# On Fine's Fragmentalist Interpretation of Special Relativity

Fragmentalism was first introduced by Kit Fine, in his 'Tense and Reality' (2005). According to fragmentalism, reality is an inherently perspectival place that exhibits a type of fragmented structure. The current paper defends the fragmentalist interpretation of the special theory of relativity, which Fine briefly considers in his paper. The characteristic feature of this interpretation is that it makes room for genuine facts regarding simultaneity, duration and length. It will be argued that the sort of scenarios that are standardly taken to motivate a Minkowskian conception of spacetime provide as much motivation for a fragmentalist account of variant properties. One might think that positing such variant properties is a turn for the worse in terms of theoretical virtues because such properties are not involved in physical explanations and hence theoretically redundant. It will be argued that this is not right: if variant properties are instantiated, they will also be involved in straightforward physical explanations, and hence not explanatory danglers. The paper concludes with a discussion of a recent objection offered by Hofweber and Lange in 'Fine's Fragmentalist Interpretation of Special Relativity' (2016). They object that the fragmentalist interpretation is in tension with the right explanation of why the Lorentz transformations hold. I will offer a reply to their objection.

Consider some faraway place in the universe. There is no fact of the matter about what happens there, at the very moment you are reading this sentence. It is a mistake to think that there is an objective course of time through which all current things in the universe are progressing. It is not the case that the things you see have intrinsic mass, or intrinsic shapes or lengths. Similarly, things cannot be classified into those things that are at rest and those that are moving. There are not absolute velocities.

If this story were not being told to us by our physics textbooks, we would regard it as radically revisionist metaphysics. As we all know though, the story simply lists the standardly accepted metaphysical consequences of the special theory of relativity, which are neatly captured in the Minkowskian conception of spacetime.

Certain well-known considerations are involved in the move from the special theory of relativity to the Minkowskian conception of spacetime. These considerations involve metaphysical assumptions, in particular the general assumption that what varies across perspectives must be unreal. This assumption is rejected by a metaphysical framework known as fragmentalism. Fragmentalism is the view that reality is an inherently perspectival place that exhibits a type of fragmented structure. The view was first introduced by Kit Fine (2005), who argues that a fragmentalist version of tense realism is comparatively superior to more standard versions. Fine argues in particular that a fragmentalist view of time is in a position to (1) better account for passage, (2) better account for the relation between tensed talk and temporal reality, and (3) that it renders tense realism compatible with (a fragmentalist interpretation of) the special theory of relativity.

The focus of this paper is not on the fragmentalist interpretation of special relativity as a way of bolstering a tense realist view of time. The focus of this paper will rather be on the interpretation of special relativity as such and explores its worth as a self-standing view.[1] The aim of this paper is to show that the fragmentalist interpretation, though highly nonstandard, is well-motivated and worth to be taking seriously.

Since Fine's paper, there have been various discussions of the conceptual foundations of the fragmentalist view and various alternative formulations have been offered (see Lipman 2015, Loss 2017, and Simon *forthcoming*). The aim of the current paper is not concerned with the conceptual or technical aspects of fragmentalism but solely with the general sort of motivations for a fragmentalist interpretation of special relativity. I will therefore restrict the discussion to Fine's formulation of fragmentalism. The discussed considerations should however support alternative formulations just as well.

It is also important to keep in mind that none of what follows is in any way a criticism of the standard interpretation. The fragmentalist interpretation disagrees with the standard interpretation, but showing how the fragmentalist interpretation is motivated by various considerations is not the same as showing that it is also better than the standard interpretation. These two matters should not be kept apart. In my view, the question of which theory is ultimately better will depend crucially on wider theory integration, how well each interpretation generalizes and meshes with other scientific theories. This question lies beyond the scope of this paper. The aim here is to show intrinsic interest, not superiority.

As the main interest in fragmentalism lies within metaphysics, the paper assumes no real background knowledge in the relevant physics and some basic matters will be briefly explained afresh. Apologies for those who know these matters well.

[1] By showing how the fragmentalist interpretation of special relativity is independently motivated and not an ad-hoc reinterpretation, the current paper provides further support for Fine's overall argument that fragmentalism about tense is superior to standard realism about tense.

The paper proceeds as follows. The paper argues, first of all, that the considerations that motivate a standard Minkowskian conception of spacetime point just as well towards a fragmentalist account of variant properties. After discussing the positive motivations for the fragmentalist interpretation, it will be shown how the variant properties naturally play explanatory roles and are not merely epiphenomenal additions to our metaphysics. The paper will then discuss an objection against the fragmentalist interpretation due to Hofweber and Lange (2016). They object that fragmentalism is in tension with the right explanation of why the Lorentz transformations hold. The final section replies to their objection.

