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Becoming Inflated

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ABSTRACT

Some have thought that the process of the expansion of the universe can be used to define an absolute 'cosmic time' which then serves as the absolute time required by tensed theories of time. Indeed, this is the very reason why many tense theorists are happy to concede that special relativity is incompatible with the tense thesis, because they think that general relativity, which trumps special relativity, and on which modern cosmology rests, supplies the means of defining temporal becoming using cosmic time. I argue that cosmic time is not up to the task, and that these tense theorists should rethink their strategy in dealing with the theories of relativity.

1 Introduction

Some, e.g., Swinburne ([1981], p. 202), Dorato ([1995], Chapter 13) and Lucas ([1999]), have thought, and others, e.g., Savitt ([2000]), have at least been open to the idea, that the process of the expansion of the universe can be used to define an absolute 'cosmic time' which then serves as the absolute time required by tensed theories of time, i.e., those theories that ascribe an ontological privilege to the present time, and state that time 'flows' as future moments become present and then past. Indeed, this is the very reason why many tense theorists are happy to concede that special relativity (STR) is incompatible with the tense thesis, because they think that general relativity (GTR), which trumps STR, and on which modern cosmology rests, supplies the means of defining temporal becoming using cosmic time. But the case for defining temporal becoming in terms of cosmic time is always left at the level of suggestive remarks and is never adequately made. I shall argue that this is unsurprising since cosmic time is not up to the task, and that these tense theorists should rethink their strategy in dealing with the theories of relativity.[1]

2 The Mellor-Rees argument against tense theories

Mellor, in *Real Time II* ([1998], p. xii), writes:

> The main addition [to the original chapter on spatial analogues of tense and tenseless theories in *Real Time* ([1981])] is a short section (for which I am indebted to Sir Martin Rees) showing that modern cosmology does not, as some [tense theorists] suppose, undermine objections to [tense theories] based on the special theory of relativity. Far from yielding a privileged reference frame and hence absolute simultaneity across space, its uniform treatment of the expansion of the universe implies that there is no such thing.

This argument is misguided, but in dealing with it, we can appreciate what these tense theorists are doing, and its limitations.

Consider the following argument (ARG) from STR against tense theories, as put forward in various forms by, e.g., Putnam ([1967]), Weingard ([1972]), Mellor ([1974]), Maxwell ([1985]), Callender ([2000]) and Savitt ([2000]). (I set up the problem as it applies to presentism, for many of the arguments apply *mutatis mutandis* to all the other tensed theories):

ARG: Presentists state that only what is present exists; hence only things simultaneous with the present exist. STR, however, states that there is no absolute (i.e., frame-independent) simultaneity relation between events, and hence no privileged set of events that constitute the present—there is no *absolute* present. The best that can be said according to STR is that what is present (i.e., simultaneous with an event we suppose to be present) is *relative* to a frame of reference. But then, if both STR and presentism are true, it follows that what *exists* is relative to a frame of reference. But what exists is an absolute matter, not relative. Therefore, we must reject either presentism or STR. And, since STR is one of our most successful scientific theories, we should reject presentism rather than abandon STR.

Let us remind ourselves of the core features of STR:

(i) *The Principle of Relativity*: all inertial frameworks are equivalent for the description of all physical phenomena: the same laws hold in all inertial frames.
(ii) *The Law of the Propagation of Light*: light (*in vacuo*) is propagated in straight lines with a constant speed *c*.

[1] See also Earman ([2002]), who argues that GTR is a rather inhospitable environment for tense theorists.

By (i), (ii) must hold in every inertial reference frame, i.e., the speed of light in empty space is constant for every observer in each inertial frame. As a consequence of this, we have:

(iii) *The Limit Principle*: no matter how fast an observer travels, they can never overtake a ray of light: however near that of light their speed approaches, light still retreats at *c*.

