Imprints in Time: Towards a Moderately Robust Past

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Presentism says that only present objects exist (timelessly). But the view has trouble grounding past-tensed truths like "dinosaurs existed". Standard Eternalism grounds those truths by positing the (timeless) existence of past objects—like dinosaurs. But Standard Eternalism conflicts with the intuition that there is genuine change—the intuition that there once were dinosaurs and no longer are any. By drawing from the resources of Einstein's General Relativity, I offer a novel theory of time that does a better job preserving both the grounding and genuine change intuitions. The theory says that the past and present exist (in the timeless sense), but where the present exhibits mass-energy, the past only consists of curved empty regions of spacetime. We therefore avoid saying that there are dinosaurs, since there is no mass-energy in the past; but the curvature of the past gives us a way to ground the truth that "dinosaurs existed".

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There are two intuitions that we should hope that our theory of time can accommodate. These can be roughly stated as: (i) tensed truths must be grounded and (ii) there is genuine change. The first requires, for example, that the truth of 'there were dinosaurs' be grounded in the way the world is. The second requires that change in 'there are dinosaurs' isn't just a matter of dinosaurs standing in an earlier than or later than relation to a time; rather it's a difference in whether there are dinosaurs around *at all* to stand in relations. The challenge in accommodating these intuitions is that they seem to push in opposite directions: the grounding intuition pushes us to incorporate past objects with features robust enough to ground past tensed truths, yet the objective change intuition pushes us to keep past objects from having features that are *too* robust. I don't think extant views of time balance these intuitions in a satisfying way. My aim is to a better job.

How, then, do we ground the truth of 'there were dinosaurs' without having dinosaurs existing in the past to be those grounds? My preferred answer draws from Einstein's theory of General Relativity on which spacetime regions have a *curvature*. My answer is this: though there are no dinosaurs in the past, there nevertheless are past curved regions of spacetime that do the grounding. And even though those regions are empty—they lack mass-energy—the dinosaur-shaped curvature provides the needed grounds. The curvature of the past is the imprint mass-energy leaves on time. Though positing spacetime curvature is not a novel idea, I employ it in this novel way to ground past-tensed truths.

The structure of the paper is this. In section 1, I discuss the first intuition. I sharpen it and explain what sorts of views it rules out. I then further explicate the second intuition in section 2 and explain how it poses a problem for other prominent views. I then present my own account in greater depth in section 3 and respond to objections in section 4.

1 First intuition: past-tensed truths are grounded

As Sider (2001: 36) notes, there are two ways[1] of cashing out the intuition that past-tensed truths must be grounded. The first is the truth-maker principle that for every truth, there's an entity whose existence suffices for its truth. The second is the supervenience claim that truth supervenes on the existence and properties of objects and the relations they stand in with one

[1] A third option is to take grounding as a *sui generis* relation (e.g. Schaffer (2009a)).

another. Many find one or the other of these grounding principles gripping (see Bigelow (1996); Lewis (2001); Sider (2001); Mozersky (2011); Cameron (2015); McDaniel (MS)). Others, such as Merricks (2007) and Kierland and Monton (2007), deny them. But I will assume that something like them captures what we want from a theory of time. Though I prefer to be neutral between the two principles, for simplicity I will talk in terms of supervenience rather than truth-making.

The supervenience claim seems to rule out Presentism—the view that only present objects exist. (I will assume that there's a timeless sense of 'exist' on which Presentism neither turns out trivially true or trivially false). Presentism has no past objects around (in this timeless sense) for the truth of 'there were dinosaurs' to supervene on. Nor do they supervene on any present objects. For consider a world, *W*, where the present is just like ours—complete with paleontologists and fossils (that are intrinsic duplicates of the fossils we have) in the supervenience base—but where dinosaurs never existed. Perhaps we can imagine this as a world that came into existence only five minutes previously. If so, then the actual world (at present) and *W* (also at present) seem to have all the same objects with the same properties and relations between those objects, yet they differ in the truth of 'there were dinosaurs'. There's a strong sense that the truth of this claim can't just 'float free' from the world in this way; it must supervene on the way the world is.

John Bigelow (1996: 46) has tried to preserve Presentism[2] in the face of this charge by pointing out that objects can have properties like *previously containing dinosaurs*. Assuming Presentism, 'there were dinosaurs' can be true in the actual world but not *W* since only the universe in the actual world has the property of *previously containing dinosaurs*. But there's a general sense of dissatisfaction with this solution (shared by Sider (2001); Heathwood (2007); Merricks (2007); Cameron (2015); McDaniel (MS) among others). For this response seems to be *cheating*. Even if objects do instantiate such past-directed properties, the properties themselves shouldn't belong in the supervenience base. Since they 'point beyond' their instances,[3] they should supervene on something further.

