

Why Does Time Pass?

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1 The Moving Spotlight

According to the moving spotlight theory of time, the property of being present moves from earlier times to later times, like a spotlight shone on spacetime by God. In more detail, the theory has three components. First, it is a version of eternalism: all times, past present and future, exist. (Here I use “exist” in its tenseless sense.) Second, it is a version of the A-theory of time: there are non-relative facts about which times are past, which time is present, and which times are future. That is, it is not just that the year 1066 is past relative to 2007. The year 1066 is also past full-stop, not relative to any other time. (The A-theory is opposed to the B-theory of time, which says that facts about which times are past *are* relative to other times.) And third, on this view the passage of time is a real phenomenon. Which moment is present keeps changing. As I will sometimes put it, the NOW moves from the past toward the future.¹ And this does not mean that *relative* to different times, different times are present. Even the B-theory can say that 1999 is present relative to 1999 but is not present relative to 2007. No, according to the moving spotlight theory, the claim that which moment is present keeps changing is supposed to be true,

¹The grammatical category to which I assign “NOW” is not consistent throughout this paper. But all my uses of this term are just short-hand for talk about various times instantiating the property of being present.

even from a perspective outside time.²

My main goal in this paper is to present a new version of the moving spotlight theory (though in some respects the theory I present also resembles the growing block universe theory of time). This version makes a connection between the passage of time (the motion of the NOW) and change. In fact, it uses facts about change to explain facts about the passage of time. The bulk of the paper is devoted to describing, in detail, how the theory works. I also believe that my new version has advantages over the standard version. It explains things that the standard version cannot explain. It explains both why the NOW moves, and why it moves at a constant rate. I will discuss why I think these are advantages in the final section.³

2 The Standard Version

The standard version of the moving spotlight theory has the three parts I mentioned: eternalism, the A-theory, and passage.⁴ In section 1 I said how talk of the NOW's motion is *not* to be understood. I will start here by saying how it is to be understood.

Talk of the NOW's motion is to be understood using primitive tense operators.⁵ “The

²Distinguishing the A-theory from the B-theory is a subtle business, especially when we are discussing an eternalist version of the A-theory. See [Zimmerman 2005] for a discussion of these subtleties.

³[Schlesinger 1982] is a recent defender of the moving spotlight theory. But in my presentation of the theory as standardly understood I rely more on conversations with other philosophers than on Schlesinger's presentation.

My aim in this paper is to compare my version of the moving spotlight theory to the standard version of the theory. So defending the moving spotlight theory against objections that apply equally to all versions is beyond the scope of this paper. I will not, for example, have space to address the (important) objection that eternalist versions of the A-theory lead to skepticism about whether it is now. (For that debate, see [Braddon-Mitchell 2004], [Forrest 2004], and [Heathwood 2005].)

⁴Eternalism is a thesis about what times exist; so I should say something about what I take times to be. I am working in the context of pre-relativistic physics, so I take times to be three-dimensional hyperplanes of simultaneity in classical (galilean) spacetime. As a consequence, I will assume that there is no first instant of time, though the details of my theory could be worked out to make it consistent with the existence of a first instant.

⁵See, for example, chapter 1 of [Sider 2001].

NOW is moving into the future” means (roughly) “The NOW is located at t , and *it will be the case that* the NOW is located at a time later than t .” “It will be the case that” here is a primitive tense operator; it is not analyzed in terms of quantifiers over times. (If it were, then the second conjunct above would mean “there is a future time at which the NOW is located at a future time”; but this makes no sense, since on this theory the property of being NOW is not had relative to times.)

That is how the NOW’s motion is to be officially understood. But I find it helpful to think about the NOW’s motion using a metaphor: supertime (also known as hypertime). I will explain the metaphor first, and then say a few things about its metaphorical status.

Supertime is a dimension that is distinct from time, but is in other respects much like it. Like time, supertime is one-dimensional, and there are “distances” between the points of supertime (though these are not spatial or temporal distances). More importantly, supertime is also like time in the following respect. Here is an important feature time has: the existence of time permits temporal variation in the state of the universe. That is, time provides a kind of perspective on the universe: relative to different times the universe can be in different states. Similarly, supertime provides a perspective on *both* the universe and time. Instants of time themselves can be in different states relative to different points in supertime. The relevant “states” that instants of time can be in, the relevant properties that characterize instants of time, are the property of being past, the property of being present (or NOW), and the property of being future. So with supertime we can make sense of the NOW’s motion: for the NOW to move is for it to be located at different times relative to different points of supertime.

As I said, on the official version of the moving spotlight theory there is no such thing as supertime. So the previous paragraph cannot be taken as a literal expression of the theory. But the relationship between the story about supertime and the official presentation of the theory using primitive tense operators is straightforward. In the story, the tense operators that are officially primitive can be analyzed using quantification over points in supertime. “It will be the case that the NOW is located at t ” just means “Relative to a point of supertime Later than

the Current one, the NOW is located at t .” (Note the capital “L.” Even if we read the supertime story literally, no point of supertime is later than any other point. The *later than* relation relates instants of time, not points of supertime. But there is some relation structuring supertime in just the same way that *later* structures time. For convenience I call it the *Later Than* relation—with capitals. In general I will adopt the convention of giving relations on supertime the same names as corresponding relations on time, but spelled with initial capitals.)

So far I have presented features of the moving spotlight theory that my version and the standard version share. There are two respects in which my version differs from the standard version, and I will briefly say what they are before presenting my theory in more detail.

We can get at the first difference by asking: why, according to the standard version, does the NOW move? Why isn’t the NOW at the very same time, relative to every point in supertime? There is no answer to this question on the standard version. That the NOW moves is a fundamental fact about the universe, one that has no deeper explanation. It is then in the same category as, say, the fact that space has three dimensions. My version of the moving spotlight view, on the other hand, will explain why the NOW moves.