And let us recall that Einstein required that a definition of simultaneity should meet the following condition:

NAT: The definition should supply us with a method by which we can decide by experiment whether given events occurred simultaneously. (Einstein [1920], §VIII)

For the sake of argument (i.e., setting aside the debate over whether it rests on verificationist assumptions, etc.), I shall read this as a demand for a *naturalistic* basis for a definition of simultaneity. Now, according to Einstein, all assignments of time to events involve the concept of simultaneity:

> If, for instance, I say, 'That train arrives here at 7 o'clock,' I mean something like this: 'The pointing of the small hand of my watch to 7 and the arrival of the train are simultaneous events.' (Einstein [1905], §A.1)

Thus, according to Einstein, the assignment of times to events involves judgements of simultaneity. Events occurring simultaneously at the *same* point in space according to one inertial observer are observed by all inertial observers to be simultaneous. The assignment of times to events in the immediate vicinity of a clock is taken to be simple and unambiguous. The question remains, however, of how to determine simultaneity and how to attach times to events in a single inertial reference frame when the events are separated in space. What we might use for this, in principle at least, are many clocks, all synchronized with each other. We can then imagine placing a synchronized clock, at rest, at the location of every event to which we wish to assign a time. In this way, the time of every event can be read off a stationary clock, located at the event, by an observer located at that clock. To synchronize these clocks (in a given inertial frame), Einstein suggested we use the following method involving light signals:

> If at the point A of space there is a [stationary] clock, an observer at A can determine the time values of events in the immediate proximity of A by finding the positions of the hands which are simultaneous with these events. If there is at the point B of space another [stationary] clock in all respects resembling the one at A, it is possible for an observer at B to determine the time values of events in the immediate neighbourhood of B. But it is not possible without further assumption to compare, in respect of time, an event at A with an event at B. We have so far defined only an 'A time' and a 'B time'. We have not defined a common 'time' for A and B.

> The latter time can now be defined in establishing *by definition* that the 'time' required by light to travel from A to B equals the 'time' it requires to travel from B to A. Let a ray of light start at the 'A time' t_A from A towards B, let it at the 'B time' t_B be reflected at B in the direction of A, and arrive again at A at the 'A time' t'_A. (Einstein [1905], §A.1)

So clock B is synchronized with clock A if $(t_B - t_A) = (t'_A - t_B)$, i.e., if the clock at B is set to read such that $t_B = (t'_A + t_A)/2$. Now, there are many things on which to comment concerning this procedure, such as the assumption that the speed of light is the same in both directions, but the procedure sketched here is enough for the purposes of this paper. The point is that by synchronizing clocks according to this procedure, we have defined a measure of time for all points within our inertial frame of reference by means of a set of clocks at rest in this frame. Furthermore, this method is equally valid for synchronizing clocks at rest within *any* particular inertial frame of reference. This leads to the following definition:

DEF: If an observer, under the above conditions and definitions, judges some given events to occur at the same time, then they are simultaneous.

This, however, immediately leads to the *doctrine of the relativity of simultaneity*, since, as we all know, events judged to be simultaneous in one inertial frame of reference will not necessarily be judged to be simultaneous in another. This fact sets up the argument ARG.

This is the familiar story from STR. The new interest lies in what the tense theorist can gain from moving from STR to GTR, on which modern cosmology rests. Mellor says not much.

Many tense theorists think that what generates the tension in ARG is the fact that STR is tied to the universe having the structure of Minkowski space-time; i.e., that there are infinitely many possible partitions of space-time into past, present and future, no one of which can be non-arbitrarily selected as the absolute frame required by tense theorists. Consequently, the strategy of many tense theorists has been to brush STR under the carpet and look elsewhere in physics for a naturalistic way of defining the required absolute planes of simultaneity. It seems they need not look far. For whereas the Minkowski structure in STR is inflexible, the space-time structure according to GTR is *determined by* the density and distribution of matter in the universe. And due to the particular distribution and density of matter in the *actual* world, not all reference frames *are* equivalent for the description of reality: observers of one class *do* appear privileged, namely 'those which follow in their motion the mean motion of matter' (Gödel [1949a], p. 559).

So the situation is commonly held to be this: general relativity is a better theory (of the actual world) than special relativity; so, *even if* special relativity *is* incompatible with tense theories by undermining the notion of absolute planes of simultaneity, general relativity can be invoked to trump special relativity and supply a naturalistic way of privileging a frame of reference. (Lucas ([1999], p. 10) contains the most recent argument). The tense theorist strategy, then, is thought to be one that undermines the idea that all frames are equivalent according to our cosmology; and that it is this that is taken to be the difference between STR and GTR, and thus the motivation for the move. But, as Mellor ([1998], p. 57) writes:

> The expansion of the universe takes remote galaxies away from us at speeds proportional to their distances, given by the so-called Hubble constant (about 0.037 m/sec per light year). We can use this fact to define unique local reference frames in which the Hubble constant is the same in all directions. (This in turn defines local velocities, like that of the earth, by how much and in which directions they make the Hubble constant vary.) And we may grant that, since the universe is expanding uniformly, such frames exist everywhere. Will they do what [tense theorists] want?
>
> Obviously not. For as the universe *is* expanding, anything at rest in any one such frame will be moving in every other. Thus in the rest frame of a galaxy G, n light years north of us, anything at rest in our frame will be moving south at $0.037n$ metres per second. But this is just [special relativity] writ large [. . .]. [A]t any earthly date, our frame and G's will make different G-events present. And as the uniformity taken for granted by modern cosmology stops anything making any one of these frames right and the others wrong, this is bad news for [tense theorists]. Cosmology, far from saving them from special relativity, only makes matters worse.

Thus Mellor disposes of the strategy to find a privileged frame using cosmology by exploiting the fact that our universe is expanding in all directions *at every point*, and thus that everybody is in exactly the same boat: nobody is privileged and simultaneity remains relative.

This is correct. And if this were the whole strategy of those tense theorists who appeal to cosmology after conceding that STR is incompatible with their thesis, then Mellor's argument would go through. For carrying through the core features of STR *and* DEF to GTR results in relative simultaneity regardless of anything else that cosmology can offer. Of course, someone might object that this issue cannot get off the ground in the first place because the notion of an inertial frame only makes sense in STR, whereas in GTR the closest we get are approximate, local, inertial systems. But Mellor's point is that the physical system described *does* act like the inertial systems of STR, and so it is legitimate to extend the definition of simultaneity in STR to GTR, and thus extend the argument from STR against tense theories to the case of cosmology. But, in any case, Mellor's argument is impotent, for this is *not* the whole strategy of these tense theorists; the strategy is not simply to argue that cosmology supplies a privileged frame. Rather, what those who appeal to GTR rely on is the fact that a *different naturalistic definition of simultaneity is available*. That is, what is gained in the move from STR to GTR is that *cosmology offers an alternative to DEF.*

3 Can expansion combat such wrinkles?

By moving to cosmology, we can exploit the process of the expansion of the universe to define an absolute 'cosmic time' that then serves as the absolute time required by tense theorists. The essentials of this strategy are as follows. Tense theorists require an order of temporal becoming, which requires absolute planes of simultaneity (on pain of being subject to ARG) that can be ordered to give a temporal sequence. Let us label these planes of absolute simultaneity, or planes of becoming, as ${}^{B}\Sigma_t$, and the order in which they come, the order of temporal becoming, as Φ^{B}. The suggestion is to define such absolute planes of simultaneity in terms of *planes of homogeneity*. Let ${}^{H}\Sigma_t$ be a hypersurface of homogeneity, i.e., where the distribution of matter in every region in ${}^{H}\Sigma_t$ has the same values of density and pressure. It is possible to use this as a hypersurface of simultaneity, since observer O in ${}^{H}\Sigma_t$ can set a clock to a particular time corresponding to a given value of density and pressure in his vicinity. Since other observers in different locations in the same hypersurface, ${}^{H}\Sigma_t$, can set their clocks to the same time based on the same method of correspondence used by O, every observer in ${}^{H}\Sigma_t$ will read off the same time from their respective clocks. Thus, ${}^{H}\Sigma_t$ is also a plane of simultaneity that extends across the whole of space. As the universe expands, the values of density and pressure change, defining different planes of homogeneity ${}^{H}\Sigma_t$, ${}^{H}\Sigma_{t'}$, ${}^{H}\Sigma_{t''}$, ... It is then possible to form a sequence of all such global planes of simultaneity ${}^{H}\Sigma_t$, ${}^{H}\Sigma_{t'}$, ${}^{H}\Sigma_{t''}$, ..., ordered by an *earlier than* relation, and identify this sequence with cosmic time. Call this particular global time function Φ^{H}. These tense theorists then equate ${}^{B}\Sigma_t$ with ${}^{H}\Sigma_t$ and Φ^{B} with Φ^{H}. From this we can see just how different this procedure for determining the times of events is from that employed by Einstein.