It might be helpful to spell out what makes past-directed properties a cheat a bit more precisely. Ross Cameron has this to say about it: 'the suspiciousness of properties such as *having been 4ft tall* consists in their not making a contribution to the intrinsic nature of their bearers at the time at which they are instantiated' (2015: 136). On this account, having the property *having been 4ft* in the supervenience base is a cheat since it doesn't tell you how tall I am now. This explanation is a bit limited since it doesn't account for the fact that the property *having been 4ft tall, but now 5ft11* seems like just as much of a cheat but *does* tell you how tall I currently am.[4] So to rule out this case as well, I think we should instead say:

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[2] Tom Crisp (2007) defends Presentism like this: he posits the existence of abstract times and the temporal relations of 'earlier than' and 'later than' that hold between them. 'There were dinosaurs' is therefore grounded in the fact that a time that entails the existence of dinosaurs is earlier than the present time. My main difficulty with the view is that the view requires that there are times t_1 and t_2 such that: (A) t_1 is earlier than t_2, yet (B) t_1 and t_2 are both present (since it's a Presentist view). Yet (A) and (B) seem inconsistent; how could they both be present if the one is earlier than the other? In response, Crisp (2007: 103) distinguishes two construals of (B): (B') t_1 and t_2 are at no temporal distance from the present, (B'') t_1 and t_2 are both true. He accepts (B') but rejects (B''). But I don't see how this distinction helps. (A) and (B') still seem inconsistent. (If we instead analyzed 't_1 is earlier than t_2' as 't_1 was true relative to t_2' then the inconsistency fades. For then (A) would be talking about the *truth* of the times in question and (B) would be talking about the *existence* of the times in question. But of course this analysis itself would be invoking past-tensed truths to ground past-tensed truths.)

[3] Or, as Chisholm (1976: 100) says, they are "rooted outside the times at which they are had".

[4] Cameron doesn't see a need for revision since he doesn't think it's a cheating property. But I find it hard to agree.

Cheating Properties
If property *p* (i) is instantiated at *t*, (ii) entails that some (non-trivial) intrinsic property[5] was instantiated before *t* and (iii) is in the supervenience base, then *p* is a cheat.

This seems to get the right results: both the property *having been 4ft* and the property *having been 4ft tall, but now 5ft11* are cheats if included in the base since they both tell you that something used to be *4ft*.

We should note that we ordinarily infer all sorts of truths about the past just by looking at the present. Given that Spot is a dog, I infer that there once were two other dogs that copulated and eventually gave birth to Spot. Given the conservation of mass-energy, I infer that the total amount of mass-energy that existed in the universe yesterday is the same as it is now. And it doesn't seem like cheating to include the instantiation of *being a dog*, *having a total amount of mass-energy* m, in the supervenience base. But we should note that none of these examples violate Cheating Properties since none of them *entail* certain features about how things were.[6] Even though they make it reasonable to assume that there were dog parents of Spot, or that there once was the amount of mass-energy that there currently is, there's no *guarantee* that these were the case. For example, the instantiation of such properties is compatible with the entire universe coming into existence at the moment of their instantiation. This is unlike the instantiation of *having been 4ft tall*, which not only makes it rational to believe that something was 4ft tall, but also *entails* it.

I have explained why Presentism fails to respect the grounding intuition and the ban against cheaters. On the other hand, views that respect it generally include merely past objects with robust features in their ontology. Take, for example, The Block view on which *now* is a temporal location much like the spatial location *here* in two important resects. First, times earlier and later than *now* are as real as *now* just as spatial locations other than *here* are as real as *here*. Second, just as there is no spatial location that is the privileged or objective *here* location, so there is no temporal location that is the privileged or objective *now* location. Another view is The Growing Block, which is much like The Block view, except the spatiotemporal block 'grows' in the future direction—new times are constantly added to the side of the block pointing to the future—and the present is the time on the 'cutting edge'. Both views can treat 'there were dinosaurs' as supervenient on the existence of dinosaurs at some time earlier than the present (however 'the present' is spelled out). And this doesn't require cheating. Furthermore, even if I have the property of *having been 4ft* on these views, this property supervenes on the further fact that I exist (in the timeless sense) at some earlier time *t*, and have the property *being 4ft* at *t*. So all the properties in the supervenience base are non-cheaty; and any past-directed properties supervene on them.

The Block and Growing Block theory do well with the grounding intuition. But how well they handle the genuine change intuition is what we turn to next.

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[5] For an analysis of the notion of 'intrinsic properties' see Lewis (1986: 61-3).

[6] If Sober (1980) is right that species have their origins essentially, then *being a dog* might entail that some dog—the first of the species—existed at some point in the past. If so, then I should think that including *being a dog* in the supervenience base is a cheat. Nonetheless, a more purely qualitative description such as 'being dog-shaped' would not be.

2 Second intuition: there's genuine change

Things change. We start out as fetuses and grow larger and stronger. The day changes to night and back to day. But how do we understand this change? On The Block view, this change is just like the sort of difference we see in spatial location: currently *this* part of the street is well lit, but *that* part of the street is dark. So we can say that America changes from bright to dark in the same sort of sense that the street (spatially) changes from bright to dark. But many object that this sort of change isn't *genuine* change. As A. N. Prior puts it, 'I believe that what we see as a progress of events *is* a progress of events, a *coming to pass* of one thing after another, and not just a timeless tapestry with everything stuck there for good and all.' (1996: 47) Yet The Block view doesn't give us this. Though it tells us that America has 'changed' from being bright to now being dark, the bright part is still there and bright! This doesn't seem to capture the sort of change we want. It is, however, controversial whether there is an intelligible sense of 'genuine change' over and above the sort of change The Block view has (see especially Skow (2015)). But I will assume that there is such an intelligible sense and it's something we should want our theory of time to have.