Turning to the second difference, consider the question opponents of time’s passage love to ask: *how fast* does the NOW move? The standard answer for moving spotlight theorists to give is that it moves at a constant rate of “one second per supersecond.” There is a natural follow-up question: *why* does the NOW move at the rate it does, rather than some other rate? This is a request for an explanation. The standard version of the moving spotlight theory either cannot provide an explanation, or can only say that the NOW moves at the rate it does because it is something like logically impossible for it to move at any other rate. I don’t think these responses to the question are very good. (I will say more about why in section 5.) My version of the theory will give a better response.

I am just about ready to present my theory. But first I want to make a comment about the structure of time (and of supertime). Time is continuous. However, since my explanation of the NOW’s motion in the continuous case gets technical, it will often make my theory easier

to understand if I first present it under the supposition that time is discrete. (Actually, I am not always sure what other philosophers mean when they say that time is continuous or that time is discrete. When I say that time is discrete, I shall mean that its structure is relevantly like the structure of the integers; and when I say that time is continuous, I shall mean that its structure is relevantly like the structure of the real line.⁶) However, even though I start out with the discrete case, it is the continuous case that I really care about. If my theory works only in the discrete case, I will consider it a failure; if it works only in the continuous case, I will consider it a success.

3 A New Version, Part 1: Why the NOW Moves

My version of the moving spotlight theory explains features of time in terms of more fundamental features of change.⁷ I will first present the fundamental metaphysical principles of my theory. Then I will show how those principles explain the passage of time. I postpone a defense of the fundamental metaphysical principles themselves until section 6.

Let us begin. On my view, change is the engine that pushes the NOW into the future. There is irresistible pressure for the universe to change; but the universe cannot change if the NOW remains at one time. The pressure forcing the universe to change, then, pushes the NOW into the future.

I need to turn this picture into a real explanation. I start by elaborating on some ways that my theory departs from the standard version. According to the standard version, things look different from different perspectives in supertime, but only in a limited way. The only way in which perspectives differ is over which time is NOW. All perspectives agree on which properties the universe has at which times.

⁶I say “relevantly” because, for example, there is no time that plays the special role that zero plays in the integers or the real numbers. The relevant structure is the order and the metric structure.

⁷The idea that there is a connection between change and the passage of time goes back at least to Aristotle (See [Coope 2005], especially Part II).

This is not so, on my theory. But before I tell you how it works on my theory, let's explore briefly the possibilities that the moving spotlight theory affords. Pick two nearby points of supertime, p_1 and p_2 . Figure 1 indicates, in a generic way, what things must look like, relative to p_1 and p_2 , on the standard version of the theory. All that has happened is the NOW has moved into the future. (Here is how to read the figure. The vertical lines represent time, and the box with the NOW in it indicates which time is NOW (relative to that point of supertime). The letters S_1, S_2, \dots stand for maximally specific states of the entire universe. A letter to the right of a time indicates which maximally specific state the universe is in, at that time (relative to that point of supertime).)

But once we start allowing the NOW's location to vary from one point of supertime to another, other possible kinds of variation suggest themselves. Figure 2 presents another way things might vary from p_1 to p_2 . As in figure 1, in this figure the NOW moves between p_1 and p_2 , though now it has moved into the past; and in addition, the universe has changed which properties it has at each time.

Figure 1:

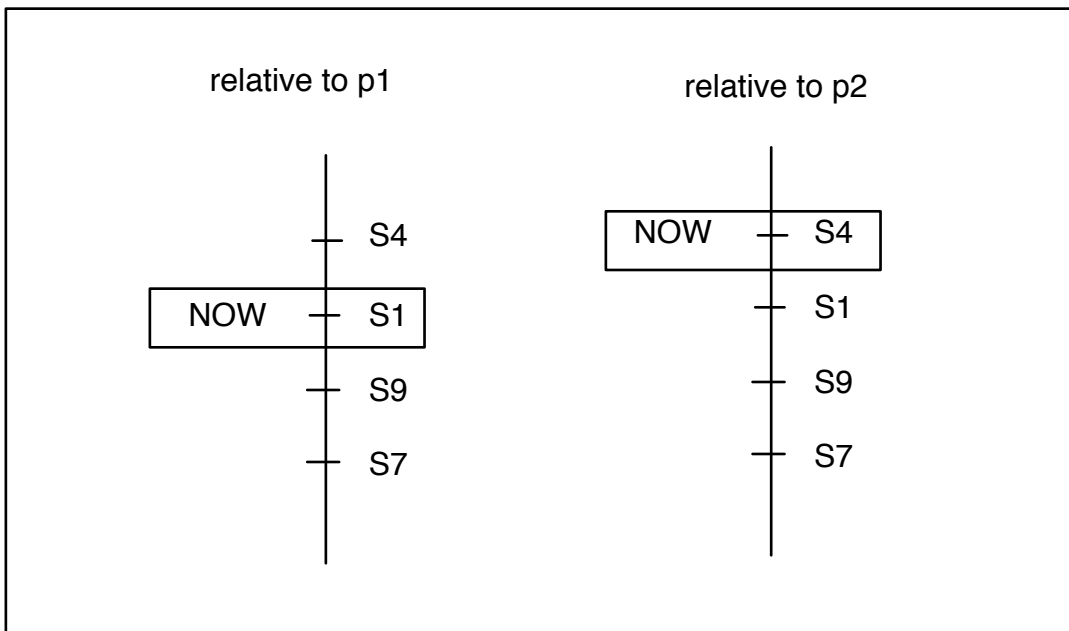
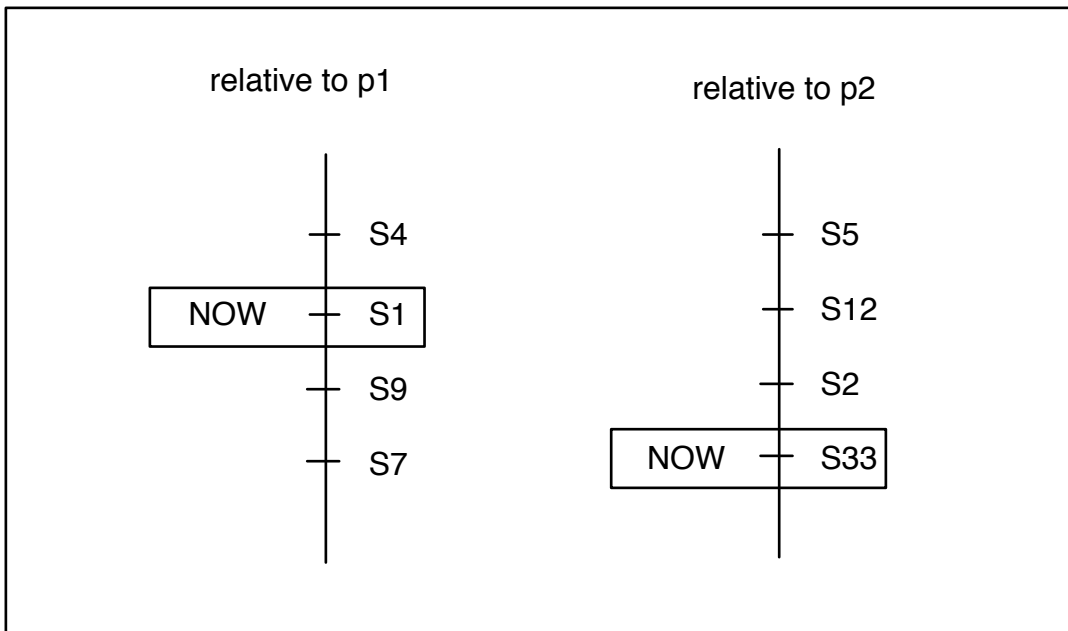