Furthermore, whereas Mellor is absolutely correct that the expansion of the universe in all directions at every point 'only makes matters worse' if we combine this (under those conditions which allow for its application) with DEF, it is, ironically, the fact that nobody *is* privileged which *helps* tense theorists who appeal to the alternative definition that cosmology offers! For the universe, being isotropic in the large implies that it is spatially homogeneous, and this fact is precisely what justifies us in extending our local measurements of the density and pressure of matter in our vicinity to the rest of space.

The definition of simultaneity used in cosmic time is entirely different from DEF. It does not rely on what would be judged to be simultaneous by observers under the circumstances specified in the definition; it is neither here nor there that different observers attached to various galaxies in relative uniform motion would disagree in their observations as to which events happened 'at the same time'. For what determines simultaneity here are universe-wide facts about the distribution of matter in the universe; specifically, facts about along which plane the values of density and pressure of this matter are equal. Mellor's argument, then, is not so much wrong as misconceived, for it misunderstands the point of the move from STR to cosmology. Whether or not this alternative naturalistic definition of simultaneity and the subsequent ordering of these planes is the sort of thing tense theorists should equate with the order of becoming is a matter I discuss below; but whatever difficulties there are with this tense theorist strategy, it won't be Mellor's argument that prevents it from succeeding. But are there any other difficulties for this strategy?

4 Event and creation horizons

> [Light is] like a runner on an expanding track with the winning post receding faster than he can run. (Arthur Eddington [1933], p. 73)

Let us assign observers, $O_1, \ldots, O_n$, to the various regions of the planes of homogeneity, i.e., where the observers are at rest with respect to the matter in their vicinity, ignoring 'small' variations in the motion of matter in their vicinity. (Just what 'small' means here, and its implications for the tense theorist's project, is discussed in Section **4** below.) Let us call these observers *fundamental observers*. In 1917, de Sitter found an interesting model of the universe whereby observers O_i and O_j could find themselves in the situation where no signal emitted by O_i could ever reach O_j, and *vice versa*. This situation is called an *event-horizon* and exists for any fundamental observer O_i in any expanding model where the rate of expansion increases with time so fast that eventually signals emitted by O_i will never arrive at O_j [De Sitter (1917)].

There are other models, however, in which the rate of expansion decreases after an initial expansion that is so fast that no light emitted by O_i could reach O_j. Because of the decrease in expansion, the signal emitted by O_i eventually reaches O_j after a certain amount of time. Because it seems to O_j that matter is continually coming into existence as it becomes visible, this phenomenon is known as a *creation-horizon* (or *particle-horizon* in some writers), and exists in all models where expansion behaves in this way.

Suppose we allow the fundamental observer O_i to be detached from the region at which he is at rest and move through the universe, then the number of events that could, in principle, be observed by O_i would be increased.

However, if the model contains an event-horizon before O_i moves, then wherever O_i goes he will not be able to observe every event in the universe. The horizon will change for O_i, but cannot be eliminated. Furthermore, most of the expanding models that could possibly model the actual world have been found to have at least one of these horizons.

Dorato ([1995], p. 200) concludes from this that 'this must count as a limitation of the idea of cosmic time, since [it] cannot be extended beyond the horizon, [...] [although horizons of either kind] do not represent a threat to its existence "within" the horizon'. But this is mistaken: since cosmic time relies on the distribution of matter in the universe, and it is this that determines simultaneity relations and the successive states of the universe, the fact that it is not possible to send light signals between certain events in no way invalidates the extension of cosmic time to events outside the horizon. (Of course, horizons may raise *epistemological* problems of justifying the extension, but this is an entirely different matter from whether cosmic time *exists* beyond the horizons.) So, unlike light in Eddington's quote above, cosmic time is still in the running. But will it do?

5 Bursting the balloon

The first reason for thinking that cosmic time does not quite hit the spot in capturing our notion of simultaneity and temporal becoming is *epistemological*. Callender ([1997], p. 120) writes:

> [c]osmic time is only definable via elaborate averaging procedures over the matter distribution and is not at all the sort of thing to which we have access [...]. The passing of cosmic time is not the passing of time that [tense theorists] seek to describe.