In order to account for the change, it looks like we need to move to some form of A-Theory—where 'A-theoretic' views can be understood, roughly, as views on which there is a 'privileged present' (see Cameron (2015) for further explication). But not just any A-Theory will do. For example, we might try adopting the Classical Moving Spotlight view ('The Spotlight' for short) instead. This view is much like The Block, except it posits a primitive monadic property of 'presentness' that moves through the block—the 'moving spotlight'—which is the *objective present*. But the addition of this property is too little of a difference from The Block view to really do justice to the genuine change intuition. As Sider puts the point:

> the only reason for invoking (the monadic property of presentness) at all is to be able to say that there is genuine change in which moment is present. But notice that the spotlight theorist does not admit genuine change for anything else! For her there is no genuine change in whether I am sitting, or in whether there are dinosaurs, or in whether a war is occurring, since her account of these matters is identical to (The Block theorist's). All that genuinely changes is which moment has presentness. Is securing this smidgen of genuine change worth the postulation of primitive tense? (2011: 260).

And Cameron agrees:

> The change we want to account for when we start theorizing does not concern times and presentness, it concerns dinosaurs, people, tables, etc. and their properties. If we cannot account for change in such ordinary, concrete goings on, we have lost track of our subject. (2015: 111)

The idea is that even though we can deny that there are dinosaurs that presently exist, there nevertheless still *are* (in the timeless sense) dinosaurs. So even though The Spotlight gets us some change, it doesn't seem to get us the degree of change that we're after. (Though see Deasy (2015) for further discussion.[7] Also Cameron (2015) defends what he calls 'The Moving

[7] Daniel Deasy (2015: 2078-9) argues that The Moving Spotlight does accommodate the sort of genuine change we're after. He claims that the intuition expressed by 'dinosaurs don't exist' employs a quantifier that is restricted to

Spotlight', though his view is not the traditional one usually associated with that name. Cameron's view also violates the restriction against cheating properties spelled out in the previous section.[8,9])

In order to avoid dinosaurs being located in the block, we need a more drastic alteration of The Block view than The Spotlight gives us. I think the right way to accommodate the genuine change intuition is to start 'deleting' characteristics from past objects. Peter Forrest's (2006) Growing Block view employs the deleting strategy to a small degree: on his view nothing in the past location of the block has consciousness (though they did have consciousness when those temporal locations were present). This allows us to say that there is genuine change in what things have pain and conscious experiences—only present things! But it doesn't make for genuine change in the existence of dinosaurs, tables, etc.

I think the lesson is that we need to use the deleting strategy more aggressively to account for this. Of course the danger of applying it *too* aggressively is that past objects won't be robust enough to ground past-tensed truths—thus falling prey to the first intuition. So my aim is to find a sweet spot that balances the two intuitions: thin out the features of past objects to the point that we don't have dinosaurs and tables in the past, but keep them thick enough to ground past-tensed truths.

3. A moderately robust past

We saw that merely deleting conscious states from all past times doesn't go far enough in preserving the genuine change intuition. It leaves untouched past dinosaurs and tables. What more, then, should we delete? We might be tempted to simply delete all mass-energy from past spacetime regions (much like in Zimmerman's (2011) empty box view[10]). All that would be left in the past is just the fabric of spacetime—empty spacetime regions. Yet such regions seem not to have enough interesting properties to ground past-tensed truths. How would they account for the difference between a world where there were dinosaurs versus a world where there weren't? Wouldn't both worlds have just the same empty and uninteresting past regions of spacetime?

The route that I propose and will explore for the rest of the paper is to include 'trackers' in spacetime. These trackers are objects in, or properties of, spacetime that somehow track where in spacetime objects have been, without themselves being dinosaurs or tables. That is, the trackers somehow 'light up' various regions of spacetime, thus indicating that objects were located at those regions. (Notice that entities such as Szabo's (2006: 414) "resultant states"—presently

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only the present. Hence, as the spotlight moves, the sentence goes from true to false. I find this to be a hard line for The Spotlight view to take. Surely its proponents wouldn't want to say that the intuition '*this* is the privileged present' employs a quantifier restricted to the present. But if the privileged present intuition works with this unrestricted tenseless quantifier, why doesn't the intuition concerning dinosaurs also?

[8] Cameron (2015) tries to satisfy the grounding intuition by appealing to temporal distributional properties (TDPs)—such as the property of having once contained dinosaurs, but no longer. The important feature of TDPs is that even though they are temporally non-homogenous (they imply different features at different times), they aren't *reducible* to homogenous properties. This is suppose to give us a non-cheaty ground of 'there were dinosaurs' since that truth supervenes on the TDP without also supervening on the purely past-directed property *having once contained dinosaurs*. My concern with this account is that even if the TDP isn't *purely* past-directed, it's past-directedness still seems like a cheat.

[9] Sullivan's (2012) minimal A-theory also resembles The Spotlight, since they both hold that there exist objects that were once spatially located, but no longer are. The difference is that on Sullivan's view, such objects *permanently* exist—that is, they exist at all times, even at those times at which they aren't located anywhere.

[10] Though Zimmerman proposes the empty box view in order to ground cross-temporal truths (such as whether an object has moved inertially or non-inertially) rather than truths like "there were dinosaurs".

existing entities that state what occurred—don't count as trackers. This is simply because Szabo doesn't take the objects to exist in past regions, since his aim is to defend Presentism.) Having spacetime complete with trackers looks like a promising grounding strategy: roughly speaking, 'there were dinosaurs' could then be grounded in the fact that the past has dinosaur-shaped regions lit up by trackers.

