preferred frame, one that may even be experimentally detectable (Albert 1998). If one instead adds something to quantum mechanics (as in Bohm's theory), and specifies a dynamics for this addition, then the (necessarily) nonlocal dynamics seems to pick out a preferred frame. The last two strategies for dealing with the problem (which I believe are far and away the most promising) pick out a preferred foliation. The relativistic extensions of these resolutions of the measurement problem, where they exist, also seem to pick out a preferred foliation. Quantum mechanics, therefore, may put us in the position of adopting the Lorentzian interpretation or of retaining the Minkowski metric but adding more structure to spacetime. The latter option may be methodologically preferable to the former (Maudlin 1997). But on either account, tenses can be defined. Any final judgment now on this topic would be wildly premature, of course. However, early indications are that quantum mechanics may provide good reason to reconsider the geometrical structure of our world, even considered only special relativistically. Finally, though extremely speculative, it is worth mentioning that some strategies for resolving the so-called 'problem of time' in quantum gravity may reintroduce a preferred frame (see Goldstein and Teufel forthcoming). These speculations raise the following question: Given the situation with quantum mechanics, should the friend of tenses point to these developments in support of tenses, or at least, in support of brushing aside the challenge from special relativity?

No. Developments in physics may push us away from the traditional understanding of relativity, but I urge the reader not to allow the tensed theory to do the same. This is not because I believe that only arguments based on physics ought to have a bearing on our interpretations of physics. Good arguments in metaphysics often rightly have some influence on interpretations of physics. The problem is that I simply don't believe that the arguments in metaphysics in favor of tenses are particularly good ones, though this is an argument for another paper. Here I can only ask, if science cannot find the 'becoming frame', what extra-scientific reason is there for positing it? If the answer is our experience of becoming, we are essentially stating that our brains somehow have access to a global feature of the world that no experiment can detect. This is rather spooky. If the answer instead comes from conceptual analysis on metaphysical categories such as change, we must ask whether there is reason to think our concept *accurately* mirrors reality. Our concept of (say) change is loaded with pre-scientific connotations. Why think it reveals something about the properties of spacetime that science cannot? Quantum theory's potential suggestion that we abandon the conventional interpretation of special relativity, radical as it is, would if pursued ultimately be the normal outcome of best trying to fit together the data supporting relativity and quantum mechanics. The commonsense metaphysician's advocacy of alternative pictures arises mainly from analysis of pre-scientific concepts. In terms of the justification of nonstandard interpretations of relativity, there is a huge gulf between the two.

6. On Sidestepping Gödel's Modal Step. Let me finally say a word about becoming's prospects in the general theory of relativity (GTR), for it is sometime said that becoming may find a home here. Interpreted realistically (that is, not instrumentally) and assuming that becoming would be something common to all models of GTR, it is more than clear that GTR is hostile to becoming. There is absolutely no chance that a plausible sense of becoming can be defined in *all* the models of GTR. It is well-known that GTR allows plenty of spacetime models not admitting definitions of either a global time function or a cosmic time, e.g., the many models containing closed timelike curves. Without even these 'times', it is hard to see how a definition of becoming or tense could get off the ground.

Those hoping to resuscitate becoming do not question this fact, however. What is questioned is why a lapse of time must be definable in *every* model of GTR. Gödel famously argued that the existence of solutions like his own to the field equations spelled the end for time. Gödel spacetime's closed timelike curves cannot be 'unrolled' since the spacetime is simply connected—it therefore cannot be foliated into spacelike hypersurfaces. Since Gödel considered a foliation a necessary condition for lapsing of time, he believed his spacetime is incompatible with becoming. More controversially, he claimed that since Gödel spacetime and our spacetime differ only by having different matter-energy distributions, and yet locally our experiences may be the same, *our* world cannot have becoming in it either. This is Gödel's 'modal step'. The crucial point in the argument is his claim that the matter distribution cannot determine the lapse of time.

Earman (1995) finds no support for this premise. Whether space is open or closed depends on the matter distribution, he writes, so why shouldn't the lapsing of time?

Until more is known about becoming we simply cannot answer this question. Gödel himself clearly has the traditional tensed theory of time in mind. Becoming, for him, involves slices of time successively acquiring the monadic property of existence. Plausibly, on this reading of becoming, the matter distribution does not affect the lapse of time. It is hard to imagine a connection between the magnitudes and locations of matter-energy and the existence or nonexistence of entire spacelike hypersurfaces. There is no mechanism in place by which different distributions of matter-energy would produce differences of the kind envisioned by advocates of the tensed theory. But on other readings of becoming, who knows? Stein's becoming relation, for instance, may be a good example of Earman's point. R can not live in Gödel spacetime, but it may live (non-uniquely) in a Friedman-Robertson-Walker spacetime like ours.

Finally, a word of caution is advisable. If the proposed becoming relation does depend on the matter distribution, I doubt the traditional philosopher of time will be much interested in it. For it seems odd to say (for example) that whether the universe admits McTaggart's *real* change depends on the matter distribution. Yet the only motivation that I know of for positing becoming in the first place arises from ordinary language and (allegedly) common sense, not from science. So if matter-dependent becoming is not useful to traditional philosophers of time, to whom will it be useful? Before philosophers of science bother to investigate the definability of becoming in different spacetime models, then, proponents of becoming must first tell us precisely what it is and convince us of its utility. My suspicion is that we will find that becoming's scientific respectability and its philosophical utility are inversely proportional.

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