## *1. Fragmentalism*

Fragmentalism is the view that the world is inherently perspectival. It is standardly assumed that, whenever we are dealing with conflicting perspectival representations of reality, there is always some kind of relativization to standpoints involved in the underlying facts and that it is only ever representations that are properly said to be perspectival, and not the world itself (see Moore 1997: Ch. 3). We standardly assume that we only ever have perspectival representations of a non-perspectival world. Fragmentalism denies this assumption, allowing that the world is itself an inherently perspectival place where facts do not simply obtain or fail to obtain, as we ordinarily assume, but where certain facts can obtain in the context of one set of facts and yet fail to obtain in the context of other sets of facts.

Fine’s formulation of the view revolves around a primitive relation that he calls coherence. The overall collection of facts, ‘über-reality’, includes pairs of mutually incompatible facts. They are the facts that we would be tempted to describe as being somehow ‘from conflicting perspectives’ such as obtaining ‘at different times’. Fragmentalism denies this tempting resort to substitute apparent facts with more relational facts however, and instead accepts the incompatible facts as being all equally constitutive of the world. Instead of 'relativizing' facts in some way or another, we should recognize that some of the facts cohere, and some do not. This means that there are maximal coherent collections of facts, what Fine calls the 'fragments'. These play various important theoretical roles, such as playing the roles of times (2005: 308-10) and playing the role of the indices against which we evaluate the truth of ordinary utterances (2005: §9).

Fine's characterization of fragmentalism follows his more general methodological view that the intended formulation of many metaphysical views requires a distinction between what is merely the case and what is *in reality* the case (see his 2001: §8-10; and 2005: §2). What is *in reality* the case is expressed using a sentential operator $\mathfrak{R}(\ldots)$, which is governed by formal and more substantive principles. A metaphysical realist position about it being the case that *p* should be understood, according to Fine, as the position that it is *in reality* the case that *p*, i.e. that it is the case that $\mathfrak{R}p$. Tense-realism, on this approach, becomes the claim that various tensed sentences are embedded under the reality operator $\mathfrak{R}$ in a correct description of reality. Which facts are real together and which are not is expressed using the earlier mentioned notion of coherence. One possible view here is that two facts are real together if it is *in reality* the case that they cohere. But Fine also suggests that it might be possible to understand the fragmentalist's notion of reality in terms of coherence: that a fact is real if and only if it self-coheres (2005: 281, fn.13). This way we do not need both the notions of reality and coherence, but we can make do with the single notion of coherence – stipulated as itself conveying the fundamental reality of whatever it relates.

A complete description of the world must tell us which fact coheres with which. To illustrate with a toy-case consisting of three times, a partial fragmentalist description of their A-theoretic properties might look as follows:

$\mathfrak{R}$($t_1$ is present, $t_2$ is future, $t_3$ is future) & $\mathfrak{R}$($t_1$ is past, $t_2$ is present, $t_3$ is future) & $\mathfrak{R}$($t_1$ is past, $t_1$ is past, $t_3$ is present)

Instead of saying that $t_1$ is present, $t_2$ and $t_3$ are future 'from the perspective of $t_1$' or 'when it is $t_1$' or 'at $t_1$', the fragmentalist drops the relativization. As Fine argues (2005: §11), the relativization of the facts would undermine the tensed or A-theoretic character of the supposed facts, which is in turn responsible for temporal change and passage.

The central thesis of fragmentalism is that conflicting matters that appear to obtain from equally good but conflicting perspectives, whether they be different times, or some other kind of 'perspective', do not have to be thought of as *mere* appearances of an underlying layer of compatible facts. In the case of the special theory of relativity, we encounter a particularly striking case of conflicting facts across perspectives. There are some differences over what the relevant 'perspectives' are in this context. Einstein's so-called 'radar' definition of simultaneity uses a relativization to paths of inertial motion through spacetime (see e.g. Einstein 1905); but one could also relativize to spacetime locations, or to pairs consisting of frames of references and times, what we may call 'frame-times' (see Fine 2005: §11). Regardless of what the index of relativization is taken to be, there are conflicts between the relevant perspectives about which events succeed one another, about the duration of a given event, and the intrinsic spatial shapes and intrinsic masses of objects. They are the so-called variant (or 'frame-dependent') properties of special relativity. When '$p$' is a sentence attributed frame-dependent property to an object or event, realism about such properties is captured – on Fine's approach – by us taking it to be the case that $\mathfrak{R}p$. The fragmentalist interpretation of the special theory of relativity requires not a radical revision of the way we think about space, time and their occupants, but requires rather a radical revision of the metaphysical structure we attribute to reality: taking there to be various collections of cohering facts and, across such fragments, incompatible facts concerning the variant properties of things. As Fine remarks, the resulting view can be pictured as 'a plurality of physical space-times […] each of them Newtonian in structure' (2005: 306).[2]

