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No Time for (No) Change

Abstract

The paper provides an overview of the main metaphysical theories of persistence—that is, of three and four-dimensionalism, as applied to a relativistic setting. It then addresses and undermines one of the most powerful objections against one of those views—i.e., four-dimensionalism. That objection is labeled the No-Change objection in the literature and has it that four-dimensionalism abolishes genuine change. Finally, building on the case against the No-Change objection, I contend there is some pressure to abandon the widespread assumption that change requires reference to distinct earlier and later times, let alone the passage of time.

The aim of this paper is threefold. First, I provide an overview of theories of the metaphysics of persistence in a relativistic setting.¹ Then, I offer a new discussion of the so-called “No-Change objection”,²—which is considered one of the most powerful objections against a particular metaphysics of persistence, i.e., four-dimensionalism, and undermine it. Finally, building on my case against the No-Change objection, I contend there is some pressure to abandon a widespread intuition and widely held philosophical thesis according to which genuine change requires reference to two distinct times, if not its passage. It should already be clear from my plan that the discussion of the No-Change argument plays a twofold role. On the one hand, it is supposed to provide a way to resist one of the objections that has been considered, and still to this day is considered³—for better or worse—one of the most significant objections against four-dimensionalism. On the other hand, it paves the way to address some crucial metaphysical questions about the relation between time and change⁴.

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1 Henceforth, by *Relativity theory* I will mean the disjunction of Special Theory of Relativity (STR) and General Theory of Relativity (GTR).

2 The name is from Sider (2001, 212–216).

3 (see §3)

4 (see §4)

I should note from the start that some of my arguments will crucially depend upon relativistic considerations and cannot be translated in any straightforward way into a more classical setting. Also, they rely on what I shall call the *space-time conception of time*, and although such a conception does not directly require Relativity theory, it seems to be far more palatable once the latter is accepted. If so, my arguments can also be read as a contribution to the debate about whether relativistic physics favors some metaphysics of persistence over some others.^{5,6} The plan is as follows. In § 1 I start with a brief introduction about some general assumptions at work in the paper. In § 2 I provide a formulation of different metaphysical theses about persistence in relativistic spacetimes. I then sketch in § 3 the so-called “puzzle of change” and its solutions, and I show how the four-dimensionalist account is allegedly vulnerable to some variants of the No-Change objection, which I reject. In the conclusion of that section I put forward what I take to be the most interesting variant of the No-Change argument. The final section, § 4, is dedicated to undermining such a variant and to offering a general suggestion about change and its relation to time. Once again, the rebuttal of the last variant of the No-Change argument is not only interesting in itself, but also for its wide-ranging consequences.

1 Space, Time, and Spacetime

In this section I lay down some general assumptions I will rely upon in what follows. They are *assumptions* in that I will not argue for them in this paper. However, this does not mean they cannot be argued for. In fact, they have been extensively argued for in the literature.⁷

The first general assumption concerns the very *talk of time* in a relativistic setting. Following Lockwood (2005, Ch. 3), Sattig (2006, Ch. 2; Ch. 8, § 1), Skow (2015; Ch. 2), and Gilmore, Costa and Calosi (2016, § 1) we can distinguish two very general conceptions of time. I shall label them the *spacetime conception* of time and the *classical conception* of time. To give but a first intuitive characterization, according to the spacetime conception of time we inhabit a single four-dimensional manifold–spacetime, and time is just an aspect-for lack of a better word-of this more fundamental four-dimensional entity. *Contra* this, the classical

5 The literature on this topic is rapidly growing. To mention just a few, see Balashov (1999); Giberson and Pooley (2006); Gilmore (2006); Balashov (2010); Davidson (2014); Balashov (2014a); Balashov (2014b); Calosi (2015) and Sattig (2015).

6 But I will not press this point here.

7 For an introduction to the relevant arguments, see, e.g., Gilmore, Costa and Calosi (2016).

conception of time has it that we literally inhabit two different manifolds: a three-dimensional spatial manifold and a one-dimensional temporal one.⁸

A little more precisely, according to the spacetime conception of time there is only a four-dimensional spatiotemporal manifold; instants or intervals of time, on the one hand, and regions of space on the other, are simply spacetime regions of different sorts that share some constituents (that is, some spatiotemporal points).⁹ By contrast, according to the classical conception of time, time is a one-dimensional manifold, and it is completely distinct from a three-dimensional spatial manifold: the two fail to share any constituents.

Though the spacetime conception of time can also be held in a classical setting, I will simply assume that it is the most natural choice once some features of Relativity are taken into account.¹⁰ As I already mentioned, I will not argue for this claim; as a piece of evidence though, I will simply quote some passages that point in this direction. Arguably the most famous reference goes back to Minkowski (1908): “Henceforth space by itself and time by itself are doomed to fade away into mere shadows and only a union of these two will preserve an independent reality” (Minkowski 1952, 75). The same spirit is vindicated in the following, more recent excerpts: “Space and time are just different ways in which the same real thing (spacetime) appears from a given perspective” (Lange 2002, 220); “There is no one-dimensional time distinct from three-dimensional space but rather a four-dimensional spacetime of which time is merely an aspect” (Sattig 2006, 1); “I assume a spacetime framework according to which the notion of a time is not fundamental, but rather is to be defined in terms of the notion of a region of spacetime [...] region of spacetime are ontologically prior to times” (McDaniel 2014, 15). All of these passages suggest that spacetime is the *fundamental* entity in Relativity theory, so that in order to take Relativity seriously we should refer to spacetime regions rather than to spatial regions or temporal intervals.¹¹

8 Skow (2015) calls them *4D view* and *3+1 view*. Gilmore, Costa and Calosi (2016) calls them *unitism* and *separatism*. I adopt the terminology in the main text mainly because I will use “4D” for the metaphysics of persistence.

9 *Modulo* Whiteadean worries about the existence of points.

10 It should be noted that this conception can be challenged in certain formulations of Quantum Gravity. See, e.g., Monton (2006).

11 The standard set-theoretic construction of the spacetime manifold is assumed throughout. “According to this view, we inhabit a four-dimensional manifold of spacetime points, where points are mereologically simple and unextended, spacetime *regions* are non-empty sets of points, any such set counts as a region, and one region is a subregion of another iff the first is a subset of the second” (Gilmore 2006, 199). Spacetime regions are thus a model of the so-called (Atomistic) “General Extensional Mereology”; since I will be using mereological notions

The second general assumption concerns *the contents* of the spacetime manifold and spacetime regions. I will assume that the physical content of relativistic physics does not mention (nor does it need to mention) frames of reference. Rather, it is simply given by the contents (of regions) of spacetime, and the latter can be described independently of any reference frames. The most vivid formulation of such a view is given by Gibson and Pooley (2006):

What is wrong with the first¹² [...] (is that) it seeks to attach metaphysical weight to frames of reference that they simply do not carry. Inertial frames of reference [...] are no more than the spatiotemporal analogues of Cartesian coordinate systems [...] But just as no one would attach ontological weight to features of an object that are relative to a choice of Cartesian coordinates, so no one *should* attach significance to properties of objects that are essentially defined in terms of canonical frames of reference. From the physicist's perspective, the content of spacetime is as it is. One can choose to describe this content from the perspective of a particular inertial frame [...] But one can equally well choose to describe the content of spacetime with respect to some frame that is not optimally adapted to the geometric structure of spacetime, or indeed, choose to describe it in some entirely frame independent manner" (Gibson and Pooley 2006, 161–162).¹³

Gibson and Pooley also declare: "It should be clear from our discussion of perdurance that the *wrong* way to relativistically re-construe all this is to *replace reference to moments and times with reference to times of inertial frames*" (Gibson and Pooley 2006, 164). Finally, I will assume that Relativity favors some sort of B-theoretic eternalist metaphysics of time, according to which all spatiotemporal regions of the entire spacetime manifold are ontologically on a par and there is nothing objectively and metaphysically privileged about one such region, called "the present".¹⁴ I take these assumptions to suggest-to say the least-that any metaphysical thesis, insofar as it is meant to seriously engage with the hints coming from Relativity, should replace talk about spatial distances, temporal intervals and frames of reference with talk about spacetime regions of different sorts that build up the entire relativistic spacetime.

to define persisting objects already, I will use mereological notions as opposed to set-theoretic ones, to minimize ideology.

¹² I.e., with the option of relativizing times to reference frames.

¹³ This assumption might be more controversial in the case of Special Relativity. However, it is possible to give a formulation of Special Relativity that is frame-independent as well. See, e.g., Malament (2009).