3.1 What are these trackers?

But what might the trackers be? A first suggestion is that material objects leave behind *bare* objects. These bare objects have locations in spacetime, but they don't have the usual 'physical' properties such as mass, charge or causal abilities (much like the non-concreta of Williamson (2002) and Sullivan (2012), the main difference being that the bare objects I have in mind have locations). Thus we could say that dinosaurs leave behind these bare objects that exactly occupy those spacetime regions that the dinosaurs occupied. A second suggestion is that there are past objects with a *lesser degree of being* than present objects. Kris McDaniel says there's an intuitive sense in which holes and shadows have this lesser degree than the things that have the holes and shadows. (2013: 3-4) So we might say that past regions of spacetime contain these less real objects—objects like holes and shadows.

I'm not too enthusiastic about either of these suggestions. My main hesitation with the first is that I'm not sure I can make sense of such a bare object being located. It makes sense to say that matter is located somewhere. But if an object doesn't have matter, it's harder to see how this could be the case. We might grant that non-physical souls can be located (at least in a derivative sense) by having causal effects that are located. But the bare objects appealed to above don't even have these.[11] Borrowing from the second suggestion, we can point out that holes and shadows have location without having mass. So we could instead think of a dinosaur-tracker as being a dinosaur-shaped hole or shadow. But this suggestion is problematic since holes and shadows couldn't exist in empty space. Holes need to be surrounded by something with mass.[12] And shadows require there to be (i) surfaces of material objects—since that's what shadows are draped on—and (ii) light beams that shine on such surfaces—since the 'edges' of shadows are adjacent to surfaces that are exposed to light. So my main hesitation with the second suggestion is that I'm not sure how to think about these 'less real' dinosaurs. Do they, like holes and shadows, lack mass? If so, are they just as bare as the objects in the first suggestion? Or perhaps they 'have mass', but only in a less real sense of 'have'? But how should we understand this less real sense?[13] Perhaps there are ways to develop these strategies that address these questions. But I see a more promising strategy.

On my preferred view—what I'll call 'The Imprint' view—the trackers correspond to a *curvature* of spacetime regions. Much like a snake leaves its imprints in the sand as it moves through it, so material objects leave curvature imprints in spacetime. And we can think of different objects as leaving unique imprints: chairs leave chair-shaped imprints, dinosaurs leave

[11] Though Hawthorne and Uzquiano (2011) think non-material angels can be primitively located at a region—not in virtue of there being effects in the region caused by the angel.

[12] If we just think of holes as empty regions of spacetime, then we can avoid saying this. But this doesn't ultimately help the proposal. Holes will just be located somewhere in the sense that a region of spacetime is located at itself. But this is true for any region. A unicorn-shaped slice of past spacetime, for example, will likewise have something located at it—itself! But that shouldn't mean that there was once a unicorn.

[13] We could understand it in the same way a composite object might be said to have mass derivatively, whereas its fundamental parts have mass non-derivatively. But if past dinosaurs 'have mass' in that sense, then don't past dinosaurs have mass in just the same sense that present dinosaurs do?

dinosaur-shaped imprints, etc. The proposal then is this: even though the past is empty (it has spacetime regions, but lacks non-gravitational mass-energy) we can ground "there were dinosaurs" in the fact that some past regions have dinosaur-shaped imprints.

The idea of spacetime curvature is relatively familiar, especially with the development of Einstein's theory of General Relativity. According to General Relativity, the Moon orbits the Earth because the spacetime around the Earth is curved; this prevents the Moon from moving in a straight line, instead moving in an orbit.

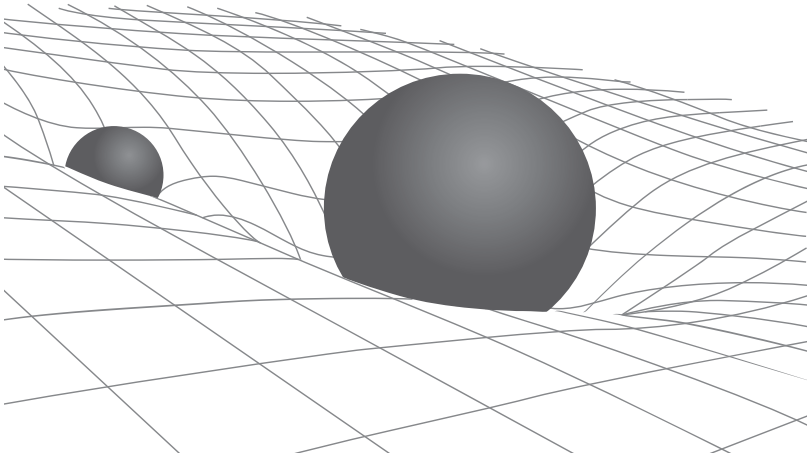

Fig. 1 According to Einstein, spacetime's curvature makes the moon orbit Earth.

So there is good reason to think that the idea of spacetime curvature is coherent.

We can also take a cue from General Relativity to tell us what past curvature is like. The Einstein Field Equations (given in Einstein (1916)) tell us that all the characteristics of non-gravitational mass-energy are relevant for determining the curvature of spacetime. They also tell us exactly how spacetime curves in the presence of non-gravitational mass-energy.