The fragmentalist interpretation contrasts with the Minkowskian conception of spacetime. The Minkowskian conception effectively rejects the reality of anything that differs across the relativistic perspectives, and only takes that which is invariant to be real.[3] The result is the familiar fusion of space and time into spacetime (Minkowski 1964/1908: 297), undermining the various properties that are based on a neat separation of space and time, such

[2] It is worth noting that there are other possible fragmentalist interpretations of special relativity, including ones that stay much closer to the Minkowskian conception of spacetime. Stein (1968) mentions for example the possibility of a 'solipsist' interpretation according to which 'for any event, it and it alone is real' (1968: 18). This locational view can be neatly captured in the fragmentalist framework as the view that there is a spatiotemporal fragmentation across relativistic events, taking only the properties of a single relativistic event all to co-obtain. Fine (2005: 304-5) briefly argues against this view within the context of tense-realism, which wants to maintain a real difference between spatial and temporal indexicality, which is lost on this view. But this consideration does not apply if we are willing to abandon this assumption of tense-realism. There are also other possible fragmentalist interpretations besides the locational view just mentioned. The following discussion is not meant to apply to all possible fragmentalist interpretations, it only applies to the fragmentalist interpretation that adopts a total Newtonian separation of space and time, which stands out for discussion due to its radical divergence from the Minkowskian picture.

[3] Our discussion will employ only coordinate descriptions of the Minkowski spacetime instead of the more typical geometric description of spacetime as a 4-dimensional real vector space together with a certain metric signature (*viz.* a nondegenerate, symmetric bilinear form with signature (−,+,+,+) or (+,−,−,−); see Naber 1988: 1). This characterization of the intrinsic geometric structure is not congenial to our discussion since it has already abstracted away the perspectival representations that are the common starting point with the fragmentalist. This paper is concerned precisely with the assumption at play in the transition from the perspectival representations to the intrinsic structure of spacetime, and so Minkowski's own Erlanger approach of seeing intrinsic structure as that which is invariant across coordinatized descriptions provides a more suitable context for our discussion.

as shape, duration, rest mass, simultaneity, and so on. The Minkowskian conception of spacetime is widely adopted, in part because of simple considerations that invoke the very surprising but well-established fact that the speed of light is observed to be the same from any relativistic perspective. The fragmentalist picture sheds new light on these familar considerations.

## *2. Old considerations in a new light*

The possibility of an inherently perspectival world sheds new light on the type of considerations that lead us away from a Newtonian separation of space and time. Let us briefly rehearse these well-known considerations.

Imagine that you are in a space shuttle hanging still in space and that, for as long as you remember, you have experienced the shuttle as being at rest. Imagine that I am in an exactly analogous situation, that is to say, I am also in a space shuttle that, for as long as I remember, I have experienced as being at rest. One day, we see each other's space shuttles. You experience my space shuttle as drifting by with a constant speed of 5 km/h towards the east, still experiencing yourself at rest. I experience you as drifting by with a constant speed of 5 km/h towards the west and still experience myself as being at rest. Our observations of each other's shuttles therefore disagree about who is moving and who is at rest: you observe that I am moving, whereas I observe myself as being at rest.

Now you do an experiment. You are standing in the exact middle of your space shuttle (which you still observe as being at rest) and you emit some light beams towards both ends of the space shuttle. You observe that the light beams arrive simultaneously at the front and end of the shuttle. This is as you would expect: as you are at the middle of a space shuttle at rest, the lights have the same distance to travel and *should* arrive at the same time, given that light always has the same speed *c* (roughly 300,000 kilometres per second) regardless of what direction it moves in. I am in my space shuttle, observing your experiment. From my perspective, the beams also have the same velocity *c* as in yours. But since I observe your shuttle as moving by, the forward moving light has to travel more distance, and since it still has the same constant speed *c*, arrives later than the light sent towards the back. As before, our observations conflict. This time, our observations do not conflict concerning the constant velocity of light, but concerning the simultaneity of the light arriving at, respectively, the front and back of your space shuttle: you observe them arriving simultaneously, whereas I observe them arriving one after the other.

This story was originally told in terms of trains, and there are some complicating factors that we have glossed over (cf. Einstein 1920: Ch. IX; see also Einstein 1905: §A.2). The crucial overall point however is that there is no way whatsoever of singling out one of the two conflicting sets of observations. Could one of us be right? According to Newton, only one of us is indeed right. Newton took space to be a three-dimensional spatial realm that endures through time (Newton 1689/1934: 6). Any spatial location at one time is taken to be identical to a spatial location at a different time, and which location is which is an entirely objective matter. This implies that there is a single right answer to our dispute: if you remain located at the same location throughout the interval in which I seem to pass by, then you are right: you are at rest and I am passing by.

But how can we figure out which spatial location at one time is identical to which spatial location at a different time? Here a well-known difficulty arises. The different locations do not come with intrinsic qualitative differences by which we could individuate them, telling us which point is which. We also cannot identify one location in virtue of its distance from another particular location because, for such relations to be of any help, we need to have already identified the second location in order to identify our location as being a certain distance from *it*, but the question is precisely how to re-identify any point at all at another time.