¹⁴ The literature on this last issue is simply too wide to even be briefly mentioned. For recent, opposing views, see Zimmerman (2011) and Wüthrich (2013) and references therein.

Therefore, in what follows, whenever reference to e.g., temporal facts is explicitly mentioned, an attempt should be made to identify the sort of more fundamental spatiotemporal facts behind them, so to speak.¹⁵ I take this to be a first step towards engaging with a challenge that was raised in Gibson and Pooley (2006, 157). The goal in engaging that challenge would be to *start* with the relativistic world-picture, and then ask how things persist and change according to such a picture.

2 Persistence in Relativistic Spacetimes

In this section, I will provide a rigorous formulation of the main metaphysical theories of persistence¹⁶ in relativistic spacetimes.¹⁷ This formulation takes the lead from the pioneering works of Gilmore (2006; 2008; 2018) and Balashov (2008; 2010),¹⁸ though in certain respects I will depart considerably from them.¹⁹ I will use only two primitive notions-plus first-order plural logic with identity:²⁰ the mereological notion of *parthood* and the locational notion of *exact location*. Gilmore (2018) offers the following intuitive gloss on the latter: “an entity *x* is exactly located at a region *y* if and only if *x* has (or has-at-*y*) exactly the same shape and size as *y* and stands (or stands-at-*y*) in all the same spatial or spatiotemporal relations to other entities as does *y*”.

15 This characterization, though deliberately vague, is sufficient for my aims: it is meant to point out that facts about spacetime are in some sense more fundamental than facts about (respectively) space and time considered separately, without any commitment as to the specific nature of the relation between facts of the three categories. Sattig (2006) mentions *supervenience*, while Skow (2015) seems to suggest some stronger notion of *dependence*—possibly something like the *grounding* relation. For an introduction to this last relation and cognate notions, see Correia and Schnieder (2012); Bliss and Trogon (2014).

16 I will focus on “three-dimensionalism” (or “endurantism”) on the one hand, and “four-dimensionalism” (or “perdurantism”) on the other. I will not discuss the so-called “Stage-View” (or “exdurantism”). See Sider (1996) for a defense.

17 This section is not intended to be exhaustive. Interested readers are referred to Gilmore (2006); Balashov (2010); Calosi and Fano (2015).

18 To be fair, Balashov (2010) mentions frames of reference. His formulation can however be slightly modified to avoid such a reference.

19 My claims will considerably depart from Balashov’s formulation. It does not coincide with Gilmore’s formulation either, especially in the definition of a temporal part. I will require temporal parts to be *proper parts* of four-dimensional objects. This seemingly small difference has significant consequences. Although I cannot enter into details here, see footnotes 27 and 29.

20 From now on double signs such as “*xx*” stand for plural terms (both constants and variables).

For the sake of completeness, let me also mention that in what follows I will assume that parthood is a partial order and obeys the so-called “Weak-Supplementation Principle” (Simons 1987; Varzi 2016) and that the exact location relation obeys two axioms to the effect that everything that is located somewhere in spacetime has an exact location and that composite objects are located where their parts are located.²¹ Such axioms sometimes go under the names of *Exactness* and *Expansivity* in the literature.²²

Before approaching the metaphysics of persistence properly, some mereological notions need to be defined:²³

- (1) x is a *proper part* of y = x is part of y and x is distinct from y .
- (2) x and y *overlap* = there is a z that is part of both x and y .
- (3) x is the *mereological fusion* of the yy = each of the yy is part of x and each part of x overlaps one of the yy .

I will also need to define the notion of an achronal spacetime region—which can be informally understood as the relativistic counterpart of an instantaneous, temporally unextended region—and the notion of a path of an object. To this end, I shall use basic geometrical features of relativistic spacetimes:

- (4) R is an *achronal* region = for any two distinct points p_1 and p_2 in²⁴ R , the vector connecting them is space-like.
- (5) The spacetime region $Path(x)$ is the path of an object x ²⁵ = $Path(x)$ is the mereological fusion of x ’s exact locations.

It is customary to quote Lewis at this point: “Let us say that something persists iff, somehow or other, it exists at various times; this is the neutral word” (Lewis 1986, 202). This can be elegantly captured by (6) below, for (6) entails that the

21 Note that these two axioms are in line with relativistic physics insofar as the notion of spacetime trajectory is relativistically well-defined. This is not so obvious in the quantum mechanical case.

22 See e.g., Casati and Varzi (1999); Parsons (2007). Note that the latter assumes a different primitive notion, that of “weak location”. Strictly speaking, *Exactness* is a *theorem* in a theory of location that takes “exact location” as a primitive. In such theories, it is customary to define the notion of weak location as follows: x is weakly located at R = x is exactly located at R^* and R and R^* overlap. Once this definition is in place, *Exactness* follows. See e.g., Gilmore (2018).

23 In the following, simple signs such as “ x ” will be used as singular variables whereas double signs such as “ xx ” will be used as plural ones.

24 Point p is *in* region R = point p is part of region R .

25 The path of an object is—intuitively—its entire spatiotemporal career.

spatiotemporal career of an object comprises at least two points that are causally separated, i.e., either time-like or light-like separated²⁶ —thereby ensuring that the entity in question exists at different times, as per Lewis' request:

(6) An object x is a persisting object = $Path(x)$ is not achronal

One of the great merits of Gilmore (2006) and Balashov (2010) is that of having clearly stated the difference between what we might call *locational* and what we might call *mereological* persistence. In the former case, conditions for persistence are given in terms of the exact locations of material objects; in the latter, they are given in terms of their mereological structure. When we think in locational terms, (locational) three-dimensional objects are exactly located at achronal, temporally unextended regions, whereas (locational) four-dimensional objects are uniquely exactly located at not-achronal, temporally extended regions.²⁷ This is supposed to capture one way of parsing the pre-analytical intuition that three-dimensional objects are not extended in time, while four-dimensional objects are. This suggests the following definitions:

- (7) An object x is a *locational four-dimensional* object $4D_L(x) = x$ is a persisting object that is uniquely exactly located at its path.
- (8) An object x is a *locational three-dimensional* object $3D_L(x) = x$ is a persisting object that is exactly located at achronal spacetime regions.

It follows from these definitions and the mereological and locational axioms I assumed that:

- i. four-dimensional objects have a unique exact location-i.e., their paths;
- ii. three-dimensional objects are multi-located at different achronal regions that are proper parts of their paths.

The metaphysical debate about persistence has been traditionally cast as a debate about the mereological structure of persisting objects. In particular, it has most commonly been approached as a debate as to whether persisting objects divide into *temporal parts* or fail to thus divide. To define a temporal part in a relativistic setting, I follow Gibson and Pooley (2006) and first define an *achronal maximal region of another region*. The easiest way to define such a notion is the

²⁶ This ensures that photons count as persisting objects.

²⁷ Note that this is in line with the intuitive gloss I gave for the notion of “exact location”.

following:

- (9) A spacetime region R is a *maximal achronal region* of a spacetime region R^* = (i) R is part of R^* ; (ii) R is an achronal region, (iii) R is not a proper part of any other achronal region that is part of R^* .

Now we can define an achronal temporal part x of y :

- (10) x is an *achronal temporal part* of y = (i) x is a proper part of y ; (ii) x is uniquely exactly located at region R ; (iii) R is a maximal achronal region of $Path(y)$ ²⁸

The general notion of a temporal part can be defined as a mereological fusion of *some* achronal temporal parts:

- (11) x is a temporal part of y = (i) x is a proper part of y ; (ii) x is the mereological fusion of some achronal temporal parts of y .

Note that this definition explicitly requires that temporal parts of 4D-objects-which will be defined below-are *proper parts* of such objects.²⁹ Mereological four and three-dimensional objects are defined, respectively, as follows:

- (12) x is a *mereological four-dimensional object* $4D_M(x) = x$ is a persisting object that is the fusion of its temporal parts.
 (13) x is a *mereological three-dimensional object* $3D_M(x) = x$ is a persisting object that does not divide into temporal parts.

For my purposes here, it will suffice to define (respectively) three and four-dimensional objects as follows:

28 There are a few differences between this definition of a temporal part and others that can be found in the literature, as I already pointed out in footnote 18. Since such differences do not play any crucial role for the arguments I advance in this paper, I will not discuss them. As far as I know, the approach that gets the closest to the one I suggest here can be found in Gibson and Pooley (2006).

29 This immediately undermines Van Inwagen's infamous argument against four-dimensionalism in Van Inwagen (1990), in that the argument crucially depends upon considering a four-dimensional object a temporal part of itself.