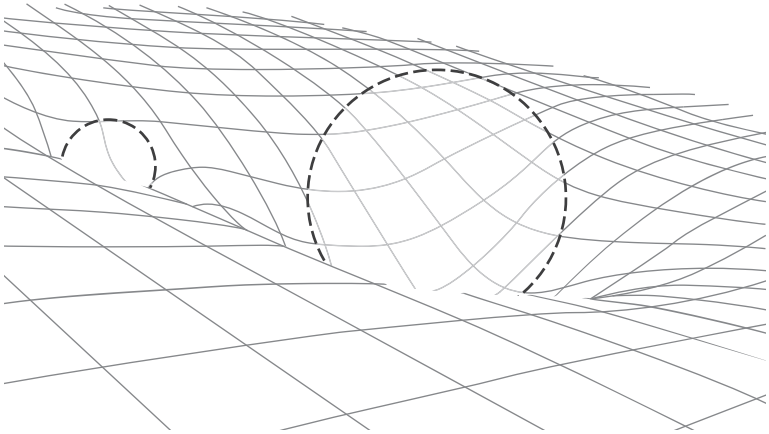

Fig. 2 Though empty, the spacetime region retains its curvature.

The Imprint can employ the equations to give us at least one principled way to state what the curvature is like at a time: for any temporal slice *t* of spacetime, if *D* is the complete description of the curvature at *t* that the Einstein Field Equations give of *t* when *t* is present, *D* continues to

be the true description of the curvature at *t* (even though *t* is past).[14] And the fact that *D* continues to be the true description is a brute fact not grounded in anything further.

We might wonder what dispositional facts these empty but curved past regions of spacetime entail. For instance, if a particle appeared in a region in the past where no particle had been, would the particle create addition warping to the region's curvature? And if so, wouldn't that be problematic—either because past facts would be changed, or because the curvature at that time could no longer ground truths concerning that time? I think we should say that it's impossible for any past regions to be occupied once they've become past. Thus, asking how the past regions would react if it were now occupied is like asking what mathematical truths would follow if 1+1=3. (If The Spotlight and Growing Block theorists were asked 'how would past objects react if new particles appear where there weren't any before?', the best answer there *also* seems to be that such a thing is impossible.) But why should we think the past couldn't be re-occupied? This is simply because it's intuitively true that the past is fixed and unalterable.

One worry with The Imprint view is that it seems to conflict with the Einstein Field Equations: the equations are supposed to be true at all times, yet doesn't The Imprint imply that the equations don't hold true of the past—the past has curvature without the accompanying non-gravitational mass-energy! But this objection is misguided—it confuses the distinction between how a time is when it is present and how it is when it is past. For instance, on the Spotlight theory, Jan. 1, 2000 instantiated the monadic property of presentness when it was present, but now that it is past, it no longer does. Similarly The Imprint says that Jan. 1 2000 had non-gravitational mass-energy when it was present, but now no longer does. The Imprint doesn't conflict with the Einstein Field Equations since it doesn't deal with the same domain: the equations tell us how times are *when they are present*, whereas The Imprint tell us how times are *when they are past*. And I think this captures what physicists have in mind when they claim that General Relativity is always true. After all, physicists are interested in positing theories that capture observable phenomena. And we can only observe times when they are present. I think it's the metaphysician's job to figure out if the Einstein Field Equations accurately describe all times when they aren't present—the claim here is that they do not.

Let me put the point another way. One might say 'Presentism conflicts with the scientific claim that the universe existed before the present—Presentism says there is no past!' (Lewis (1986: 204) makes this sort of objection). But Presentists (such as Bourne (2006: 52, fn. 5) and Merricks (2007: 124, fn. 6)) will respond that there is no conflict here. Though Presentism holds that there *are no* past objects, this is consistent with the fact that *there were* objects. Of course, some (e.g. Meyer 2005, Lombard 2010) deny that there is a distinction here to make—for they deny that there is a timeless sense of 'exists' on which it's a substantial question whether what did, does or will exist also exists in the timeless sense. But Presentists (and, more generally, those who think there's a substantial Presentism-Eternalism debate) think such a timeless quantifier is coherent.[15] Likewise, though The Imprint says there is no past non-gravitational mass-energy, this is consistent with the fact that *there was* non-gravitational mass-energy. The Imprint is consistent with General Relativity and the Einstein Field Equations.

[14] The equations are, however, extremely complex, and only very few exact solutions to them have been discovered.
[15] See for example Crisp (2004a + 2004b), Zimmerman (2005) and Sider (2006) for responses.

3.2 The Imprint view: possible add-ons

I have displayed the essential features of The Imprint view. Let me now state some ways it could be further developed in terms of the nature of the future, the present and the grounding of past-tensed singular propositions.

There are three main ways we can think of the future. First, like The Growing Block view, we can say there is no future at all. Second, as on The Spotlight view, we can think of the future as being much like the past, but just located in a different temporal direction. In conjunction with The Imprint view, the future would then consist solely of empty curved spacetime regions that ground future-tensed truths. A third main option is to have multiple futures that 'branch off' from the present. These different branches would then correspond to the different futures that are available. Again, none of these branches would instantiate non-gravitational mass-energy, but only empty curved spacetime regions.[16]

There are also three options that I see for giving an analysis of the present. The first is to analyze it as the time on the 'cutting edge' (which requires us to adopt The Growing Block view that there is no future); the second is to analyze it as the time at which there is non-gravitational mass-energy; and the last is to take it as a primitive property of times. The second option is attractive relative to The Imprint view. But one drawback is that it doesn't allow the possibility of there being a time that is present and devoid of non-gravitational mass-energy. If one judges this to be a serious drawback there are still the other two options. (And these wouldn't suffer the problems raised above for The Spotlight or Growing Block view since there still is genuine change not only in what moment is the present, but also for the sorts of things we are ordinarily concerned with.) But I'm inclined to think that analyzing the present in terms of the presence of mass-energy is well worth the cost.