Figure 2:



My theory is more liberal than the standard version about what kinds of variation between points of supertime are allowed. It permits, not just variation in the location of the NOW, but also variation in which properties the world has at each time. But not just anything goes. (In fact figure 2 depicts a situation that my theory says is impossible.) I call the principle that constrains this variation **The Open Future**:

- (1a) For any time t , if there is a point in supertime at which t is NOW, then there is an Earliest point in supertime at which t is NOW.
- (1b) Relative to each point in supertime, the universe is in a definite state at the time that is NOW relative to that point.
- (1c) Let t be any time. There are two cases:

Case 1: t is not NOW relative to any point in supertime. Then the universe is not in any definite state at t relative to any point in supertime. (That is, there is no fact of

the matter about what state the universe is in at t —not even about whether anything exists at t .)

Case 2: t is NOW relative to some point in supertime. Let q be the Earliest point in supertime at which t is NOW, and S the state the universe is in at t relative to q . Then relative to any point in supertime Later than q , the universe is in S at t ; relative to any supertime point Earlier than q , the universe is not in any definite state at t .

(These principles of my theory, and the principles that will follow, are to be regarded as metaphysical necessities.) Intuitively speaking, (1a)-(1c) say that the universe starts out (in supertime) in no definite state at all at any time, and only gets to be in a definite state at a time t when the NOW arrives at t , and that the universe stays in that state at t even after the NOW has moved on. If we picture the NOW moving from the past into the future, then the universe is in a definite state at each time in the past, but is in no definite state at all in the future. (By “state” I mean *maximally specific* state. This is the part of my theory that has affinities with the growing block universe theory of time [Broad 1923].)

I also add, as a further constraint on the way things vary from perspective,

(1d) The NOW’s motion is continuous.

(When both time and supertime have the structure of the real line, (1d) just means that the function that takes each point in supertime to the point in time that is NOW relative to it is a continuous function. (In fact I assume something stronger: that this function is differentiable.) When both time and supertime are discrete, (1d) means that if the NOW is located at different times relative to adjacent points in supertime, then those two times are adjacent.)

On my view, change is the engine that pushes the NOW into the future. With (1) in place I can introduce my theory’s framework for thinking about change. What is it, according to the moving spotlight theory, for things to change? B-theorists, who do not believe in a moving spotlight, say that the universe changes during an interval of time just in case it is not always in the same state during that interval. Change is variation in *time*. But on the moving spotlight

theory real change is variation in *supertime*. Things change during an interval of supertime just in case things do not look the same from every perspective in that interval.

Now, given this understanding, there are two pure kinds of change, as well as changes that are mixtures of the two. (That is, there are two pure kinds, as far as the definition of “change” is concerned. Some kinds of change will be incompatible with principle (1), and others will be incompatible with later principles.) Start with the case where time and supertime are discrete. Then we can ask whether anything has changed between supertime point p and its successor p' . One kind of pure change occurs when the only difference between p and p' is in the location of the NOW. The universe has all the same properties at each time, according to p and p' ; the only difference is a shift in which time is NOW. (On the standard moving spotlight theory, all change is this pure motion of the NOW.)

Another kind of pure change occurs when the only difference between p and p' is in which properties the universe has at which times. Perhaps relative to p the universe is in no definite state at all at time t , while relative to p' the universe is in some definite state at t . But the NOW is at the same location relative to p and to p' . That is the second kind of pure change.

Finally, a mixed change occurs whenever there is a difference in both the NOW's location and which properties the universe has at which times.

Although all of these kinds of changes are compatible with my definition of “change,” not all of them are, in fact, possible according to my theory. Principle (1) rules out pure changes of the second kind, and also severely limits pure changes of the first kind. For suppose a pure change of the second kind occurs: relative to p' the universe is in state S at t , relative to p it is not, and the NOW stays put. By (1c) the universe is both in S at t and not in S at t at the Earliest point in supertime at which t is NOW—a contradiction. In fact, the only kinds of changes that are permitted by (1) are pure changes of the first kind in which the NOW moves to a time it has already visited (and this kind of change will be ruled out later), or mixed changes in which the NOW moves to a time it has not yet visited, and puts the universe into a definite state at that time.

I am ready to state the second key principle of my theory. The principle is that it is necessary that the universe always be changing. But, given how complicated change is in my theory, it is not immediately obvious what I want to mean by this. My next aim is to explain its meaning more precisely.