- (14) x is a three-dimensional object $3D(x) = x$ is both a locational and a mereological three-dimensional object.
- (15) x is a four-dimensional object $4D(x) = x$ is both a locational and a mereological four-dimensional object.³⁰

Usually, Three and Four-dimensionalism are construed as, respectively, the theses that all persisting objects are three-dimensional and the thesis that all such objects are four-dimensional.

3 The Puzzle of Change and the No-Change Argument

In a nutshell, the so-called puzzle of change arises from the question as to how it is possible for an object to instantiate incompatible properties. A perspicuous formulation of the puzzle was provided in Kurtz (2006, 2).³¹ According to Kurtz, the puzzle consists in a tension between the metaphysical theses she calls—respectively—*Consistency*, *Change* and *Persistence*; such theses are so deeply entrenched as to be hardly negotiable, and yet they seem to be jointly inconsistent. The theses are the following:

- I. Consistency: Nothing can instantiate incompatible properties;
- II. Change: Change involves incompatible properties;
- III. Persistence: Objects persist through change.

The tension is easily seen. If change involves incompatible properties, how can an object persist through change, given that it cannot instantiate incompatible properties? Here is how Lewis phrases the point:

Things somehow persist through time. When they do, they have some of their intrinsic properties temporarily. For instance, shape: sometimes you sit, and then you are bent; sometimes you stand or lie, and then you are straight. How can one and the same thing have two contrary intrinsic properties? (Lewis 2002, 1).

30 These definitions raise an interesting question. Is it possible for a persisting object to be locationally four-dimensional and mereologically three-dimensional? And conversely: is it possible for a persisting object to be locationally three-dimensional and mereologically four-dimensional? For different answers, see Gilmore (2006); Calosi and Fano (2015).

31 A similar presentation is provided in Hinchliff (1996).

Each one of the metaphysics of persistence I considered in § 2 provides a particular answer to the puzzle of change.³² In what follows, let x be a persisting object that changes by instantiating incompatible properties F_1 and F_2 . The *Spatiotemporal solution* has it that spatiotemporal facts mediate the instantiation of incompatible properties. This can be considered the relativistic (or spatiotemporal) counterpart of the more familiar solution offered in a classical setting—i.e., of the one according to which *temporal* (rather than spatiotemporal) facts mediate the instantiation of incompatible properties. Such a solution comes in two variants, that are known as *relativization* and *adverbialism*, respectively. I will present the more familiar temporal variant first as a paradigmatic example.

According to the relativization strategy—advocated, e.g., by Mellor (1998, 89–93)— x has F_1 at t_1 , that is, x bears the F_1 relation to t_1 , while it has F_2 at t_2 , that is, x bears the F_2 relation to t_2 . On the other hand, according to *adverbialism*—defended, among others, in Lowe (1988) and Haslanger (1989)³³— x has t_1 -ly F_1 and has t_2 -ly F_2 , where t_1 -ly and t_2 -ly act as adverbial modifiers.³⁴ This distinction within the spatiotemporal camp does not matter for the purpose of this paper. Hence, I will not get into the question whether the solution I am considering should be advanced in line with the relativization strategy or in line with adverbialism. More generally, according to the *Spatiotemporal solution*:

- (16) For any persisting object x and any two incompatible properties F_1 and F_2 , if x changes from having F_1 to having F_2 , then there are distinct spacetime regions R_1 and R_2 which are parts of $Path(x)$, such that x has property F_1 -at- R_1 and property F_2 -at- R_2 , where “having F -at- R ”, is supposed to be neutral with respect to relativization and adverbialism.

³² These solutions presuppose a certain metaphysics of time—*that is assumed here* as explicitly claimed in § 1—namely eternalism, according to which there is no ontological distinction between the tenses. Hinchliffe (1996) criticizes this very point, i.e., the endorsement of an eternalist metaphysics of time. He claims that presentism, roughly the view that, strictly speaking, only the present is real provides a better solution to the puzzle of change. I will grant such a point. However, the tenability of a presentist metaphysics of time in a relativistic world is problematic to say the least. The literature on the subject is literally too vast to be mentioned. See also 13.

³³ See Lewis (2002) for an argument to the effect that the two variants are not as different as they may seem to be.

³⁴ This formulation is an example of the classic “temporal variant” insofar as *temporal instants* mediate the instantiation of properties. In a spatiotemporal setting, temporal instants will be replaced by *spacetime regions*, as in (16).

Gibson and Pooley (2006) provide the more straightforward example of the spatiotemporal solution in a relativistic setting.³⁵ This solution is advocated by three-dimensionalists. A notable difference between the temporal and spatiotemporal variant is that the latter seems more defective, at least in the formulation I have given at first; for it does not mention *which spacetime regions mediate the instantiation of properties*. I will engage with this issue again in due time. The rival account is universally known as the *Temporal Parts solution*:

- (17) For any persisting object x and any two incompatible properties F_1 and F_2 , if x changes from having F_1 to having F_2 , then there are two distinct temporal parts y_1 and y_2 of x , exactly located at distinct spacetime regions R_1 and R_2 which are part of $Path(x)$, such that y_1 has F_1 and y_2 has F_2 .

According to such a solution, a persisting object changes *vicariously* by having two distinct temporal parts that instantiate, respectively, one of the relevant (mutually) incompatible properties *simpliciter*. The passage from the temporal to the spatiotemporal context is less dramatic in the case of the *Temporal Parts* solution. For, in effect, this passage has been already addressed in the definition of the very notion of a temporal part. Needless to say, this is the solution that four-dimensionalists prefer. One of the most common objections against four-dimensionalism focuses exactly on the *Temporal Part* solution to the puzzle of change. Sider (2001, 212–216) calls such an objection the “*No-Change*” argument.³⁶ The point can be traced back at least to McTaggart (1927), but we can find classic variations on such an argument in Geach (1972, 304), Lombard (1986, 108), Simons (1987, 135–137), Mellor (1998, 89–90).

Before properly engaging with the argument, let me highlight (albeit briefly) its significance.³⁷ The argument is not confined to the classic formulations presented above. It is continuously discussed nowadays—see, among others, Kurtz (2006), Hinchliff (2006), Hales and Johnson (2007), Hawley (2015, 10–11), and Skow (2015, 24). Wasserman (2006, 52) calls it “the most familiar objection to the temporal parts approach”. It is not only discussed, but also *endorsed* in,

³⁵ They focus on particular properties, namely shape properties.

³⁶ For the sake of precision, this paper focuses only on that part of the No-Change argument that Sider calls *the argument from spatial analogy*.

³⁷ I will simply grant that A-theorists could advance a more radical argument to the effect that the *Temporal Parts* solution abolishes genuine change, for in their view the alleged “dynamical aspect” of change would be lost in such an account. On the other hand, it should be noted that, beginning with Sider himself, the No-Change argument is not considered as an argument against the B-theory of time *per se*, but rather as one against four-dimensionalism.

e.g., Oderberg (2004) and Alai (2016). Leading figures that have recently endorsed the argument include McCall and Lowe (2009)³⁸ and Simons (2014).³⁹ This should be enough to call for its thorough assessment. On top of that, as I pointed out in the introduction, the discussion of the No-Change argument has an *indirect significance*, so to speak, in that it will be pivotal to address some metaphysically crucial relations between time, spacetime and change in § 4. In that section, I will suggest that relativistic physics already contained the seeds of a view according to which reference to distinct earlier and later times is not necessary for change.

In discussing the argument, it will be useful to take the lead from a passage of Geach (1972) that conveys several points that I will discuss in due course. To quote Geach at length:

The view in which time is merely a fourth dimension in which things extend is in any event quite untenable. On this view the variation of a poker's temperature with time would simply mean that there were different temperatures at different positions along the poker's time axis. But this, as Mc Taggart remarked, would be no more a change in temperature than a variation of temperature along the poker's length would be [...] We thus have a view that really abolishes change, by reducing change to a mere variation of attributes between different parts of a whole (Geach 1972, 304).

From these words we can extract a quick, preliminary, deliberately vague, formulation of the No-Change argument:

(P₁) Spatial variation is not genuine change

38 “Without enduring objects, there is no such thing as motion. A simulacrum of motion can be created by filming the two hands coming together and rapidly projecting the stationary images on the wall. In this case nothing moves” (McCall and Lowe 2009, 279). Though McCall and Lowe focus on motion, it is clear that their worry is much more general and extends to any kind of change.