A separate issue concerns the grounding of true past-tensed *singular* propositions. For example, perhaps there aren't just general past-tensed truths like 'dinosaurs existed,' but also propositions like '*Delilah* the dinosaur existed'. There are numerous ways of addressing this issue that can be straightforwardly added to The Imprint view.[17] We might deny that there are singular propositions concerning objects that no longer exist; we might think that there are such propositions, but they now have 'blanks' where they once had individuals; we might think there are such propositions and that they don't have blanks, but that they concern or are grounded solely in purely qualitative truths (such as truths concerning only the curvature of spacetime). But a different claim that can't be straightforwardly added to The Imprint view is this: the singular proposition 'Delilah the dinosaur existed' expresses a singular proposition *not* grounded in purely qualitative truths—this might be because the purely qualitative truths don't determine that it was *Delilah* that existed, rather than some intrinsic duplicate.

To accommodate this last view, we can add to The Imprint the claim that material objects are *identical* to regions of spacetime (a form of supersubstantivalism). For example, the Eiffel Tower isn't distinct from the region *R* that it occupies, rather it's identical to that region. And the Eiffel Tower's properties, such as having mass *m*, are directly 'pinned' to the region rather than some distinct intervening object (see Schaffer's (2009b) for further explication). So what grounds the

[16] David Lewis has objected to standard branching views in this way: "if two futures are equally mine, one with a sea fight tomorrow and one without, it is nonsense to wonder which way it will be—it will be both ways—and yet I do wonder" (1986: 207). Nuel Belnap *et al* (2001: 206-7, 225) have responded that this objection mistakenly relativizes truth to a moment in time. Rather it must be relativized to a moment *and history* (a maximal line through a tree). The sentence "there will be a sea fight tomorrow and there will be no sea fight tomorrow" therefore fails to come out true—on no moment-history pair is it true.

[17] Many such views are surveyed in Markosian (2003).

fact that Delilah the dinosaur existed, rather than some intrinsic duplicate? Part of the answer is that *Delilah herself* exists in the past region to do the grounding. And since Delilah is *identical* to a region, this is compatible with the fact that all that exists in the past are curved regions of spacetime.[18]

If we take this supersubstantivalist route, there will also be options concerning what region an ordinary object is identical to. One is to take inspiration from Worm Theory (defended by Heller (1984) and Lewis (1986)) and identify it with a four-dimensional region. But the view will differ from Heller and Lewis' Worm Theory in the sense that only the *present* region of the spacetime worm has non-gravitational mass-energy. A second option is to draw from Stage Theory (defended by Sider (2001)) and identify the object with a three-dimensional space-time slice (while analyzing past-tensed properties in terms of past temporal counterparts). But the view will differ from Sider's in the sense that no past temporal counterparts have non-gravitational mass-energy (in this way the past temporal counterparts resemble the ersatz counterparts of Heller (1998) and Paul (2006)).

We might think that the identification of Delilah with a spacetime region is at odds with the genuine change intuition. For not only should dinosaurs fail to exist, *Delilah* should as well. Anyone who agrees with this point should opt for some other view of past-tensed singular propositions that doesn't require Delilah's existence. But if we are convinced that there are (and always will be) singular propositions about Delilah and that their existence requires Delilah's existence as well, we should also deny that Delilah could go out of existence.

4 Objections

There are a few objections to The Imprint view that are also attacks on prominent A-Theoretic views. For example, J.J.C. Smart (1956) objects that A-Theories require a *rate* at which time passes. Yet since there's no satisfactory answer to what that rate might be, the views must be false. J.M.E. McTaggart **(**1908**)** argues that A-Theories imply that objects instantiate incompatible temporal properties. And Putnam (1967) and Sider (2001) argue that A-theory is incompatible with Special or General Relativity. I note these objections, but I will leave them aside; these issues have been much discussed elsewhere[19] and they aren't aimed specifically at The Imprint view.

One objection that is specifically directed at The Imprint is that the view makes General Relativity necessarily true; more precisely, for any world in which there's non-gravitational mass-energy, The Imprint requires that there be a curvature in spacetime. Yet, surely this is only a *contingent* truth. We can conceive of a world where there's non-gravitational mass-energy but *no* spacetime curvature at all. The contingency of this matter, after all, is made obvious by the fact that we had to *discover* the connection between the two in the actual world. But I agree with Kripke (1980) that there can be *a posteriori* necessary truths. Even though we had to discover that water is H_2O, it's nevertheless necessarily true that water is H_2O. There are also necessary truths that we can conceive of as false—we can conceive of Goldbach's conjecture turning out

[18] I previously objected to the 'bare objects' view of trackers by saying that such objects are too bare to be located—doesn't an object need matter, or at least need to stand in causal relations to some region, to properly be said to have a location? The supersubstantival view I propose here can be thought of as a version of this bare objects view (empty regions are quite bare). But it gives an appealing answer to the objection: since regions *just are* locations, there's a clear sense in which they are located.