Given that the points themselves are of no help, we naturally turn to the objects that have their trajectories through space: if an object remains at rest throughout some interval, then its location is identical through time. But of course, the constant velocities of objects that we observe cannot help arbitrate our dispute, given that our observations disagree precisely about which objects have which constant velocity. Maybe, one might think, there are properties of things, other than their constant velocities, which could indicate which of our two experiences is veridical. But, as Galileo famously showed, we cannot tell from properties other than their constant velocity whether a given object has a certain constant velocity (Galileo 1632/1967: 186-187). Within our space shuttles, neither of us needs to exert more force to walk in one direction rather than another. If each of us would release a bird from the centre of the shuttle, we would see it fly with equal ease in any direction it likes. In short, it does not help to appeal to the contents of our conflicting observations because our observations agree about everything *except* for the constant velocities attributed to things.

Since being at rest and moving with a constant velocity are incompatible properties (just as having distinct constant velocities are incompatible properties), it is standardly assumed that something cannot have both. If we think with Newton that one of us must be right even though we cannot empirically settle who is right, it seems we could only arbitrarily assign one of us to be the privileged observer, without any possible empirical evidence for any particular privileging. This is where the motivation for the Minkowskian conception of spacetime orginates from. Moving from a Newtonian to a Minkowskian conception of spacetime eradicates the threat of empirical arbitrariness, as the Minowskian view eliminates precisely that about which the different perspectival observations conflict. An important role here is played by the Lorentz transformations (together with other transformations, such as those governing electric fields) in neatly separating what varies and what remains invariant across perspectives. Lorentz transformations are coordinate transformations between two inertial coordinate frames that move at a constant velocity relative to each other. If we only consider coordinate systems that are oriented the same way and which are such that one moves only in the *x*-direction of the other frame, the Lorentz transformations are the following (with the primed coordinates for the moving frame):

$$t' = \gamma(t - vx/c^2)$$

$$x' = \gamma(x - vt) \qquad \gamma = (1 - v^2/c^2)^{-1/2}$$

$$y' = y$$

$$z' = z$$

According to the standard Minkowskian interpretation of the described scenario, any quantity that is expressible in one coordinate system but changes when we move to another coordinate system moving relative to the first, is deemed unreal. Only the properties that remain constant across the Lorentz transformations reflect the intrinsic structure of the Minkowski spacetime. The so-called spacetime interval between spacetime points is the central invariant property that constitutes the intrinsic structure of Minkowski spacetime. It is written $\Delta s^2$, and defined as follows: $\Delta s^2 = (c\Delta t)^2 - \Delta x^2 - \Delta y^2 - \Delta z^2$, where $\Delta x$, $\Delta y$, $\Delta z$, and $\Delta t$ can each be different in different Lorentz-related frames but only in such a way that $\Delta s^2$ comes out the same in each frame description (where by ‘frame description’ I mean a description of events in terms of the coordinates given by a particular frame of reference). According to the Minkowskian interpretation, the spacetime interval $\Delta s^2$ is the only real spatiotemporal quantity, which can be broken up into different temporal and spatial components within different coordinate representations. The different temporal and spatial components only feature within the coordinate representations, which are now deemed to be the perspectival representations of the underlying non-perspectival world, itself only characterized by the spacetime interval.

In the context of a fragmentalist framework, the move to a Minkowskian conception of spacetime can be resisted due to the possibility of an alternative treatment of the scenario. Taken at face value, we have two conflicting descriptions that, together, imply incompatible assignments of variant properties. The Minkowskian conception neatly undercuts the apparently irresolvable conflict between two equally good descriptions, but it does so by going against both of them in a certain sense, deeming any apparent qualitative differences across them to be merely apparent differences.