39 “We standardly regard a continuant which has one property at one time and another property incompatible with the first, at a later time, as *changing* in this regard. We also standardly consider an occurrent which varies across its different times as precisely *not* changing, because the variation attaches to different (temporal) parts of the whole, not to the whole thing. So, a party which starts quietly and gets louder does not change in the literal sense, whereas a person who is dark-haired at twenty and white-haired at seventy does literally change. Proponents of occurrents as the sole inhabitants of spatiotemporal nature often try to hijack the term “change” to cover variation, but I agree with Geach and Dretske that we should resist such attempts. We do not say that the variation among the parts of a river which is fast-flowing at its source and sluggish at its mouth constitutes a change, but a spatial or geographical variation” (Simons 2014, 66–67).

- (P₂) The Temporal Part solution offers an account of change that is completely analogous to spatial variation^{40, 41}
- (C) The Temporal Part solution yields no genuine change (from P₁, P₂)

The argument, when so loosely and vaguely phrased, does not have much bite. It can be simply answered, it seems, by claiming that it is unclear why the analogy between spatial variation and change should be thought of as problematic in the first place. Premise P₁ is in fact completely un-argued for. As such, we could simply counter it without an argument, by pointing out, e.g., some cases in which we do seem to use “change language” in the case of spatial variation. Sider (2001) mentions, for instance, the case of a road that *becomes*—a typical example of “change language”—narrow. In alternative, think of a river that—we would say—“gets” deeper and deeper.

This would undermine P₁. Yet the No-Change argument can be given a much stronger formulation. In fact, I will myself propose two different stronger versions. They are stronger in that P₁ is not left un-argued, but rather is supported by two different arguments. I will start from the following passage of Mellor:

“Change, obviously if vaguely, is something having a property at one time and not at another. More precisely, it has *a thing* having *incompatible properties*, like different temperatures or B-places, *at different B-times*” (Mellor 1998, 70, italics added).⁴²

Three crucial elements are mentioned in the passage just quoted: (i) incompatible properties, (ii) *a thing* having them, and (iii) *different times*. I will simply take for granted that change does indeed require incompatible properties as I have been doing from the beginning. The other two elements can be used to for-

⁴⁰ Compare Sider (2001, 214): “the difference between merely spatial variation and four-dimensional change is vanishingly small”, and Kurtz 2006, 5: “the perdurantist takes change over time to be analogous to change over space”.

⁴¹ Note that all the variants of the No-Change argument that will be explored in the rest of the paper endorse P₂. P₂—which is in fact the core of the objection and is taken almost verbatim from e.g., McTaggart (1927); Geach (1972); Sider (2001) and Simons (2014)—to mention a few—just says that “*change through time is analogous to variation to space*”. Thus, *it should not be confused* with the controversial claim according to which “*time is analogous to space*”—see e.g., Skow (2007). To appreciate that these questions are orthogonal consider yet another case, i.e., the modal case. One can maintain that the modal dimension is *not* analogous to the temporal one—e.g., by holding *modal ersatzism* on the one hand and eternalism on the other—and yet insist that (persistence) and change through both the modal and temporal dimensions are importantly analogous, e.g., by endorsing counterpart theory. For the record, I do not want to commit myself to the endorsement of such theses.

⁴² See also Mellor 1998, 87.

mulate stronger variants of the No-Change argument. The first one strengthens Mellor's notion of *a thing* having incompatible properties-i.e., element (ii)-via the claim that the incompatible properties must be exemplified by the very same thing, where "the very same thing" is understood in terms of *strict numerical identity*. The argument can be formulated as follows:

- (P₃) Exemplification of incompatible properties by the *very same entity* is necessary for change (or, equivalently: if something counts as a change from F_1 to F_2 then we must have: (i) $F_1(x)$, (ii) $F_2(y)$, (iii) $x = y$)⁴³
- (P₄) Exemplification of incompatible properties by the very same entity is not necessary for spatial variation⁴⁴
- (P₅) Spatial variation is not genuine change (from P₃, P₄)
- (P₆) The *Temporal Parts* solution offers an account of change that is completely analogous to spatial variation
- (C) The *Temporal Parts* solution yields no genuine change (from P₅, P₆)

P₅-P₆/C is actually the very same No-Change argument we started with. But this formulation is better in that P₅ ($\equiv$ P₁) is allegedly supported by an argument, so that it will not do to simply challenge it, as I have done previously, without thereby challenging the argument supporting it. In other words. Just pointing out spatial analogues like the river and the road in which we invoke change language to describe the situation at hand is not enough. One has to undermine either P₃ or P₄. This is exactly what I will do.

The problem with such an argument is that, at least in this explicit formulation, it simply begs the question against four-dimensionalists. P₃ is basically an explicit denial of the *Temporal Parts* solution. Let me expand. It begs the question against four-dimensionalism insofar as it requires that the relation holding between the bearer(s) of incompatible properties should be *numerical identity*, whereas the *Temporal Parts* solution entails that those bearers are *numerically distinct*. No wonder the conclusion follows. So, either there is a non-question begging argument in favor of P₃ or the four-dimensionalist can simply discard it. And as a matter of fact, she should.⁴⁵

⁴³ Alai (2016) explicitly endorses such a reconstruction.

⁴⁴ As a matter of fact, it is even *ruled out* by spatial variation as we understood it so far.

⁴⁵ Someone might try to resist the question-begging charge by insisting that even four-dimensionalists can say that the *very same* four-dimensional object instantiates "being F_1 -at- R_1 " and "being- F_2 -at- R_2 ". Now, if being F_1 -at- R_1 and being- F_2 -at- R_2 are taken to be monadic properties it might be argued that these are not incompatible properties. The incompatible properties are F_1 and F_2 *simpliciter*. I will put forward the same argument when considering another possible

Actually, there might be another way for four-dimensionalists to resist the argument without charging three-dimensionalists of question-begging. She could remind her opponent that she could adopt a version of *de-re* spatiotemporal predication that mimics the counterpart-theoretic account of *de-re* modal predication. Some background details are in order here: Kripke (1972) famously puts forward what has become famous in the literature as the “Humphrey objection” against counterpart theory, as presented, e.g., in Lewis (1968). According to the counterpart analysis of *de-re* modal talk a proposition such as “Humphrey could have won the election” is true iff there is a possible world in which a counterpart of Humphrey (exists and) did win the election. Kripke’s complaint is that while Hubert Humphrey cares very much that he might have won the 1968 U.S. presidential election, he “could not care less whether someone else, no matter how much resembling him, would have been victorious in another possible world” (1972, 45). Lewis (1986, 196) has a simple and effective answer, though: according to counterpart theory, the modal property of possibly winning is the property of having a counterpart who wins. Humphrey has a counterpart that wins, and so *Humphrey himself* has the right modal property, exactly because he has the right counterpart.

Now, four-dimensionalists might want to say that according to their metaphysics the spatiotemporal property of being F_i at, say, region R_i is the property of having a temporal part exactly located at R_i that is F_i (the same goes, *mutatis mutandis*, for F_2 and R_2). The *four-dimensional object itself* has the right spatiotemporal properties *exactly because* it has the right temporal parts. If this analysis is found compelling, the four-dimensionalist could then insist that the *Temporal Parts* solution and spatial variation are *not* analogous in a relevant respect: the four-dimensional object itself has the right sort of spatiotemporal properties whereas this is not so in the case of spatial variation. Hence, the No-Change objection loses its force.

reply on behalf of the four-dimensionalist. Alternatively, it might be insisted that the *very same* four-dimensional object bears the relation F_1 to R_1 and the relation F_2 to R_2 . I am not sure whether four-dimensionalists would have any reason to say that, and there is at least one reason why they should not. One of the (alleged) advantage of the *Temporal Parts* solution is that it allows F_1 and F_2 to be *truly monadic properties*. In the end, this is what the argument from *temporary intrinsics* is crucially about. Hence what the four-dimensionalist should say is that, at best, the same four-dimensional object bears the relation F_1^* at R_1 and F_2^* at R_2 . And it bears those relations *because* it has distinct temporal parts that instantiate F_1 and F_2 . The point remains that the truly incompatible monadic properties are F_1 and F_2 , and these are had by *numerically distinct* temporal parts of the four-dimensional object.

This response has some appeal. Yet it should be noted that the argument appeals to spatiotemporal properties of “being F_1 at R_1 ” and “being F_2 at R_2 ”, rather than F_1 and F_2 *simpliciter*. And it might be argued that the spatiotemporal properties are not incompatible after all. Whatever the fate of this *de-re* spatiotemporal predication, it remains the fact that the very formulation of the previous version of the No-change argument, begs the question against the four-dimensionalist. In the light of this, we can safely conclude that the three-dimensionalist has failed so far in formulating a threatening variant of the No-Change objection.