First, demanding that the *universe* always change is to demand more than just that some change or other always be going on. (By “the universe” I just mean the sum total of things that exist in time. This excludes instants of time themselves.) But what does it mean to say that the universe has changed between two points in supertime? The universe is in different states at different times; but what “state” is it in, relative to a point in *supertime*? (To avoid confusion, let’s say that the way the universe is relative to a point of supertime is its “superstate” relative to that point.) Strictly speaking, to characterize the superstate of the universe relative to a point of supertime, you would have to list which state the universe is in at each time, from the perspective of that point in supertime. Only that would be an exhaustive characterization of the way the universe is, relative to that point. But the consequences of (1) allow us to simplify this a little bit. Consider the superstate of the universe relative to supertime point p , and relative to its successor p' . It follows from (1) that if there is any difference at all in these two superstates, it is a difference in the state the universe is in at the time that is NOW relative to p' . So let’s just identify the superstate of the universe at p with the state the universe is in at the time that is NOW relative to p . Then superstates and states are the same kind of thing: maximally specific instantaneous properties of the universe.

I am now in a position to state my next principle:

(2a) **The Necessity of Change** (discrete case): At adjacent points in supertime, the universe is in distinct superstates.

To elaborate on the content of this principle: imagine that as you move from Earlier to Later points in supertime, you see the NOW march from earlier to later times at a constant rate; as the NOW arrives at each time it always puts the universe in the same state S . Then change is

occurring: at different perspectives, the NOW is located at different times, and there is variation in which properties the universe has at certain times. But the universe itself is not changing, because it is in the same superstate at each point of supertime. So this world is incompatible with (2). (Note that (2) does not say that each material thing must change. It says that the universe as a whole must. So it is compatible with (2) that many things not be changing.)

So much for the discrete case. As I said, it is the continuous case that I really care about. To express (2) in the continuous case I will first reformulate the discrete case. I start by introducing another piece of apparatus: configuration space. Speaking abstractly, configuration space is just the set of all maximally specific ways the universe can be at a time. For example, if there is just one thing, and its only properties are color properties, then configuration space is just the set of all maximally specific colors.

The universe has a *career in configuration space*. In the discrete case its career is a sequence of properties $\langle \dots, P, Q, R, \dots \rangle$ in configuration space. The properties that appear in the sequence are all (and only) the superstates that the universe is ever in, and the order in which they appear is the order (in supertime) in which it has them. One particular sequence represents the actual world's career in configuration space. In fact, we can identify this sequence with the function that assigns to each point in supertime the superstate the universe is in at that point. But *every* possible world has a career in configuration space. Consider the set of all possible (discrete) careers in configuration space. Then (2a) is a constraint on what this set looks like: it says that in each possible career, no property immediately succeeds itself.

Now we are ready for the continuous case. When time and supertime are continuous, we will want configuration space to be “continuous” as well. That is, we want it to have some non-trivial topological structure. In fact, we want more: we want it to be a differentiable manifold with a metric. Roughly speaking, this means that you can picture configuration space as a surface in some (possibly very high dimension) Euclidean space. (I will say more about its metric structure later.) A career in configuration space is then just a function from supertime into configuration space. That is, it is a curve in configuration space. I assume, in fact, that it

is a differentiable function. A career h (“ h ” for “history”) represents a world in which at each supertime p the universe is in superstate $h(p)$.

What constraints does The Necessity of Change put on these careers? Certainly I want to demand that the universe “does not stay in one superstate for any interval.” That is, for a career h , there are not two points r_1 and r_2 and a single property A such that $h(r) = A$ whenever $r_1 < r < r_2$. But in fact I will want to demand more than this. Roughly speaking, I want to demand that careers “have no corners.” Officially, the constraint is this:

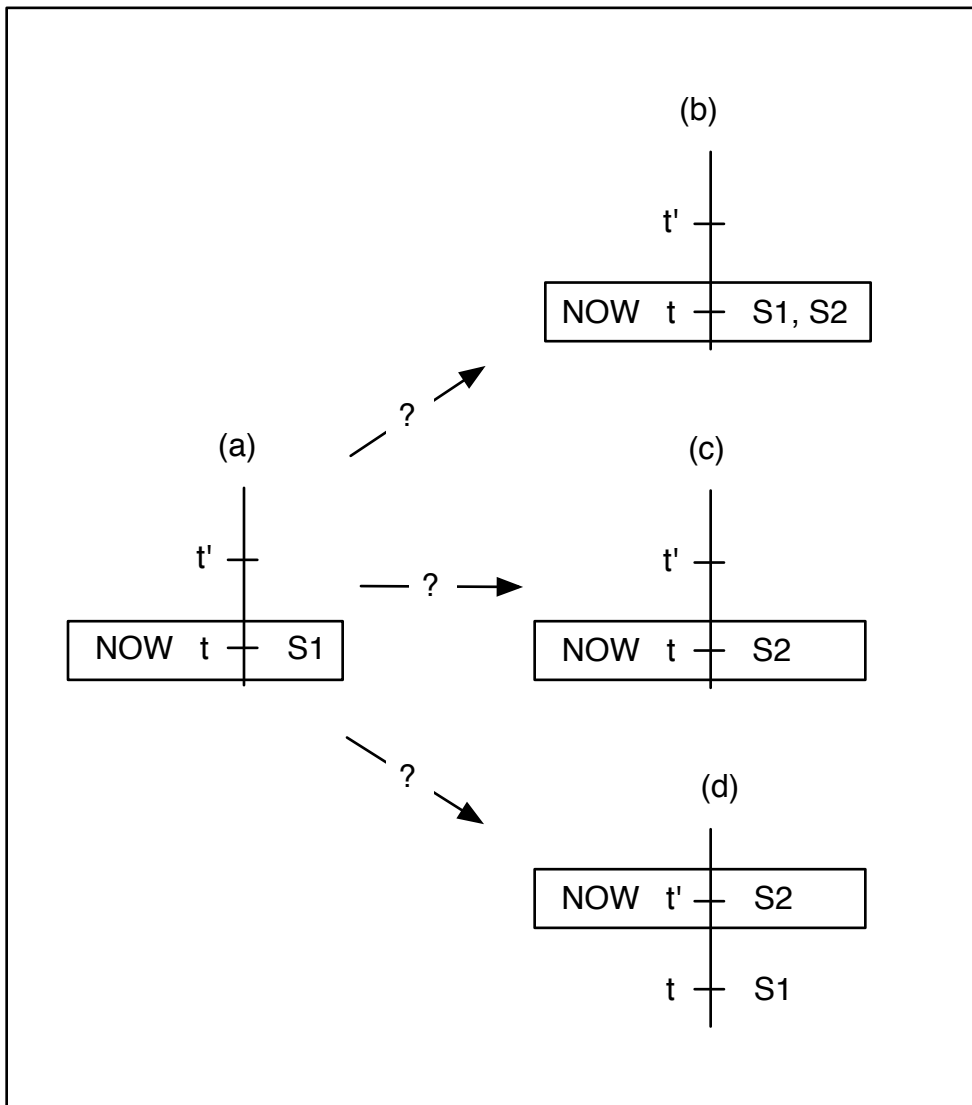
(2b) **The Necessity of Change** (continuous case): Each possible career in configuration space is a differentiable function that always has non-zero derivative.