Those who are deeply entrenched in the standard Minkowskian view might think that this is as it should be, as there are no such differences out there in the world. But it is important here to keep in mind what is a consequence of the standard interpretation, and what is independently motivated. The standard Minkowskian interpretation implies that no variant properties are instantiated out there, no constant velocity, no Euclidean shape properties, and so on. That there are no such properties cannot then also be invoked in motivating the Minkowski interpretation as the right one, or in denying any interpretation that disagrees on this issue. We need to bring ourselves in a position of theoretical naiveté for a moment. If we bracket the adoption of the Minkowski interpretation, it is an appealing thought that variant properties are instantiated out there. The very property of squareness studied in Euclidean geometry is then plausibly thought to be the sort of property instantiated by the objects around me. It is plausible to think that this is how many of us understand the world as being in our less-guarded moments, and that we even take ourselves to observe such properties (see Epstein 2017; see also Chalmer 2012: Ch. 7 on 'Edenic squareness'). A piece of paper can be square according to descriptions in one frame of reference, and oblong according to descriptions in another frame of reference. If we bracket the Minkowskian interpretation, it is plausible to think that our perceptions would not be indiscriminate between the square and oblong shapes we study in Euclidean geometry. It seems then plausible to think that there is a stark difference in what it is like to undergo an experience of a square shape, and undergoing the experience of an oblong shape, and this phenomenal difference seems due to a difference in content: they are experiences that attribute different shape properties to things, the very shape properties for which there is no place in the Minkowskian conception of the world (see Siegel 2010: Ch. 3). Note that this is how we described the conflicting observations in the shuttle scenario. Now if the Minkowski interpretation is true, all of this is controversial. If the variant properties are not instantiated out there, then externalist considerations about the contents of perception might lead us to think that such properties also cannot really feature in the representational contents of our perceptions and observations (Chalmers 2012: Ch. 7). But this is just to say that if the Minkowski interpretation is right, a disagreeing interpretation cannot be; which is trivial. The interesting question is whether the fragmentalist interpretation has appeal when we do not assume the Minkowskian interpretation. When we do, I think does have a strong appeal in the sense that it restores a simple and appealing story about what sort of properties things have, and how we perceive the world. We are considering an alternative interpretation on which the naïve picture of the world and the intuitive story of the apparent contents of our perceptual experience does not have to be controversial.

Consider in a little more detail the conflicting observations we encounter in the space shuttle scenario. I have no good independent reason to discredit your observation, and you do not a have good independent reason to discredit my observation. So between us, it seems that we have equally good evidence that I am at rest as well as evidence that I have a constant velocity. In the imagined case, you experience my space shuttle as moving *together with* your space shuttle being at rest; I experience your space shuttle as moving *together with* my shuttle being at rest. So we have good reasons to describe our imagined case as follows:

$\mathfrak{R}$(your shuttle is at rest, my shuttle moves with 5 km/h to the east, the light beams arrive at the front and back simultaneously) & $\mathfrak{R}$(your shuttle moves with 5 km/h to the west, my shuttle is at rest, the light arrives at the front only after it already arrived at the back)

Neither of our observations is arbitrarily privileged according to these descriptions. We take what we observe, namely the co-instantiation of various variant properties, at face value. We accept that your shuttle is at rest and that your shuttle is moving with a constant velocity; and we accept that the light arrives at the front and back simultaneously, and that it arrives at the front only after it arrived at the back. More generally, we both observe genuine but conflicting facts concerning the simultaneity, duration, length, shape and rest mass of things. The discussed sort of scenario thus offers support for a fragmentalist conception that matches the overall pool of empirically adequate descriptions, whilst taking the content of these descriptions at face value. From a neutral starting point on which we do not already accept one or the other interpretation, it even seems that the very considerations that normally motivate a Minkowskian conception of spacetime provide a stronger support the fragmentalist interpretation, given that the latter allows for a more common sense and simpler picture of the world and the contents of our experiences.

One might worry that the fragmentalist picture not only opposes the Minkowskian view, but more generally opposed an instance of so-called symmetry reasoning. The symmetries of theories, in this case the re-descriptions of facts in different frames of reference related by the Lorentz transformations, are normally treated as a guide to reality: we consider the variance of properties across such frame descriptions to be a sign of their unreality (for discussion, see Baker 2010, Dasgupta 2016, Earman 1989 and Ismael and van Fraassen 2003). One might worry that fragmentalism conflicts with this widely adopted method of symmetry reasoning.

But this is not quite right. We should first of all be clear that the relevant frame descriptions in cases of symmetry reasoning are all descriptions that are meant to be equally good *complete* descriptions, of *all* the facts. Treating invariance amongst arbitrary incomplete representations as a guide to reality would clearly lead to disaster, as any unmentioned feature could be filtered out in this way. If the relevant descriptions are always only equally good *complete* descriptions, then indeed any remaining differences amongst them must indeed be merely conventional differences in the ways we describe the world. This everyone can agree on.

We should secondly be clear that, for the fragmentalist, a total description of some physical system is a description of the system in all the different fragments, of its total perspectival manifestation. Although there is a real and open question of how best to think of this, one might think for example that the best representation of a system in a fragmented world consists in a collection of multiple frame descriptions. If this turns out to be the best way to represent the fragmented world (a big *if*), we should sharply distinguish between what is variant across the frame descriptions within a single collection (i.e. across fragments), and what is variant across total collections of such descriptions (i.e. across total representations of the overall fragmented world). Even on the fragmentalist view, there is the standardly presumed connection between reality and invariance across equally good *total* representations of some isolated system. The fragmentalist is not denying this connection between variance amongst total descriptions and mere ways of describing things, she denies that descriptions of single fragments are total descriptions and hence denies that the variance across fragments is an instance of the variance across equally good total descriptions. It will be convenient to continue to call ‘invariant’ and ‘variant’ those facts that, respectively, remain constant and differ across fragments. I hope I have said enough to avoid confusion with the notions of invariance and variance across total descriptions, which are the sorts of invariance and variance that (rightly) feature in symmetry reasoning.