[19] Markosian (1993) responds to Smart's objection; Prior (1967) and Lowe (1987) respond to McTaggart; Craig (2001), Lucas (2008), Forrest (2008) and Zimmerman (2011) respond to challenges from Special and General Relativity.

true, and we can conceive of it turning out false, yet it's either necessarily true or necessarily false. Some even argue (e.g., Shoemaker (1980); Swoyer (1982); Fales (1990)) that *all* laws of nature are necessarily true. So there's room to think that The Imprint's posits are necessarily true as well: spacetime substantivalism is necessarily true (or at least true at all worlds with non-gravitational mass-energy), and it's necessarily true that there's curvature at current and formerly occupied spacetime regions.

One might instead object that The Imprint doesn't get us enough of the change we want since there wouldn't be genuine change in whether spacetime regions exist. But I find a commitment to past regions of spacetime time far less troubling than a commitment to past dinosaurs and tables. This is because the sort of spacetime posited by General Relativity is a highly theoretical one—one that isn't posited as an item of commonsense, but because of its role in accounting for physical phenomena. Even if spatial regions themselves aren't so foreign to commonsense (we do ordinarily talk about space, even *empty* space), regions that warp and bend in the way General Relativity requires *are* very much foreign to commonsense. So it's not the sort of thing that commonsense really tells us about.[20] In any case, it seems that we need *something* to exist in the past to respect the grounding intuition (complete with its ban against cheating). And including empty spacetime regions seems to be the most conservative way of doing so.

I've said that the curvature of spacetime is able to ground past-tensed truths. But is such curvature able to ground the truth that *non-gravitational mass-energy was present at t* for some past time *t*? For consider a world *W* where there are past curved regions identical to the actual world's past regions, yet no past regions of *W* were ever filled. If the curvature in the actual world grounds the fact that there was non-gravitational mass-energy at past time *t*, then the curvature in *W* is sufficient to ground it as well—but that's the wrong result. In response, I'm inclined[21] to say that *W* is impossible. The sort of curvature we find in past regions of space-time *could only* be created by the presence of non-gravitational mass-energy. Without the influence of that mass-energy, there couldn't have been any curvature. (For this reason I'm also inclined to say that there are no future curved regions of spacetime—since such curvature wouldn't be created by non-gravitational mass-energy.) Hence, the properties of spacetime are enough to determine that there was non-gravitational mass-energy.

But is past curvature really discriminating enough to ground specific claims about the past? Perhaps dinosaur-shaped curvature can ground the truth that 'there were dinosaur-shaped object'. But could it really determine that a dinosaur—complete with flesh and bone—existed, rather than the sort of dinosaur replicas that we see at the museum? Or, to use a different example, if there are two spheres of the same size and mass, but one is made of bronze and the other of iron, would such a difference in composition be reflected in the curvature? My suggestion is that it would be. Even tiny particles (including photons[22]) have gravitational effects. So there's room to think that even the composition of objects at such a tiny scale can be determined by the curvature; that is, the structures of copper atoms can be thought to leave different imprints on spacetime than the structures of iron atoms. Such a difference in curvature would be far too minuscule for us to detect. After all, one of the great pieces of evidence for General Relativity came from the observed deflection of light coming from the stars. Einstein predicted that the angle at which the light from stars would hit the surface of the earth would differ when the light

[20] Zimmerman (2011: 200) also gives this sort of reply in defense of his suggestion that there are past regions of spacetime, all of which are empty.
[21] See also Cameron's (2015: ch. 4) for a response.
[22] This is why a kugelblitz (a black hole created solely out of photons) can be formed.

passes near the sun. Thus, if we took a picture of the night sky and then took a picture of the sky when the (eclipsed) sun is present, the stars around the sun will appear to have 'shifted' in location compared to the first picture. But the predicted (and observed) shift was an extremely minuscule amount—the comparative locations of the white glow of the star in the two pictures were a difference of less than a millimeter.[23] And if the curvature caused by bodies as massive as the sun is so hard to discover, it's insuperably harder to discover, first, that tiny atoms create such curvature and, second, that different atoms create different curvatures. Despite such observational barriers, the proposal is that these particles do leave unique imprints.

We might still wonder how we could differentiate the imprints of elementary particles. Even if different atoms leave differently shaped imprints by virtue of having parts that are arranged differently, elementary particles supposedly don't have component parts. So wouldn't they all leave the same dent in spacetime? Not necessarily. For one thing, they will leave different sizes of dents depending on their mass. For a second, the relative locations of those dents will differ—as Lewis says "even if positive and negative charge were exactly alike in their nomological roles, it would still be true that negative charge is found in the outlying parts of atoms hereabouts, and positive charge is found in the central parts." (2009: 207)

But consider electrons and positrons (electron antiparticles). According to Dirac's equation, positrons have all the same properties as electrons, but the opposite charge. So the size of the dent created by an electron supposedly wouldn't differ from that of a positron and so couldn't be used to ground truths about whether there was an electron or positron. And in an antimatter atom, the positive charge will be found on the outside of the atom rather than its center—so the locations of the dents won't do either.