If there were two numbers r_1 and r_2 and a single property A such that $h(r) = A$ whenever $r_1 < r < r_2$, then h would have zero derivative at r . But that is not the only way for it to have zero derivative. If h “slows down” as it approaches $h(r) = A$, “stops” when it gets to A , “takes a sharp left” (or even makes a U-turn) and then “speeds up” again, it will have zero derivative at r even though f only maps one point to A . Why are these incompatible with the necessity of change? If (2b) is true, then at any point P along a career there is an arrow that points along the curve. (The direction of the arrow is determined by the derivative of the function.) That arrow tells us something about how the universe is changing when it has property P : it tells us the direction in configuration space in which that change is happening. (Example: if configuration space is the set of maximally specific colors, and the universe is NOW red, the derivative will tell us whether the universe is NOW becoming (say) bluer, or yellower.) If the derivative were zero at some point, then there would be no such arrow, and so there would be no direction in which the universe were changing. And so the universe would not be changing at all.

That completes my presentation of the first 2 fundamental principles of my theory. The claim that the NOW moves toward the future is not among them. On my version of the moving spotlight view, that claim follows from the fundamental principles, and is *explained by* those principles. The materials are now at hand; the explanation works like this. Start, again, with

the assumption that time and supertime are discrete. Then: at supertime point p , the NOW is at some time t and the universe is in some state S_1 at t (for short: at p , the universe is NOW in S_1). Also assume that at p the universe is in no state at all at one of the times t' adjacent to t . (See figure 3a. I will explain the second assumption in a minute.)

Figure 3:



It follows from (2a) that at p' the universe is NOW in some distinct state S_2 . How can the universe go into state S_2 ? It cannot happen that between p and p' the NOW stays put at t while the universe goes into S_2 at t while remaining in S_1 at t (figure 3b). For it is impossible for the universe to be in these two states at the same time. It also cannot happen that between p and p' the NOW stays put at t while the universe changes from being in S_1 at t to S_2 at t (figure 3c). That is incompatible with (1). The only remaining option is for the NOW to move to t' , and for the universe to go into state S_2 at that time (figure 3d). Since p was arbitrary, it follows that the NOW is never at the same time at adjacent points in supertime; the NOW is always moving.

I have an assumption to discharge: the assumption that relative to any supertime point p , the universe is in no definite state at all at one of the times adjacent to NOW. This follows from (1) and the claim that the NOW cannot change its direction of motion. In the discrete case this claim amounts to the following:

- (3) Call the two directions in time X and Y . If there is any point in supertime p such that the NOW is located at one time relative to p and a time in direction X relative to its successor p' , then there is no point in supertime q at which the NOW is located at one time relative to q and a time in direction Y relative to q' .

Then the proof that the NOW is always adjacent to a time with no definite state goes as follows. Suppose for *reductio* that relative to supertime point p , the universe is in a definite state at both times adjacent to NOW. Call the three times t_1, t_2 , and t_3 , with the NOW at t_2 . Since relative to p the universe is in definite states at times other than t_2 , by (1) it has not always been at t_2 . So (since the NOW's motion is continuous) it moved to t_2 from one of those adjacent times. Stepping back from p along the points in supertime, we arrive at the most Recent point in supertime q at which the NOW was not at t_2 . It was at, say, t_1 relative to q (the argument for t_3 is the same). Then the direction X in which the NOW moved between q and q' is the direction from t_1 to t_2 . By (3), whenever it moves, it moves in direction X . But since t_3 lies in direction X from t_2 , at no supertime Earlier than or identical to p could the NOW have been at t_3 . This

contradicts the fact that the universe is in a definite state at t_3 relative to p .

With these conclusions in place, I can explain something I left out in the original argument. Examining my diagram, you may have wondered: even if the NOW has to move, why does the NOW have to move to t' , the time immediately above t in the diagram? Why can't it move to the (unpictured) time t^- immediately below t in the diagram? The answer is that, since the NOW is always moving, it has not always been at t ; so, since the universe is in no definite state at t' , it follows from (1) that the NOW arrived at t from t^- . Since it cannot change its direction of motion, if the NOW moves at all, it has to move to t' .

Now, my theory does not just say that the NOW is always moving; it says that the NOW is always moving *into the future*. But have I established that? All that follows so far is that the NOW is always moving, and always moving in the same direction. But that is enough: I identify the future direction in time with the direction in which the NOW moves. Officially, then, I take supertime to have an intrinsic direction, and time to get its direction from the direction in which the NOW moves, as one passes from Earlier to Later points in supertime. (I did speak earlier in the paper as if time also had an intrinsic direction, but that was merely for ease of exposition.)