Let's fill this out, and relate it to a second, *phenomenological*, concern. For our normal everyday experience is of things—motorbikes, children, shopping trolleys—in various states of motion. And it is everyday occurrences like these from which we draw our experiences that generate our conceptions of the world. But in cosmology, it isn't the average state of motion of all of these everyday objects that we take to be the average state of motion of matter 'in our vicinity'. Neither is it the average state of motion of the earth, or the sun, or even of the whole solar system. It isn't even the average state of motion of our galaxy! No, it is the average state of motion of *all* of the galaxies 'in our vicinity', something that covers such a *vast* region of space that we cannot possibly be said to have any phenomenological access to it. That is, the notion of simultaneity under this definition is so divorced from our experience that it leaves us far removed from our initial intuitions about the notion of temporal becoming, and what it is for events—that is, *everyday events*—to be simultaneous.

The third reason for thinking cosmic time won't do for tense theorists is *metaphysical* and concerns the direction of dependence in the definition of simultaneity and thus of what it means for something to be present. Mellor ([forthcoming]) writes:

> The credibility of this way of defining temporal presence does not [...] extend to the idea that remote existence depends on it. For the continuing uniqueness of the present so defined depends on a permanent universe-wide large-scale isotropy, i.e. on the size, shape and contents of the whole of spacetime. But this makes the present depend on what exists elsewhere in spacetime rather than the other way round. Cosmic time, far from rescuing the idea of existence depending on temporal presence, if anything, raises the stakes against it.

We can add to this by noting that cosmic time is essentially a *statistical* notion. That is to say, it does not make sense to talk of the exact average state of motion of matter at a point of space-time, for 'the average state of motion of matter in our vicinity' is only defined over a *region* of space-time, namely one that comprises a sufficiently large collection of galaxies. Thus, not only does the definition of the present depend on extrinsic matters (as with all statistical concepts), there is also an element of convention in choosing how wide we should cast our nets in specifying the size of the regions when determining the distribution of matter in every region in ${}^{H}\Sigma_t$. But, for tense theorists, what is present cannot be a conventional matter; thus, cosmic time is not what tense theorists are after.

Furthermore, our nets must be cast *very* widely. For in order to regard our universe as spatially homogeneous, we must treat a vast region of space—a region which may comprise many galaxies, and involve distances that make light-years seem tiny!—as a point. But consequently, when we say of any of these 'points' that they are simultaneous, the very nature of the procedure used to define the notion of simultaneity makes it so coarse-grained that it cannot determine, for instance, whether an event on a star 100 light-years away is simultaneous with the stubbing of my big toe. This is far too coarse-grained a notion on which to rest the metaphysical idea of temporal presence and becoming.

The fourth objection is from *physics*. There are well-known problems associated with trying to define the direction of time—let alone temporal becoming—in terms of such physical processes, such as what to say about time when the universe contracts. In the case of simultaneity, because planes of simultaneity are defined in terms of planes of homogeneity, events that lie in the planes that comprise the expanding period of the universe will be said to be simultaneous with events that lie in the planes that comprise the contracting period of the universe, since there will be (at least) two different planes where the values of density and pressure of matter are the same in every region. In the case of temporal becoming, when the universe contracts, becoming must be said to be reversing direction—either that, or such tense theorists must rule out *a priori* the possibility of the universe contracting.

These consequences are untenable, but perhaps not insurmountable. For what really matters in this conception of becoming is a *change* in the planes of simultaneity. Thus, we could equate the direction of time with the *change* of values at points in the planes of homogeneity. These could decrease as the universe expands, or increase as it collapses. Essentially, all that we need to find is some kind of increasing linear function involving time associated with a given dynamic model.

This is fine so far as it goes; but it doesn't go that far. First, for all that has been said, cosmic time can at most be a necessary condition for temporal becoming: an extra argument is needed to show that it is also sufficient. What, after all, has expansion to do with existence? Does size really matter? But let us set this point aside for the sake of considering more profound points. Regardless of whether cosmic-time tense theorists can reconcile their views with universes that contract as well as expand, there certainly are other models that are inhospitable to such views—the steady-state models, for example. Now it might be asked why we should worry about such models when they don't represent the actual world. But it is here that we can invoke an argument similar to Gödel's so-called 'modal' argument (for more details, see Gödel ([1949b]); Yourgrau ([1991]) or ([1999]); Savitt ([1994]); Earman ([1995]), Chapter 6). Gödel argues that time must be tensed in order to exist (it is an essential feature of time that it flows), and that in order for time to exist, it must be tensed in all worlds where time exists. But since time exists in some models where it cannot be tensed—Gödel's own ([1949a]) pathological model being a case in point—Gödel argues that time cannot exist at all. Apply this to the current proposal: there are models in which cosmic time cannot exist, so temporal becoming is not essentially this physical process. Thus temporal becoming cannot be equated with the physical process.