(Un)fortunately, this is not the end of the story. For yet another variant of the No-Change argument can be given by focusing on element (iii) from Mellor’s passage, namely the reference to *distinct* times. This is, as far as I can see, the most interesting version of the No-Change objection and the one that has the most wide-ranging implications. I will therefore conclude this section by spelling out such a variant in some detail.

We seem to have a strong pre-theoretical intuition that change requires reference to distinct earlier and later times, if not the passage of time.⁴⁶ The passages from Geach and Mellor I considered explicitly mention that reference. And the relevant examples are legion. One of the most commonly quoted passages that make such a platitude explicit is arguably in Gödel (1949, 558): “Change becomes possible only through the lapse of time”. If so, the following argument can be put forward:

- (P₇) Reference to distinct earlier and later times is necessary for change
- (P₈) Reference to distinct earlier and later times is not necessary for spatial variation
- (P₉) Spatial variation is not genuine change (from P₇, P₈)
- (P₁₀) The *Temporal Parts* solution offers an account of change that is completely analogous to spatial variation
- (C) The *Temporal Parts* solution yields no genuine change (from P₉, P₁₀)

4 Spatiotemporal Change

This section contains a thorough discussion of the argument I just presented and of its metaphysical consequences. What has been said about the overall dialectic of the argument P₃-P₆/C applies here as well. I will eventually argue that both

⁴⁶ Presentists, or A-theorists more generally, would probably disagree in that they will have an account of change in terms of tense operators that does not refer to distinct earlier and later times. However, as it is explicit in §1, this paper assumes some sort of B-theoretic framework.

three and four-dimensionalists should give up on P_7 and on our strong pre-theoretical intuition about the need to refer to distinct times in order to have genuine change. Or, at least, they should seriously consider this option. But before that, I will give another argument on behalf of the four-dimensionalist; the argument consists in rejecting P_{10} *in this precise context*. I will cast the argument in purely temporal terms first. This contravenes both the letter and the spirit of the conclusion of §1. Yet this needs to be done, for the sake of perspicuity.

As I just pointed out, when the No-Change argument is presented as I did in P_7 - P_{10}/C the four-dimensionalist could, and should, simply deny P_{10} at first. The argument, so phrased, is essentially an argument by analogy. But consider the necessary requirement for change presented in P_7 i.e., the reference to distinct earlier and later times. Spatial variation and the *Temporal Parts* solution are *not analogous in that respect*. While it is true that reference to distinct and later times is not necessary for spatial variation, reference to *two distinct temporal parts* is necessary when providing a *Temporal Parts* solution to the puzzle of change. And this reference is an *indirect reference to two distinct and later times*. To appreciate this point, recall one of the most influential definitions of temporal part in the literature—the one in Sider (2001, 59). That definition is cast in purely temporal terms: x is an (instantaneous) temporal part of y at $t =$ (i) x exists at t but *only* at t ; (ii) x is part of y at t ; (iii) x overlaps everything that is part of y at t . It follows immediately from clause (i)—an uncontroversial one—that reference to two distinct temporal parts entails a reference to two distinct times. This should be enough to warrant the rejection of P_{10} on the part of the four-dimensionalist.

This argument is however not immediately available to those who want to take the hints from Relativity at face value and thus aim to talk about *spatiotemporal* facts of different sorts. In this case, the spatiotemporal facts behind the temporal facts mentioned either explicitly or implicitly in the previous argument should be made clear. First of all (and naturally enough), we should replace the definition of a temporal part in the argument with the one given in (11), that mentions solely spacetime regions that are the exact locations of those temporal parts. But what about the requirement mentioned in P_7 / P_8 — i.e., the *reference to two distinct times*? Call it the “Distinct Times Requirement”, DTR. This leads to the following DTR-related question (DTRQ):

DTRQ: What are the spatiotemporal facts behind DTR?

The problem of spelling out a precise answer to DTRQ constitutes the main driving force behind the arguments in this section. Before getting into details I shall just give the bare skeleton of the overall argument. I suggest that there are at least two ways to answer DTRQ, which I shall label *Weak DTR* and *Strong DTR*

answers. I shall argue that (i) if the *Weak DTR* answer is endorsed then there is no No-Change objection against four-dimensionalism and, (ii) if the *Strong DTR* answer is endorsed, then the Three-dimensionalist is in no better predicament than the Four-dimensionalist, because premise P_7 of the No-Change argument above fails in both of their metaphysical pictures, respectively. This is enough to show that there is no No-Change problem that troubles the four-dimensionalist *alone*. The argument in (ii) suggests a general problem for persistence theories. Building on my case against the No-Change argument, I will then set forth yet another argument for the claim that there is indeed some pressure to abandon P_7 anyway, thus accepting a metaphysics of change that does not require reference to distinct times. This, I contend, is a suggestion that should be explored further-and that, I suspect, deserves an independent scrutiny.

To get into the dialectic I just sketched, consider first, e.g., two distinct achronal temporal parts x_1 and x_2 of an object y , that are exactly located at maximal subregions of y 's path-i.e., R_1 and R_2 respectively. A weak answer to DTRQ has it that the spatiotemporal facts behind DTR are the ones captured in the following claim, that, as I said, I label WEAK DTR:

- (18) There exist two points p_1 in R_1 and p_2 in R_2 such that the vector connecting them is causal, i.e., time-like or null.⁴⁷

In other words, according to WEAK DTR the existence of any two causally separated points on R_1 and R_2 is enough to ensure a reference to distinct and later times. It can be easily seen that if (18) *does* provide a satisfactory answer to DTRQ, it follows from the definitions I provided that reference to distinct times is *entailed* by the reference to two distinct temporal parts. This simply follows from the fact that distinct temporal parts are exactly located at distinct maximal subregions of a persisting object's path. Thus, a *spatiotemporal/relativistic friendly* variant of the argument I started with in this section is *available* to four-dimensionalists. They could-and simply should-reject P_{10} . So, in the end, there is no No-Change argument with *Weak DTR*.

The problem with this reply is that (18) is far too weak to claim rights to be an adequate answer to DTRQ. Or so should the three-dimensionalist contend at first. That answer, she should go on, should be much stronger. In fact, it should

⁴⁷ Those who wish to restrict their attention to material objects and want to claim that only fermions can be constituents of material objects, could replace causal with time-like. A photon, whose path is such that every two points in it are null-separated, is a boson, and thus will not count as a constituent of any material object given this account.

be something like the following, which, for obvious reasons, I label Strong DTR:

- (19) *For every point p_1 in R_1 there is a point p_2 in R_2 such that the vector connecting them is causal.*⁴⁸

Given STRONG DTR, the right way to ensure a reference to distinct and later times is to claim that for *every point* in R_1 there is at least one point on R_2 that is causally separated from it. Clearly enough, (19) entails (18), but the converse does not hold. This is why (19) is much stronger. Why does this answer to DTRQ give the three-dimensionalist an advantage? The reason is that nothing in the definitions we have given so far guarantees that (19) is met by different exact locations of different temporal parts of four-dimensional objects. For in effect, exact locations of temporal parts can overlap, and overlap entails the failure of (19).

Let us see the point in some details. Once again, consider the previous case, that is, consider *two distinct achronal temporal parts* x_1 and x_2 of y , that are exactly located at maximal subregions of y 's path, namely R_1 and R_2 , and suppose, furthermore, that R_1 and R_2 *do overlap*. Since they overlap, there is at least a point—call it p , that is part of both. Both R_1 and R_2 are achronal regions by definition of an achronal temporal part. Thus, in particular, for R_2 we will have that:

- (20) For every two distinct points p, p_2 in R_2 the vector connecting them is space-like.

This holds for p_1 as well, which is, recall, part of *both* R_1 and R_2 . This just means that there is at least a point in R_1 , namely p_1 that is space-like separated from every other point in R_2 . Hence, if (20) holds, then (19) fails. And if (19) is the right answer to DTRQ, then three-dimensionalists have indeed a No-Change argument against four-dimensionalism. This is a fairly interesting argument indeed. For it crucially depends on the fact that exact locations of *achronal temporal parts overlap*. This happens only in the relativistic case. In fact, in the classical case disjointness of distinct instantaneous temporal parts is guaranteed by, e.g., clause (i) in Sider's definition of temporal part above. Thus, if successful, the argument would give three-dimensionalism a truly relativistic argument against four-dimensionalism, contrary to the widespread agreement on the idea

⁴⁸ See the previous footnote.

that relativistic physics, if it does not support directly, at least favors a four-dimensional metaphysics.⁴⁹

But, once again, this is not the end of the story. In fact, in the following I shall argue that if (19) is the right answer to DTRQ then three-dimensionalism has no advantage over four-dimensionalism. As I pointed out, according to the spatiotemporal solution to the puzzle of change that three-dimensionalists prefer, spacetime regions mediate the instantiation of properties. But (16), the rigorous formulation of the *Spatiotemporal solution*, fails to tell us *which regions these are*. Consider a three-dimensional object. Arbitrariness considerations seem to favor the following *Exact Location Principle*:

- (21) If a three-dimensional object x has property *F-at-R* then x is *exactly located* at R .