(3) played an important role in the argument above, but where does (3) come from? It is not a question-begging principle, since it is perfectly compatible with (3) that the NOW never move at all. Still, I would like to be able to say something in its defense. Unfortunately, in the discrete case that cannot be done. But it is the continuous case that I really care about, and in the continuous case the analog of (3) follows from principles already stated (as I will explain below).

So how does the explanation of the NOW's motion work when both time and careers in configuration space are continuous? The answer involves more calculus, so I will quarantine it in a separate section.

4 The Continuous Case

I begin with a clarification. Consider the function $N(s)$ that takes each point in supertime to the time that is NOW relative to that point. The derivative dN/ds of this function tells us about the NOW's motion. The value of dN/ds at p can be pictured as an arrow attached to the instant $N(p)$, pointing in the direction in which the NOW is moving at p . When this "arrow" has zero length, the NOW is not moving at p . So the NOW is moving at p just in case $(dN/ds)(p) \neq 0$. That is what I need to show.

So let p be any point in supertime; $t = N(p)$ is the time that is NOW relative to p . Let $h(s)$ be the universe's career in configuration space: the function that takes each point s in supertime to the property in configuration space that the universe is NOW in relative to s . By (2), the derivative $(dh/ds)(p) \neq 0$.

First note that the NOW has not always been at t . That is, there is a point of supertime q Earlier than p such that $N(q) \neq N(p)$. This follows immediately from (1) and (2).

So the NOW arrived at t from some other time. Since the NOW's motion is continuous, it passed through all the points between there and t . So there is some time $t' \neq t$ such that, relative to p , the universe is in a definite state at every time between t and t' . (Call the set containing the times between t' and t "I.") I must show that the NOW did not come to rest at t .

Define a new function $g(x, y)$. This function takes two arguments—a point in supertime and an instant in time—and returns the property in configuration space that the universe is in at that time relative to that point. (For example, in figure (3d), which depicts things relative to a supertime point p' , $g(p', t) = S_1$.) Then h can be defined in terms of g and N :

$$h(s) = g(s, N(s)).$$

The derivative of h at p , then, is

$$\frac{dh}{ds}(p) = \frac{\partial g}{\partial x}(p, N(p)) + \frac{\partial g}{\partial y}(p, N(p)) \frac{dN}{ds}(p).$$

Before going on I should say a few things about the function g and its derivatives. Strictly speaking $g(x, y)$ is only a partial function: if at supertime point p , the NOW has not yet been to time t , then $g(p, t)$ is undefined. But g is always defined at $(p, N(p))$. Still, the fact that g is only a partial function means that we need to be careful interpreting its partial derivatives.

In fact, $\partial g/\partial x$ may not be defined at $(p, N(p))$: if p is the Earliest supertime point at which the NOW is at $N(p)$, then by (1) for every ϵ , $g(p - \epsilon, N(p))$ is undefined (the universe is in no state at all at time $N(p)$ relative to supertime points Earlier than p). But, fortunately, (1) also tells us that for $\epsilon > 0$, $g(p + \epsilon, N(p))$ is always defined, and always has the same value (at p the NOW is at $N(p)$ so the universe is in a definite state at $N(p)$, and it stays in that state at $h(p)$ relative to all Future supertime points). So I will interpret $(\partial g/\partial x)(p, N(p))$ to be the “right hand” derivative got by approaching p in the first argument place from above. And this right hand derivative is always equal to zero. Similarly, since $g(p, y)$ is defined for all y in interval I (defined above), one side of the derivative $(\partial g/\partial y)(p, N(p))$ always exists.⁸

Now return to the equation. We know that $(\partial g/\partial x)(p, N(p)) = 0$. (This claim corresponds to ruling out possibility (c) in figure 3.) So if $(dN/ds)(p) = 0$, then $(dh/ds)(p) = 0$, which (by (2b)) it does not. Hence, $(dh/ds)(p) \neq 0$, which is what was to be shown.

All that is left is to show that the NOW always moves in the same direction. Since N is differentiable, an intermediate value theorem is true for its derivative. That is, if dN/ds points in one direction at some point and the opposite direction at some other point, then it must be zero at some point in between. So for the NOW to change its direction of motion, it must at some point come to rest. But I have already shown that this is impossible.

⁸In the spirit of (2b), I assume that g is differentiable wherever it is defined. (This may, in fact, follow from (2b).)

5 A New Version, Part 2: Why the NOW Moves at a Certain Rate

So far I have shown how my view explains why the NOW moves. But *how fast* does it move, and why does it move at that rate and not some other?

The picture that accompanies the moving spotlight theory is a picture of the NOW moving at a constant rate into the future. I said in section 2 above how to interpret talk of the NOW's rate in the moving spotlight theory: it is distance traveled in time divided by Elapsed Supertime during the trip.⁹ As I see it, the standard version of the moving spotlight theory can be developed in two different ways, each permitting different stories about why the NOW moves (and must move) at a constant rate.

On the first way of developing the theory, it is analytic that the NOW moves at a constant rate. Distance in supertime is defined in terms of distance in time: for any two points of supertime p and q , the distance between p and q is just defined to be the temporal distance between the time that is NOW relative to p and the time that is NOW relative to q .¹⁰ No surprise, then, that the NOW covers equal amounts of time in equal Amounts of supertime. Asking why the NOW moves at a constant rate is like asking why all bachelors are unmarried.

I find this development of the theory unsatisfying. I want facts about the rate at which the NOW moves to be substantive facts, not tautologies. This is, at least in part, because when I imagine the NOW moving from past to future, I can certainly imagine it moving first faster, and then slower. And I prefer a theory that says I am not making any conceptual mistake when

⁹There is a well-known argument that postulating supertime to make sense of the rate at which the NOW moves leads to a vicious infinite regress. (See, for example, [Smart 1949].) Since in my theory talk about supertime is not to be taken literally, but is to be understood as shorthand for talk about primitive tense operators, the theory does not fall prey to this argument. (See [Markosian 1993] for an attempt to make sense of the rate at which the NOW moves that does not appeal to either supertime or primitive tense operators.)