*3. The explanatory potency of variant properties*

The elevation of variant properties to genuine properties of things in the world might raise the worry that this creates a jungle of epiphenomena. Giving that the standard interpretation of the special theory of relativity is both successful and explains matters in terms of invariant properties only, does the fragmentalist not introduce a layer of superfluous qualitative structure, unneeded for the scientific explanation of phenomena? If so, parsimony considerations will speak strongly speak against a fragmentalist interpretation. Contrary to the worry, though, it turns out that variant properties will naturally slot into various kinds of physical explanations, due to the fact that they would themselves exhibit law-like dynamic behaviour.

It should first of all be clear that the Lorentz transformations play a different role within the fragmentalist interpretation than in the Minkowskian interpretation. In the fragmentalist interpretation, the Lorentz translations relate not different representations of entire worlds, but different descriptions of fragments within the same world. So the transformations figure as guides to other fragments that we might be able to observe. Very roughly: if things that are at rest in a first fragment have a constant velocity $v$ in the $x$-direction in a second fragment, then the Lorentz transformations (see above) predict other variant properties in the second fragment. The Lorentz transformations thus seem to be underwritten by cross-fragmental laws that govern the distribution of variant properties across different fragments in the way that dynamical laws govern the distribution of temporal properties across different times. It is not the Lorentz transformation themselves that are these laws, given that they are transformations of coordinates and do not relate variant properties directly. I will thus speak of the laws that 'underwrite' the Lorentz transformations. Whereas dynamical laws across time underwrite physical explanations, of one temporal distribution of properties in terms of an earlier distribution, the fragmentalist's Lorentz 'laws' do not seem to underwrite similar explanations. It does not seem right to state that an object is both at rest and square together (i.e. that these facts cohere in Fine's sense) *because* it is both moving and oblong together. The distribution of variant properties in one fragment does not naturally feature in explanations of distributions of variant properties in another fragment, even though the distribution of variant properties in one fragment constrains the distribution of variant properties in another fragment and vice versa.[4] We cannot plausibly assume the connections across fragments to be explanatory in any intuitive sense.

Although the connections across fragments might not be explanatory, the variant properties still feature in the typical explanatory connections across time. The variant properties, if they are indeed instantiated, will themselves be amongst the properties that are governed by dynamic laws. The variant properties of things at one time naturally figure in explanations of variant properties at a later time, and hence they are not explanatorily redundant. Given that the attribution of variant properties differs across fragments, and given that dynamic explanations feature such properties, one and the same phenomenon may be explained in quite different ways in different fragments.

This is nicely illustrated by the following well-known case (taken from Mermin 2005: 185-186 but originally due to Bell 1987). Imagine that there are two rockets Rocket I and Rocket II, separated by some spatial distance $\Delta x$, with a rope stretched tightly between them.

[4] N.B.: This talk of what is the case 'in fragments' is merely loose talk and not part of the official fragmentalist statement of the relevant matters (given the relativization to fragments in this loose talk, whilst relativization is precisely what the fragmentalist ultimately avoids). Instead of saying that the distribution in one fragment constrains the distribution in another fragment, we should say that it being the case that $\Re(A, B)$ physically necessitates it also being the case that $\Re(C, D)$, where $A$, $B$, $C$ and $D$ state facts involving variant properties.

Say we observe things as follows: Rocket I and Rocket II are initially at rest and then they start to move in the *x* direction at the same time at the same rate, keeping their spatial separation $\Delta x$ unchanged. As the rope has, at this later moment in time, gained a velocity in the *x* direction, the length of the tightly strung rope must be contracted. Now imagine that the rope is contracted beyond its elastic limit and breaks at the moment that the rockets are moving. Here we explain the breaking of the rope in terms of the contracted length of the rope and the constant spatial separation between Rocket I and Rocket II. We thus have an explanation in terms of length contraction.

Things are different from the perspective of a different frame: here Rocket I and Rocket II are initially moving in the -*x* direction, and then come to a standstill at which moment the rope breaks. (From our earlier perspective, we say that this is the perspective of someone initially moving in the *x* direction). It can be shown that the moment that Rocket II stops comes before the moment that Rocket I stops, so that Rocket I continues in the meantime to travel in the -*x* direction, thereby stretching the rope until it breaks. Here we explain the breaking of the rope in terms of a temporary difference in constant velocities between Rocket I and Rocket II, and the briefly increasing distance between them. As Mermin points out, 'the mechanism that gives the real explanation for a phenomenon in one frame of reference, may be quite different from the mechanism that gives the real explanation in another' (2005: 185). This is all in line with the fragmentalist picture, illustrating both how variant properties can feature in explanations and how this implies a difference in explanations across fragments. The breaking of the rope happens in both fragments; its explanation differs in different fragments because there are different distributions of variant properties that account for the phenomenon.