One solution is to reject Gödel's modal argument and argue that the existence of temporal becoming is a contingent matter. There are two ways in which we could do this. The most obvious is to hold that temporal becoming is only possible in worlds where cosmic time is available, and so long as it is available in the actual world, that's all that matters. This is what Dorato ([1995], p. 204) suggests. But is it plausible that the metaphysical notion of temporal becoming can be equated with a physical process that is contingent on the particular distribution of matter in the universe? A much better proposal is this: the only appealing way of viewing the matter is to invoke the notion of a functional rôle: specifically, we might hold that cosmic time plays the temporal-becoming-rôle in worlds where cosmic time is available, whereas other processes in another world might play the temporal-becoming-rôle in that world. This certainly bypasses chauvinism towards worlds where contingent matters of fact just happen to allow for cosmic time, over worlds that are receptive to the idea of temporal becoming but can't deliver on cosmic time. Viewing temporal becoming as this more abstract feature of worlds certainly appeases those who say metaphysical notions should be more robust with respect to contingent features of the world and not be so world-relative.

Maybe. But neither the identity nor functional rôle suggestion quite hits the spot. For isn't it strange that our common sense conception of tense does not change in the slightest when we learn of the different models of how the universe may develop? On discovery that the universe is not a steady-state universe, for example, right-thinking people don't start wondering whether the world might be tensed in light of this. (Although, unfortunately, Jeans ([1936]) notoriously did.) The fact that we now suspect our universe is expanding does not lead us to think that we have better reasons now for thinking our universe is tensed than we would have done had the universe been steady. Thus it is not at all clear that cosmic time *can* be identified with, or play the rôle of, temporal becoming as it is conceived of in this world.

To press the point, cosmic time as used by these tense theorists only gives us an account of one of the platitudes—namely *that time flows*—which we hold about time: it tells us what time's flow amounts to. But, although it defines what it is for events to be simultaneous (setting aside for the moment the reasons above for thinking it is too coarse-grained a definition), it says *nothing* about what it is for us to be located in the present, something that any adequate theory of time and tense must do (see Bourne [2002]); and it doesn't explain our belief that the past is fixed and the future is open, for what does the relative size of the universe in a given temporal direction have to do with this? Nor does it tell us what makes past-, present- and future-tensed statements true. Compare this with, for instance, the tenseless error theory account of becoming (e.g., Mellor [1998]), which is intimately tied to accounting for the things we all say and believe about time. For example, according to the tenseless theory, time does not flow, but it accounts for our *saying* that it does by showing how we can account for the illusion that it does. This typically involves causation: time appears to flow because perception works causally, and so we can only perceive past and present events, but not future, etc.; and similarly, although there is no ontological difference between earlier and later times, according to the tenseless theory, the reason we *say* that the past is fixed and the future open is that we cannot causally affect earlier times than now, but can causally affect later times than now, and so on.[2] Comparing all this with what the cosmic-time account of becoming can offer shows just

[2] Of course, defenders of equating cosmic time with temporal becoming can use notions such as causation to explain these things, but then the appeal to cosmic time is entirely redundant.

how deficient and unsuitable a candidate it is for playing the rôle of temporal becoming as we conceive of it in this world.[3]

Furthermore, compare identifying cosmic time and temporal becoming with other more convincing theoretical identifications, such as water = H_2O, or mental states = brain states, where the identification has explained and informed much of our pre-theoretical views, and perhaps even changed them to a certain extent after the discoveries were made.

Thus we have no compelling reason to think that cosmic time is the kind of thing tense theorists require, and every reason to reject the idea that it is. This is not to say that there can be no asymmetries in time based on these notions; it is to say that temporal becoming cannot be equated with them.

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[3] And I suspect, although this would have to be shown, that similar arguments could be constructed to show that the current fashion for appealing to certain processes in quantum mechanics in defining a physically respectable notion of becoming is at least too ambitious. For such physical theories of becoming have got to bear the weight that more traditional metaphysical theories can in order to be serious contenders as theories of becoming. At the moment, such theories are far from that.

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