¹⁰We could also go in the other direction and define distance in time in terms of distance in supertime. I find this development of the theory unsatisfying for the same reasons I am about to give. (What I say here about the relationship between distance in time and distance in supertime applies also to the relationship between the ordering of instants in time and the ordering of points in supertime.)

I imagine this.¹¹

Of course, according to the way of developing the theory that I prefer, I am still imagining the impossible when I imagine the NOW moving at a non-constant rate, I am just not making a conceptual mistake when I do this. Why is that better? Because the marks of conceptual error are not present in this case. What goes wrong when I imagine that the NOW moves at a non-constant rate is not the kind of thing that goes wrong when a child imagines a five-sided square. The child fails to fully grasp the concepts *side* and *square*; but there is no concept that I fail to fully grasp. And what goes wrong when I imagine that the NOW moves at a non-constant rate is not the kind of thing that goes wrong when I watch (say) *Back to the Future*, and so imagine an inconsistent time travel scenario. I am not failing to notice inconsistencies between different parts of an extended episode of imagining.

Facts about the NOW's rate are substantive on the second way of developing the standard theory. Then Distance in supertime is not defined in terms of distance in time. It is not defined in any other terms (just as distance in time is not defined in any other terms). Then there is room to contemplate the (conceptual) possibility that the NOW does not move at a constant rate.

The problem is that the standard version of the moving spotlight theory can say nothing about why these conceptual possibilities are not metaphysically possible. There is nothing to explain why they are ruled out.

So how does my theory explain why the NOW moves at a constant rate? The explanation builds on the role that change played in the previous section. I will start, as usual, with the discrete case. But first a warning about what the theory looks like in the discrete case. In the previous section, my explanation of the NOW's motion in the continuous case is analogous to my explanation of the NOW's motion in the discrete case. Here, though, the explanations of its

¹¹Some, like Tim Maudlin [2007], seem to be happy to let facts about the rate at which the NOW moves be tautologies. But Maudlin is not defending the moving spotlight theory. As far as I can tell, he is defending a version of the B-theory. And B-theorists should think that the only answer to "how fast does time pass?" that makes sense is "at one second per second" (understood so that this is a tautology).

constant rate of motion will not have much in common.

In the discrete case, that the NOW moves at a constant rate follows immediately from the principles already stated. Those principles entail that for any point in supertime p , the NOW moves from one time to an immediately adjacent time between p and its successor. So those principles explain why the NOW moves at a constant rate of one step in time for each step in supertime.

It would be wonderful if things worked as well as this in the continuous case. But they do not. The problem is that there is no next moment in time, and no next moment in supertime. Pick any two points in supertime p_1 and p_2 ; the NOW is at some time t_1 at p_1 and a distinct time t_2 at p_2 . We know that between p_1 and p_2 the NOW has to move from t_1 to t_2 , but nothing so far prevents it from going quite quickly for the first part of its journey, and then slowing down for the rest.

So I need an extra principle in the continuous case. Before I say what it is, I need to say some more about the structure of configuration space. Configuration space, I said, has a metric on it. It allows us to assign lengths to curves in configuration space. With this metric we are measuring the *amount the universe has changed*. That is, for two points p and q in supertime, the length of the career between $h(p)$ and $h(q)$ gives the amount the universe has changed between p and q . Here is an example (in discrete time) to make this concrete.

Space is made of up infinitely many smallest regions. Each region has the same finite size. Think of it as a checkerboard spreading to infinity.

There is just one material body. At any time, it can occupy one, and only one, of the smallest regions. It moves by jumping from one region to an adjoining region.

Configuration space, then, is the set of smallest regions of space.

In this example there is a smallest amount by which the universe can change. It changes by this amount when the material body moves directly from one region to an adjoining region. Any change is made up of a sequence of these minimal changes. It should be intuitive that,

in this example, the length of a path in configuration space between two points is equal to the amount the universe has changed between those two points. In this example, configuration space is isomorphic to physical space; a long straight path in configuration space is a history in which the single material body moves a long distance in a straight line; and a short straight path is a history in which it moves a short distance. Clearly, the universe changes more when the one material body has moved a longer distance. (In the limiting case where the curve in configuration space stays at the same point for all time, the length of the curve is zero and the universe does not change at all.)

For a more realistic example of configuration space, suppose the world is a world of massive point particles in three-dimensional Euclidean space. Then the world changes when (and only when) one or more of the particles moves. The amount by which the universe changes is determined by the distance the particles have moved. The greater the distance a particle moves, the more the universe changes; and the more massive the moving particle is, the more the universe changes. (What motivates this second clause? Imagine a world with just two particles, one of which is a thousand times more massive than the other. The intuition here is that moving the more massive particle one meter is more of a change than moving the less massive particle one meter. It would, after all, require more work to move the more massive particle, and bigger changes require more work.) If we wanted an explicit formula for the distance between two points q_0 and q_1 in configuration space, we could use

$$\sqrt{\sum_i m_i d(q_0(i), q_1(i))^2}$$

where m_i is the mass of the i -th particle and $d(q_0(i), q_1(i))$ is the spatial distance between particle i 's location in q_0 and particle i 's location in q_1 . The length of a path in configuration space is defined in terms of the distances between points on that path in the usual way. (Technically, the metric on configuration space assigns lengths to tangent vectors, and mathematics books often define the distance function on the manifold using the metric, rather than vice versa.)

(There is a minor complication that I should mention here. In some possible worlds there may not be a (natural) metric on configuration space. That is, there may not be a natural way to measure how much the entire universe has changed. For example, suppose there is just one material body with mass m and charge c , and it moves a certain distance d . If there is a way to measure how much this entire world changes during some interval, then there must be answers to questions like: if the body's mass were three units less than m , how many units greater would its charge have to be for its moving distance d to constitute the same amount of change? But, I take it, there are no (non-arbitrary) answers to questions like these.