There will also be fragment-specific phenomena which can only gain fragment-specific explanations. To take an obvious case: constant velocities at one time are naturally involved in explanations of constant velocities at a later time (cf. Sklar 1977: 180; and Dasgupta 2016:

846). If in one fragment an object remains at rest, its being at rest at $t_1$ may be explained by it having being at rest at $t_0$ and its having being unperturbed by external forces in the time between $t_0$ and $t_1$. Given that the object's being at rest is unique to the relevant fragment, it also only receives an explanation within this fragment.

The variant properties are certainly not physically redundant within the fragmentalist conception of space and time, and feature in physical explanations of phenomena.[5] This can seem puzzling: surely the Minkowski conception, which enjoys such wide adherence, is not lacking in adequate physical explanations, and yet it does not recognize the instantiation of variant properties or, ultimately, explanations phrased in terms of them. The Minkowskian is indeed not lacking in adequate explanations, but that is because the Minkowskian does not acknowledge the phenomena that would stand in need of explanations in terms of variant properties. Because the Minkowskian denies that an object is really at rest at a given time, for example, she also does not need to explain this in terms of changes in the constant velocity of the object at a previous time. The Minkowskian only acknowledges phenomena characterized in terms of spacetime intervals, and she also only needs to appeal to (changes in) spacetime intervals to explain them. The Minkowskian is thus not lacking physical explanations when considered on its own terms.

From the perspective of the fragmentalist, however, which does admit phenomena characterized in terms of variant properties, the Minkowskian spacetime structure is too meagre to support the needed dynamic explanations. The Minkowskian construal of the dynamic laws will be silent about the evolution of constant velocities over time. Capturing the law-like

[5] Cf. Sklar: 'As von Neumann has remarked, the problem with a non-relativistic explanation of the facts is not that one can't be given but that too many can be given, and no reason can be given for selecting one rather than another. In a clear sense, the motivation behind special relativity is the elimination of arbitrary choice from physics' (1977: 280).

evolution of constant velocities requires dynamic laws governing constant velocities. Similarly for other variant properties.

The fragmentalist and Minkowskian differ over what the phenomena are to which our physics should be held accountable. The fragmentalist admits a richer variation of phenomena, for example, it distinguishes a case in which two particles are both rest to be one from a case in which two particles are both travelling with 5 km/h in the *x* direction. There is thus a finer conception of modal space. If there are indeed such phenomena, it is not just that variant properties happen to be serviceable in physical explanations, it seems that they serve in physical explanations that could not be given in any other terms.

## *4. Hofweber and Lange's worries*

Hofweber and Lange argue that the fragmentalist interpretation of special relativity is in tension with the proper explanation of why the Lorentz transformations hold (2016: 1). On the standard interpretation, the Lorentz transformations of the coordinates attributed to events arise from what we take to be the admissible ways of giving the Minkowski spacetime descriptions in terms of coordinates frames. The Lorentz transformations amongst the different frame descriptions obtain *because* of the way in which the same underlying world is coordinatized in the different frames of reference. Hofweber and Lange argue that this is the right explanation of why the Lorentz transformations hold, but that the fragmentalist cannot offer this explanation.

Before going deeper into the objection, I want to point out that the objection relies first of all on a mistaken conception of what is and isn't a theoretical commitment of the fragmentalist interpretation. Hofweber and Lange assume that fragmentalism 'takes frame-dependent facts to be fundamental rather than derivative from frame-invariant facts such as facts about the spacetime intervals between various events' (2016: 4). But nothing that we have seen so far commits the fragmentalist to this. There is nothing in the fragmentalist interpretation that is incompatible with postulating a Minkowski spacetime next to the various fragments, and to take the distributions of the variant properties to be grounded in the spacetime intervals of the Minkowski spacetime. In particular, Fine is not committed to the idea that something is in reality the case if and only if it is ungrounded: two matters may in principle both be real even when the one grounds the other (2001: 27).[6] Where Fine speaks of 'fundamentality' (as in 2005: 281) this can be read as meaning reality. Fine's notion of 'reality' is independent from the notion of 'fundamentality' in the sense of 'ungroundedness'. The fragmentalist interpretation is an account of what sorts of things are the case in reality; it is *not* also an account of what grounds what, or about how certain matters are derived or explained. Figuring out the various grounding relations is thus independent of the fragmentalist view. The real issue is that the moment you are willing to say that something is at rest (given one frame) but also has a non-zero constant velocity (given a different frame), something needs to be said to make sense of something being both at rest and not at rest. The fragmentalist propose a way of making sense of that. Whether the facts concerning constant velocity are derivate or fundamental is beside the point with respect to the issue of finding room for conflicting facts. It is their being genuine facts that is the central claim of the fragmentalist.