In other words: the spacetime regions that mediate the instantiation of properties in the *Spatiotemporal* solution to the puzzle of change are the exact locations of objects. By ‘arbitrariness consideration’ I mean the following. Any choice of R beside one of the exact locations of the three-dimensional object in question seems quite arbitrary.⁵⁰ Consider any other region R_7 distinct from any of the exact locations of the object. Why R_7 instead of, say, a region that has R_7 as a proper part? Why that, instead of a region that is a proper part of R_7 ? I admit that it would be better to have a stronger argument in favor of (21). Yet in the absence of any other plausible candidate, I contend that it is at least the most natural choice. Note that some philosophers that are sympathetic with three-dimensionalism, most notably Gibson and Pooley (2006, 164),⁵¹ endorse such a principle explicitly, albeit with no argument.

Let us go now back to the definition of locational three-dimensional object in § 2, i.e., definition (9). As we saw, it follows from that definition that three-dimensional objects are exactly located at different achronal proper parts of the object’s path. But the definition in itself does not suffice to *single out which ones among the many*. Following Gilmore (2006), this problem is sometimes called in the literature the location question (LQ). Roughly, the question is the following:

⁴⁹ See Balashov (1999); Balashov (2010); Calosi (2015); Gilmore (2006).

⁵⁰ It might be thought that there is a less arbitrary suggestion: the entire spacetime. Yet this would contradict (16).

⁵¹ Here is a relevant quote: “The endurantist should hold that persisting objects do not (in general) instantiate properties *simpliciter*, but rather only *relative to particular spacetime regions*, viz. their locations” (Gibson and Pooley 2006, 164).

LQ: Let x be a persisting object. Which subregions of its path is x exactly located at?

Gilmore (2006) classifies the answers that a three-dimensionalist may provide to LQ as either *overlap* or *non-overlap* answers. According to the latter, exact locations of three-dimensional objects do not overlap one another, whereas according to the former they do. Gilmore convincingly argues that any non-overlap answer would not do in relativistic spacetimes. As a matter of fact, it is virtually universally held that, whatever the answer to LQ might be, it is an overlap answer.⁵² Actually, *overlapping of exact locations* can be regarded as the *hallmark* of the *passage from a classical to a relativistic setting*.

We thus have the following: three-dimensional objects instantiate incompatible properties at their exact locations, and their exact locations can overlap one another. Furthermore, it follows from the definition of a three-dimensional object that these overlapping exact locations are *achronal*. Hence, the situation three-dimensionalists are in *is exactly the same situation* that was supposed to spell trouble for four-dimensionalists in the first place.

A further way to describe the predicament is the following. The No-Change objection against four-dimensionalism that I am considering crucially depends on the fact that different temporal parts that instantiate incompatible properties *overlap one another*. But the same argument would concern the three-dimensionalist as well, insofar as the relevant spacetime regions that mediate the instantiation of incompatible properties—i.e., the exact locations of the three-dimensional object—*overlap one another*.

This leads to the following conclusion: if (19) is the right answer to DTRQ, then the *No-Change argument* $P_7\text{-}P_{10}/C$ *cuts both ways*. Before moving on to sum up the overall dialectic of the No-Change argument, it is worth spending some time on a question that naturally arises in this context. As I already pointed out, the previous argument depends crucially on the fact that exact locations of achronal temporal parts on the one hand, and exact locations of persisting three-dimensional objects on the other, *overlap one another*. Such exact locations turn out to be the major actors—so to speak—in the metaphysics of change. This raises an interesting question—one that I shall label the *possibility of overlapping change question* (POCQ):

⁵² The fact that LQ is such a difficult question for three-dimensionalist to answer, whereas it has a simple answer for four-dimensionalists— x is exactly located at the only improper subregion of its path, namely the path itself—can be taken as a starting point for an argument favoring four-dimensionalism. See Gilmore (2006).

POCQ: Is change possible at overlapping regions?

Now, either change is possible at overlapping regions, or it fails to be; no third possibility is given. In fact, a number of arguments seem to favor the former option. First, if change is *not* possible at overlapping regions, then we should not count relativistic length contraction as a change.⁵³ Yet it does seem to have all the credentials to be counted as one. As a matter of fact, according to an influential, though highly controversial, explanation of relativistic length contraction—the one that is labeled *dynamical explanation* and was advocated in Brown (2005)—the phenomenon is as genuine a change as any one we are familiar with.⁵⁴

One needs not rely on Brown's dynamical explanation. Consider the account of relativistic length-contraction three and four-dimensionalists are likely to give. Three-dimensionalists should claim that they measure different lengths of the same rod at different spacetime regions that are both among the exact locations of the rod. Four-dimensionalists on the other hand should claim that they measure different temporal parts of different lengths of the same four-dimensional rod. Upon inspection, this fits exactly the template for a general case of change.

A second argument to the same end is more general and—I think—the most effective one available. Overlap is not transitive. Now consider, for instance, three distinct exact locations of a three-dimensional object⁵⁵ R_1 , R_2 , R_3 such that R_1 overlaps R_2 , R_2 overlaps R_3 , but R_1 and R_3 do not overlap, as in Fig.1.

If change is not possible between R_1 and R_2 —that is, *x*, *by hypothesis cannot have incompatible properties at R_1 and R_2* —because they overlap, then *x* has the same

53 This is because length contraction can be understood as the difference in the rod's length at different exact locations that *overlap* each other, where “different lengths” are taken to be mutually incompatible properties. This formulation implicitly assumes a three-dimensional ontology, though: four-dimensionalists should give a different account of length contraction, perhaps along the lines of footnote 56. However, the point about overlap and the incompatibility of different length-properties would arise in this context as well.

54 I do not aim to subscribe to Brown's interpretation here. As a matter of fact, I believe that, if possible, we should stick to the so-called “geometric explanation”. The point has no consequence for the sake of the dialectic here though—hence, I will not pursue it any further. For a critique of Brown's approach see Norton (2008).

55 The argument applies, *mutatis mutandis*, to four-dimensional objects as well, as can be seen by just phrasing it in terms of achronal temporal parts exactly located at R_1 , R_2 and R_3 . However, I will focus on the argument as applied to three-dimensional objects because I find it more interesting—in particular, given the way it connects to the answers to LQ that I discuss in this paper. The formulation of the parallel argument that can be raised about four-dimensional objects is left to the reader.

Fig. 1: Change and Overlap.

properties at R_1 and R_2 . The same goes for R_2 and R_3 . But then it follows that x has the same properties at R_1 and at R_3 —regions that do not overlap.⁵⁶ No matter what region(s) we consider, the argument will run the same way. But then, given the assumptions, how can x change properties at all? In other words: suppose change is not possible at overlapping regions. Then, given that overlap is not transitive, it is difficult to see how a three-dimensional object could change at all. Hence, I contend that we should answer PCQ in the affirmative and conclude that change at overlapping regions is indeed possible.

There might be two ways the three-dimensionalist can reply at this point. According to the first, despite the fact that three-dimensional objects are exactly located at overlapping regions, they change only at non-overlapping ones. This would amount to saying that, for any two non-overlapping regions such that the object changes its properties at those regions, there is no other region that overlaps the two that counts as an exact location of that object. But this just means to have a Non-Overlap answer to LQ—an option that was already ruled out. According to the second, it only makes sense to ask whether change occurs along a thing's path when the path is foliated, which requires that every leaf is mereologically disjoint from every other. This is allegedly compatible with saying, e.g., that a 3D thing is exactly located at overlapping regions: for it only says that some of these regions play a role in allowing genuine change.

The problem with this proposal is that the foliation of the path that is doing most of the metaphysical work here is nothing but a reference frame in disguise. Indeed, in non-pathological spacetimes, such a foliation could easily be extended to construct such a frame. To appreciate the point, consider the following.