Fortunately, my view does not need these questions to have answers. Whenever the universe as a whole changes, it changes because some part of it changes in some respect. We can always assign magnitudes to *these* changes—we can always say how much something's charge or mass or position has changed, even if we cannot mathematically combine the magnitudes of these changes to calculate the total amount of change. And that is enough for my theory. For simplicity, I will present the theory as if we do have a way to measure the change of the entire universe. But everything I say below makes sense if talk of the rate at which the universe as a whole is changing (represented by the metric on configuration space) is replaced by talk of the rate at which some part of it is changing in some respect.)

I are now ready to talk about why the NOW moves at a constant rate. Recall that the derivative dh/ds at a point p (where h is the universe's career in configuration space) is an arrow tangent to that career at $h(p)$. Because we have a metric on configuration space (and on supertime), we can assign a length to this tangent vector. This length gives the Instantaneous rate at which the universe is changing at p .

But this is, of course, its rate of change with respect to supertime. (That is, if we gave units to the length of the vector, the units would be (amount of change)/(distance in supertime).) We can also measure the universe's rate of change with respect to time—the amount of change divided by distance in time. To do that we need a function from time to configuration space. Then we will take the derivative of that function, which gives us a tangent vector; the length of

that vector will be the desired rate.

The material in the previous section allows us to define this function easily. Since $dN/ds \neq 0$, N has a differentiable inverse N^{-1} . For any time t , $N^{-1}(t)$ is the (unique) point in supertime relative to which t is NOW. The composite function $\gamma(t) = h(N^{-1}(t))$ then gives the universe's career in configuration space, but now parameterized by time rather than supertime. The universe's rate of change with respect to time, then, is the length of the vector $d\gamma/dt$.

Now it is time to pause and see where we are. Let p be a point in supertime, and $t = N(p)$ the time that is NOW relative to p . I have shown that we can make sense of two questions about the rate at which the universe is changing. We can ask, how fast is the universe changing in supertime (at p)? And we can ask, how fast is the universe changing in time (at t)? Still, despite the fact that these questions are distinct, asking both of them pretty much amounts to asking the same thing. That is, it would be exceedingly odd, I think, if the moving spotlight theory had to give different answers to these questions. My final principle is the demand that these two questions always have the same answer:

- (4) For any point in supertime p , the rate in supertime at which the universe is changing at p is equal to the rate in time at which the universe is changing at $N(p)$.

What follows from (4)? Let p be any point in supertime, and $\tau = N(p)$. Then tangent vectors $(d\gamma/dt)(\tau)$ and $(dh/ds)(p)$ are related by the following equation:

$$\begin{aligned} \frac{d\gamma}{dt}(\tau) &= \frac{dh}{ds}(p) \frac{dN^{-1}}{dt}(\tau) \\ &= \frac{dh}{ds}(p) \left(\frac{dN}{ds}(p) \right)^{-1}. \end{aligned}$$

This equation says that the length of the vector $d\gamma/dt$ is $\frac{1}{dN/ds}$ times the length of dh/ds . By principle (2), the vector dh/ds always has non-zero length; so (since these two vectors point in the same direction) they have the same length if and only if $\frac{1}{dN/ds} = 1$, which entails that $dN/ds = 1$. And that is exactly what I wanted to show: that the NOW moves at a constant rate

of one second per supersecond.

Finally, let me note that this explanation is not available to a standard moving spotlight theorist who does not accept (2), even if he does accept (4). If there are stretches when the universe does not change, nothing prevents the NOW from speeding up and slowing down during those stretches.

6 Conclusion

That is my version of the moving spotlight theory. My main goal in this paper has been to present this new version. Whether or not you accept the moving spotlight theory, this new version is interesting and worthy of attention—first, because it develops in precise detail a theory that takes seriously the vague idea that there is a deep connection between time and change; and second, because it has advantages over the standard version of the moving spotlight theory. It explains both why the NOW moves and why it moves at a constant rate. Let me close by saying something about these advantages.

My theory explains things that the standard theory does not; but is my theory really explanatorily superior to the standard theory? My fundamental principles may explain why the NOW moves, and why it moves at a constant rate, but I made no attempt to explain why those principles themselves are true. (Since they are fundamental, they cannot be explained.) So if we were to count unexplained principles, it looks like my version has more than the standard version. And, one might think, the better theory is the one with fewer unexplained principles, not the one with more.

I disagree. When judging the relative merits of two theories, what is important is not how much each theory leaves unexplained. What is important is whether the things that go unexplained in the theory seem to demand explanation. Insofar as I accept the moving spotlight theory, I think that the fact that the NOW moves, and the fact that it moves at a constant rate, demand explanation. Or, at least, they demand explanation more than the principles I use in my

theory to explain them.

The only exception to this is principle (2), the necessity of change. I suspect, though, that the main resistance to (2) is not that it demands explanation, but that it looks false. And this is a different complaint to make. Now, defending (2) is a big project, too big for the conclusion of this paper. Let me just say this.¹² Although (2) does not follow from the A-theory of time, it is a very A-theoretic idea. So some A-theorists will not balk at accepting a theory that incorporates it. (And it is to A-theorists that I offer my theory.) Of course, my theory is hostage to empirical evidence in a way that the standard theory is not. My theory entails that (it is necessary that) the universe always be changing; what if we discover that it is not? Fortunately, we have excellent evidence that the universe is, in fact, always changing. But don't we have physical theories that entail that it is at least possible that the universe not always be changing? My metaphysical theory is incompatible with those physical theories. I don't think that a proponent of my version of the moving spotlight theory should be troubled by this. He should say that (given what we know about the actual world) it is the job of metaphysicians to tell us what is metaphysically possible; physical theory is there to tell us which of those metaphysical possibilities are physically possible. If a physical theory has a model that correctly represents the actual world, and also has models in which the universe is sometimes changeless, he can just revise the theory by throwing out those (by his lights) impossible worlds and keeping as physically possible all the rest.

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¹²Shoemaker [1969] is widely seen as having established that there can be time without change. But the main example in that paper aims at establishing nothing so grand. The point of the example is merely to serve as a counterexample to a conditional claim: if it is possible that there be time without change, then we could never know that such a stretch of time had passed. Showing that this conditional is false falls short of showing that its antecedent is true.

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