I have three points in response here. The first is empirical. Though very little is known about antimatter apart from what Dirac's equation tells us and observational confirmations of their existence, there are observable violations of Dirac's equation (known as CP violation). Furthermore, scientists expect there to be such violations in order to explain why there's more matter in the universe than antimatter. If such asymmetries exist between *every* kind of particle and its antiparticle the dents left by them might also be differentiable.

The second point is that we can invoke objects in the *present* to do the grounding work. How can we determine, by looking at the dent in spacetime at some past time *t*, that there was an electron there rather than a positron? Perhaps we can point out, first, that at the present time there is an electron, and second, that the dent in spacetime at *t* is connected by a "trail" through spacetime to the electron. Hence, it must have been the electron that caused the dent![24]

The third, and perhaps most important, point is that there is good reason to think that elementary particles have distinguishing categorical properties—paradigm examples of categorical properties being size, shape and structure. Negative charge, for example, is a dispositional property that says what the object would do in certain circumstances—it would repel other negatively charged particles and attract positively charged ones. But surely there must be some categorical property of negatively charged objects that explains why they would behave in such a way; if a particle isn't currently repelling negatively charged particles, what explains

[23] See Will (2006: section 3.4.1).

[24] This response, however, might not always work. When an electron and positron meet, the two are annihilated, leaving radiation behind. The resulting radiation—together with the past curvature—could indicate, first, that the radiation was the result of electron-positron annihilation and, second, that one of the particles came from the west and the other from the east. But the manner of the radiation's dispersal might not be enough to indicate *which* particle came from the east.

the fact that it *would* do so? (See especially Armstrong (1997: 80) and Psillos (2006) for further defense.) And it's natural for those who think that past-tensed truths must be grounded in the existence of past objects to also think dispositional properties must be grounded in categorical properties (as Sider (2001: 40) does). If this is right, then there must also be a categorical difference between positrons and electrons. And we might expect that this categorical difference is detectable in the imprints of the particles.

Doesn't this last point conflict with our current physics, which tells us that fundamental particles are point-like and structureless? Neil Williams (2009; 2011) agrees that there is good physical evidence that elementary particles don't have component parts. But he points out that the very methodology of scientific practice prevents us from discovering whether or not the particles *themselves* (as opposed to putative parts of particles) exhibit a difference in categorical properties. That very methodology requires that we describe particles in dispositional terms since we only manage to observe particles indirectly—in terms of how they react in various circumstances. So we can plausibly hold that there are categorical differences between particles.

Notice that the 'dispositional properties are grounded in categorical properties' response makes The Imprint view closely aligned with what Dennis Lehmkuhl (forthcoming) calls "radical supersubstantivalism". This is the view that spacetime is the only substance and that it only has geometrical and topological properties and structures—all other properties, like mass and color, are reducible to them. (See Wheeler (1962), Wesson (1999), Butterfield (2005) and Bilson-Thompson *et al* (2007) for some contributions to the radical supersubstantivalist research programme.) And the response *commits* The Imprint view to radical supersubstantivalism if we adopt two further claims: (a) supersubstantivalism is true and (b) geometrical and topological properties are the only categorical properties. We saw that claim (a) helps The Imprint view deal with past-tensed singular propositions (though other avenues are also available). And claim (b) is also appealing—though we might wonder whether properties like 'being filled' (in the supersubstantivalist's sense, which doesn't imply that there is some object distinct from the region that fills it) or 'being solid' are counter-examples.

This completes my response to the electron-positron example. We might still worry, however, that various strange phenomena that arise at the quantum level could raise other sorts of difficulties for The Imprint view. Perhaps the strategies I have sketched above are useful for grounding past-tensed truths concerning quantum oddities, or perhaps they are not. But the exploration and evaluation of such issues is better left to those more qualified than myself.

There is, however, a looming issue about quantum gravity. There's a real chance that further research will reveal that gravity is best understood as a force mediated by graviton particles rather than curvature in spacetime. If so, wouldn't The Imprint be falsified?[25] One response is to say that it would not be. Even if science were to tell us that there is no curvature for any time when that time is present, there would still be room to think that there is curvature at that time when it is *past*. In other words, we could hold that the presence of curvature is never simultaneous with the presence of matter—the curvature at temporal slice t of the spacetime block only appears once the matter has moved past t. But such a response isn't too attractive; it's hard to see why the curvature should appear in past regions if the curvature fails to appear simultaneously with the matter. Alternatively, we might respond that even if such a discovery were to falsify The Imprint, this isn't a mark against The Imprint (at least not in our current situation where it hasn't yet been falsified). Karl Popper (1959) claims that falsifiability is in fact

[25] Alternatively, we might take it as a mark against The Imprint that it counts the graviton theory as necessarily false (though The Imprint theorist will treat the graviton theory as akin to other *a posteriori* necessary falsehoods).

a *virtue* of theories. Of course we should reject views that are falsified; but merely being falsifi*able* is a trait that we should want our theories to possess.

5 Conclusion

I have argued that we should think of time as a sort of four-dimensional block on which only one temporal slice of it has non-gravitational mass-energy. All the earlier slices are empty regions that have curvature that are the 'imprints' of the non-gravitational mass-energy that was there. Unlike The Block, The Growing Block and The Spotlight views, The Imprint view does a better job of capturing the intuition that there is genuine change. And unlike Presentism, the view has more resources to ground past-tensed truths in a non-cheating way. I have not tried to argue conclusively that such curvature in time can do all the necessary grounding work. But I hope to have said enough to show that the prospects are promising.

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