⁵⁶ This is actually too strong. Change requires incompatible properties (or so I assumed). From the mere hypothesis that change is not possible at overlapping regions it does not follow that x has *all the same properties* at those regions. It might very well have different properties, *albeit not incompatible ones*. This “variation” in properties would however not count as genuine change.

Take the foliation of the path. Embed every mereologically disjoint leaf of that foliation into a globally unextended space-like hypersurface. Then construct an entire family of space-like hypersurfaces that are everywhere parallel to the ones you started with. This family of hypersurfaces counts as a foliation of the entire spacetime. A frame of reference is then obtained by taking a time-like line that is orthogonal to any hypersurface in the global foliation. This construction should be slightly modified if we want to consider non-flat foliations. The problem with this proposal is that it would run against the spirit of the conclusion of §1. Remember Gibson and Pooley's words: "no one *should* attach significance to properties of objects that are essentially defined in terms of canonical frames of reference".⁵⁷

Where does that leave us? We saw that there is an interesting No-Change argument P_7P_{10}/C that builds upon the intuitive claim that "change requires reference to distinct times". I considered several ways to account for such a requirement. If the requirement is accounted for in terms of what I labeled WEAK DTR, then, I argued, four-dimensionalism is not touched by such an argument. Four-dimensionalists should *reject* P_{10} . If it is accounted for in terms of STRONG DTR, then four-dimensionalism does indeed face it, but so does three-dimensionalism. In fact, suppose we do insist that DTR should be understood via STRONG DTR. Now, the following two alternatives present themselves. Either both three-dimensionalists and four-dimensionalists raise up their arms and claim that they cannot account for genuine change, insofar as their metaphysics cannot meet DTR, or they claim that their solution does indeed account for genuine change, but change does not require satisfying DTR. And this amounts to abandon P_7 , for P_7 exactly says that satisfying DTR is necessary to account for genuine change. Indeed, I will just assume that the latter is the way both parties should go. That is to say that, should three and four-dimensionalists be confront-

⁵⁷ If change is possible at overlapping regions, Four-dimensionalists better have overlapping temporal parts. In general, this follows from the very definition of general temporal part, as a sum of achronal ones, given that parthood entails overlap. It is indeed orthodoxy that four-dimensional objects have temporal parts at all maximal slices of their path. Gibson and Pooley write: "[F]rom a relativistic point of view, the assumption that a perduring object has parts at every proper subregion of its worldtube is overwhelmingly natural. Call this the *doctrine of arbitrary spatiotemporal parts*. From a relativistic point of view, it should be a starting point, not something that falls out from a frame-relative generalization of the non-relativistic notion of a temporal part together with unrestricted composition. Indeed, from the relativistic perspective, the existence of specifically 'temporal' parts of an object does not even warrant comment" (Gibson and Pooley 2006, 162). On top of that, the No-Change argument we are considering turns exactly on 4D objects having overlapping temporal parts. If this not granted there is no No-Change argument to begin with.

ed with an argument to the point that STRONG DTR is the right answer to DTRQ, they should simply discard P_7 . I will put forward a sketch of such an argument myself.

Before turning to that, however, I will consider yet another possibility on behalf of three-dimensionalists. For there might be a way to recover the asymmetry about the No-Change argument— i.e., the dialectic situation that made their view, *as opposed to* the Four-dimensionalist's, immune to the argument. The strategy would be that of providing an answer to DTRQ that would be in between WEAK DTR and STRONG DTR. The in-between answer should be such that (i) three-dimensionalists could build a No-Change argument in terms of such an answer, and (ii) that variant of the No-Change argument affects four-dimensionalism alone. I know of no suggestion like this in the literature, so I will just present it as a challenge. It is up to three-dimensionalists to come up with an interesting proposal in this sense. However, it would not be enough for them to provide an in-between answer that suits their aim —i.e., that satisfies (i) and (ii). They also should effectively argue that (iii) such an answer is the best way to spell out the intuitive DTR requirement in P_7 .

Having said that, I will now set forth the final—yet I am afraid not fully fledged—argument of the paper. Answers to DTRQ provide different ways to account for the intuitive claim that change requires reference to two distinct times—i.e., the DTR requirement as mentioned in premise P_7 of the No-Change argument at the end of § 3—in ways that take seriously the suggestions that come from Relativity. Now, in the light of the above, there seem to be two options. On the one hand, it can be insisted that WEAK DTR is the right way to construe the intuition behind DTR. If so, I have argued, both three and four-dimensionalism can stick to the DTR requirement. This is because the No-Change argument is not a threat. On the other hand, it can be insisted that STRONG DTR is the right way to go. But then, I have argued, it turns out that both the metaphysics of persistence I have considered have to abandon P_7 , and hence reject the DTR requirement itself. What horn should one take?

In what follows, I will suggest that there is some pressure to take the second, but I shall admit (once again) that I here simply gesture towards an argument rather than providing a fully-fledged one.

I already argued that change at overlapping regions is possible. Regions R_1 , R_2 can overlap in many different ways. One such way is depicted in Fig. 2 below.⁵⁸ I take it that the intuition behind the DTR requirement is the following: when an object changes *from* having F_1 at t_1 *to* having F_2 at t_2 , t_2 is *later* than t_1 . But sup-

58 The first to bring attention to this point was Gilmore (2006). See also Balashov (2014b).

Fig. 2: Overlap and the Distinct Times Requirement DTR.

pose the persisting object x depicted in Fig. 2 changes from having F_1 at R_1 to having F_2 at R_2 . Can we still hang on to the intuition behind DTR? It seems that we should give a negative answer to *this* question, for there are points p_1 and q_1 on R_1 and points p_2 and q_2 on R_2 such that the time-like vector $p_1 p_2$ is *future* directed, whereas $q_1 q_2$ is *past* directed.⁵⁹ In other words, there are parts of R_1 that *strictly temporally precede* parts of R_2 (e.g., p_1 strictly temporally precedes p_2), whereas there are parts of R_2 that *strictly temporally precede* parts of R_1 (e.g., q_2 strictly precedes p_2).

Given all this, I contend that there is some pressure to claim that WEAK DTR is too weak an answer to DTRQ. For in effect, WEAK DTR is not strong enough to rule out possibilities such as the one depicted in Fig. 2. And, crucially, the intuitive pressure for DTR demands exactly that possibilities such as that one *have to be ruled out*. On the other hand, STRONG DTR does fill the bill. Hence, I argue, we should insist that this is the right answer to DTR—the right way, that is, to capture the DTR requirement.

And this leads to my final point. I have argued that if STRONG DTR is indeed the right answer to DTRQ, it follows that, if both three-dimensionalism and four-dimensionalism have any right to claim that they provide an account of genuine change, then they both have to abandon P_7 and claim *contra* both our pre-theoretic intuitions and a widespread philosophical agreement—that *reference to distinct times is not necessary for change*.

Now, this may sound controversial and counterintuitive. Yet there is no need to get too alarmed. Physicists and philosophers of physics have already set forth

⁵⁹ Admittedly, this restricts our attention to so-called “time-orientable spacetimes”. This is no reason to get alarmed though: for in effect, *temporal orientability* is a very weak condition. Any manifold with a Lorentzian metric that admits the definition of a continuous time-like vector field is, as a matter of fact, time-orientable.

independent suggestions to the effect that change does not require time at all. Earman (2002) suggests that, if we look at the deep structure of GTR, we will indeed find cases of temporally-independent change. Rovelli (2011) develops a formalism for a Quantum theory of gravity in which dependent and independent variables are treated in one and the same way and time does not play any role; such a formalism is nonetheless supposed to account for change.

Huggett and Wüthrich (2013) consider different candidates for theories of Quantum Gravity (Loop Quantum Gravity, String theory and Causal Set-theory) where the fundamental ontology does not include spacetime and yet its items do undergo significant changes. If the arguments in this paper are right, then the seeds of such an intriguing and deep suggestion were already in classical relativistic physics, or better, at the intersection between relativistic physics and (relativistic) metaphysics.

In effect, one might find the arguments from Quantum Gravity more compelling than the ones from classic relativistic physics. I would actually agree. But it is still interesting that something that will become clear only in later theories was somehow already hidden in classical Relativity theory. The conclusion all these considerations points at is that spatiotemporal variation is change enough. And it is all around us.

References

- Alai, Mario (2016), "Lewis, Change and Temporary Intrinsic", in: *Axiomathes* 26 (4), 467–487.
- Balashov, Yuri (1999), "Relativistic Objects", in: *Noûs* 33, 644–662.
- Balashov, Yuri (2008), "Persistence and Multilocation in Spacetime", in: Dennis Dieks (ed.), *The Ontology of Spacetime* (2), Amsterdam, 59–81.
- Balashov, Yuri, (2010), *Persistence and Spacetime*, Oxford.
- Bliss, Ricky/Trogon, Kelly (2014), "Metaphysical Grounding", in: Edward N. Zalta (ed.), *Stanford Encyclopedia of Philosophy*, <http://plato.stanford.edu/entries/grounding>.
- Balashov, Yuri (2014a), "On the Invariance and Intrinsicity of Four-dimensional Shapes in Special Relativity", in: *Analysis* 74 (4), 608–612.
- Balashov, Yuri (2014b), "Relativistic Parts and Places: a Note on Corner Slices and Shrinking Chairs", in: Claudio Calosi/Pierluigi Graziani (eds.), *Mereology and the Sciences*, Berlin, 35–51.
- Brown, Harvey (2005), *Physical Relativity. Space-Time Structure from a Dynamical Perspective*, Oxford.
- Calosi, Calosi/Fano, Vincenzo (2015), "A New Taxonomy of (Relativistic) Persisting Objects", in: *Topoi* 34 (1), 283–294.
- Calosi, Claudio (2015), "The Relativistic Invariance of 4D Shapes", in: *Studies in the History and Philosophy of Modern Physics* 50, 1–4.

- Casati, Roberto/Varzi, Achille (1999), *Parts and Places. The Structure of Spatial Representation*, Cambridge.
- Correia, Fabrice/ Schnieder, Benjamin (eds.) (2012), *Metaphysical Grounding. Understanding the Structure of Reality*, Cambridge.
- Davidson, Matthew (2014), "Special Relativity and the Intrinsicity of Shape", in: *Analysis* 74, 57–58.
- Earman, John (2002), "Thoroughly Modern McTaggart: Or What McTaggart Would Have Said if He Had Read General Relativity", in: *Philosopher's Imprint* 2 (3), 1–28.
- Geach, Peter T. (1972), *Some Problems about Time*, in Geach, Peter T., *Logic Matters*, Oxford, 302–318.
- Gibson, Ian/Pooley, Oliver (2006), "Relativistic Persistence", in: *Philosophical Perspectives* 20. *Metaphysics*, 157–198.
- Gilmore, Cody (2006), "Where in the relativistic World Are We?", in: *Philosophical Perspectives* 23. *Metaphysics*, 199–236.
- Gilmore, Cody (2008), "Persistence and Location in Relativistic Spacetime", in: *Philosophy Compass* 3 (6), 1224–1254.
- Gilmore, Cody (2018), *Location and Mereology*, in Edward N. Zalta (ed.), *Stanford Encyclopedia of Philosophy*, <http://plato.stanford.edu/entries/location-mereology/>
- Gilmore, Cody/Costa, Damiano, Calosi, Claudio (2016), "Relativity and Three Four-Dimensionalisms", in: *Philosophy Compass* 11 (2), 102–120.
- Gödel, Kurt (1949), "A Remark about the Relationship between Relativity Theory and Idealistic Philosophy", in: Paul A. Schlipp (ed.), *Albert Einstein: Philosopher-Scientist*, New York, 557–562.
- Hales, Steven/Johnson, Timothy (2007), "Time for Change", in: *The Southern Journal of Philosophy* 45, 497–513.
- Haslanger, Sally (1989), "Endurance and Temporary Intrinsics", in: *Analysis* 49, 119–125.
- Hawley, Katherine (2015), "Temporal Parts", in: *Stanford Encyclopedia of Philosophy*, <http://plato.stanford.edu/entries/temporal-parts/#3>
- Hinchcliff, Marc (1996), "The Puzzle of Change", in: *Philosophical Perspectives* 10. *Metaphysics*, 119–136.
- Huggett, Nick/Wüthrich, Christian (2013), "Emergent Spacetime and Empirical (In)coherence", in: *Studies in History and Philosophy of Modern Physics* 44, 276–285.
- Kripke, Saul A. (1980), *Naming and Necessity*, Cambridge MA.
- Kurtz, Roxanne M. (2006), "Introduction to Persistence: What's the Problem?", in: Sally Haslanger /Roxanne M. Kurtz (eds.), *Persistence. Contemporary Readings*, Cambridge, 1–26.
- Lange, Marc (2002), *An Introduction to the Philosophy of Physics*, Oxford.
- Lewis, David (1968), "Counterpart Theory and Quantified Modal Logic", in: *Journal of Philosophy* 65, 203–211.
- Lewis, David (1986), *On The Plurality of Worlds*, Oxford.
- Lewis, David (2002), "Tensing the Copula", in: *Mind* 111, 1–13.
- Lockwood, Micheal (2005), *The Labyrinth of Time. Introducing the Universe*, Oxford.
- Lombard, Lawrence B. (1986), *Events. A Metaphysical Study*, London.
- Lowe, Jonathan E. (1988), "The Problem of Intrinsic Change: Rejoinder to Lewis", in: *Analysis* 48 (2), 72–77.

- Malament, David (2009), *Geometry and Spacetime*. <http://www.lps.uci.edu/malament/geometrystpacetimedocs/GST.pdf>
- McCall, Storrs/ Lowe, Jonathan E. (2009), "The Definition of Endurance", in: *Analysis* 69 (2), 277–280.
- McDaniel, Kris (2014), "Parthood is Identity", in: Shieva Kleinschmidt (ed.), *Mereology and Location*, Oxford, 13–32.
- McTaggart, John E. (1927), *The Nature of Existence*, Cambridge University Press: Cambridge.
- Mellor, Hugh D. (1998), *Real Time II*, London.
- Minkowski, Hermann (1952), *Space and Time*, in: Lorentz, Hendrik/Einstein Albert /Minkowski, Hermann/Weyl, Hermann, *The Principle of Relativity*, New York.
- Monton, Bradley (2006), *Presentism and Quantum Gravity*, in: Dieks, Dennis (ed), *The Ontology of Spacetime*, Amsterdam, 263–280.
- Norton, John D. (2008), "Why Constructive Relativity Fails", in: *British Journal for the Philosophy of Science* 59 (4), 821–834.
- Oderberg, David S. (2004), "Temporal Parts and the Possibility of Change", in: *Philosophy and Phenomenological Research* 69 (3), 686–708.
- Parsons, Josh (2004), "Distributional Properties", in: Frank Jackson/Graham Priest (eds.), *Lewisian Themes: the Philosophy of Davis K. Lewis*, Oxford, 173–180.
- Parsons, Josh (2007), *Theories of Locations*, in: *Oxford Studies in Metaphysics* 3, 201–232, Oxford.
- Rovelli, Carlo (2011), "Forget Time", in: *Foundations of Physics* 41, 1475–1490.
- Sattig, Thomas (2006), *The Language and Reality of Time*, Oxford.
- Sattig, Thomas (2015), *The Double Lives of Objects. An Essay in the Metaphysics of the Ordinary World*, Oxford.
- Sider, Theodore (1996), "All the World's a Stage", in: *Australasian Journal of Philosophy* 74, 433–453.
- Sider, Theodore (2001), *Four-Dimensionalism: an Ontology of Persistence and Time*, Oxford.
- Simons, Peter (1987), *Parts. A Study in Ontology*, Oxford.
- Simons, Peter (2014), "Where It's At: Modes of Occupation and Kinds of Occupant", in: Shieva Kleinschmidt (ed.), *Mereology and Location*, Oxford, 59–68.
- Skow, Bradford (2007), "What Makes Time Different From Space", in: *Noûs* 41, 227–252.
- Skow, Bradford (2015), *Objective Becoming*, Oxford.
- Stein, Howard (1968), "On Einstein-Minkowski Spacetime", in: *Journal of Philosophy* 65, 5–23.
- Van Inwagen, Peter (1990), "Four-Dimensional Objects", in: *Noûs* 24, 245–255.
- Varzi, Achille (2016), *Mereology*, in: Edward N. Zalta. E. (ed). *Stanford Encyclopedia of Philosophy*, <http://plato.stanford.edu/entries/mereology/>
- Wasserman, Ryan (2006), "The Problem of Change", in: *Philosophy Compass* 1 (1), 48–57.
- Wüthrich, Christian (2013), "The Fate of Presentism in Modern Physics", in: Roberto Ciuni/Kristie Miller/Giuliano Torrenço (eds.), *New Papers on the Present*, Philosophia Verlag, 91–132.
- Zimmerman, Dain (2011), "Presentism and the Spacetime Manifold", in: Craig Callender (ed.), *Oxford Handbook for the Philosophy of Time*, Oxford, 163–246.