To make this more concrete, note that a fragmentalist could believe that things are genuinely at rest, and moving, and that they have certain intrinsic shapes and durations, and so on, *and* believe that these variant facts are grounded in a particular coordinatizations of a

[6] Also, on the alternative formulations of fragmentalism, given by Lipman (2015), Loss (2017) and Simon (forthcoming), no notion of 'reality' is even invoked and all the work is done by the features of a non-adjunctive conjunction-like connective. These formulations are all entirely silent about what is fundamental or not.

Minkowski spacetime, *and* believe that there are many other such coordinatizations, on a par with the current one, which ground incompatible frame-dependent facts. Such a view does not disagree with the standard Minkowskian interpetation about the grounds or the explanations of the variant matters; the only real difference here is that the Minkowskian takes them to be explanations of *mere* appearances, whereas the fragmentalist takes them to be explanations of genuinely real yet grounded facts. Such a fragmentalist believes that it can be a genuine fact that a football has an intrinsic Euclidean ball-shape (though taking its being so to be a grounded fact), whereas the Minkowskian needs to say that the football does not have such a property but only seems to given a certain way we describe it.

The complaint that the fragmentalist interpretation is in conflict with the right explanations of the Lorentz transformations is therefore off the mark from the start: the objection targets something that is not really part of the view, indeed, the fragmentalist can in principle adopt the very same sort of explanations that the Minkowskian appeals to, whatever they are, in which case they are just explanations of subtly different things (of mere appearances in one case, and genuine facts in the other). The most that Hofweber and Lange's objection can do is force a certain explanatory order as well as the postulation of the Minkowski spacetime onto the fragmentalist. But these matters are entirely compatible with the view. The main objection is toothless when it comes to fragmentalism itself.

To give the objection a target we need to imagine a fragmentalist who also endorses a certain grounding story. Let us therefore imagine a fragmentalist who believes: (1) that the variant properties are real, and (2) that the spacetime interval consist in a ratio of the variant properties, and (3) that the variant properties – the different spatial and temporal distances in different frames – ground such ratios. The spacetime intervals of events are real, on this story, but they are not fundamental due to being grounded in distributions of variant properties. The interval between two events is grounded in different distributions of variant properties in different fragments, yet the distribution of the variant properties are constrained in such a way that the interval comes out the same in each fragment. The Lorentz transformations of the coordinate frames underwrite the law-governed regularity between the distributions of fundamental yet variant properties in the different fragments. It is this sort of view that Hofweber and Lange seem to be targeting and it is a grounding story that might indeed seem appealing to the fragmentalist. For the remainder of this section, the fragmentalist interpretation under discussion is the one just outlined.

We have an interest in the various kinds of mathematical relations underwritten by the special theory of relativity, in particular, we study what facts can be derived from which other facts. Examples of such facts are Einstein's two principles (the principle of relativity and the light postulate), the Lorentz transformations, Maxwell's equations, and the invariance of the spacetime interval, and so on. We will focus on the Lorentz transformations and the invariance of the interval. Both the Minkowskian and the fragmentalist agree that the Lorentz transformations hold and that the interval is invariant. Starting from the Lorentz transformation plus supplementary assumptions, we can derive that the interval is invariant. Starting from the invariance of the interval plus supplementary assumptions, we can derive that the Lorentz transformations hold. About all of this, the Minkowskian and fragmentalist can agree.

Hofweber and Lange claim that one of these two derivational directions is generally treated as being explanatory, namely the direction from the invariance of the interval to the Lorentz transformations. The invariance of the interval is generally assumed to have explanatory priority, they claim (2016: 6). The assumed explanatory priority of the spacetime interval, they then argue, is naturally explained by the standard interpretation:

> Why does the spacetime interval's invariance count as explanatorily prior to various other facts, such as the transformation laws? After all, the transformation laws suffice

> to entail the spacetime interval's invariance. Why does science take the direction of explanation as running from the spacetime interval's invariance to the transformation laws rather than, say, in the reverse direction? Because the spacetime interval, as a frame-invariant fact, is the reality, whereas the facts related by the coordinate transformations are frame-dependent facts and hence are appearances of that reality. How things are explains how things appear from a given perspective. Therefore, the law that a certain quantity is invariant takes explanatory priority over the laws specifying how various frame-dependent quantities transform. (2016: 10-11)

The idea is that because the spacetime interval is real and the variant properties mere appearances, equally good frame descriptions *must* all agree on the spacetime interval of things whilst being free to vary in their description of the variant properties, and *hence* the spacetime interval must come out invariant across all the total frame-descriptions that are stipulated to be equally good. The fragmentalist interpretation that takes the variant properties to be fundamental cannot offer this explanation. Thus the standard interpretation can explain the assumed explanatory priority of the spacetime interval, whereas the fragmentalist cannot.

Although this is correct, I think the point has little dialectical significance. What we need is for there to be a neutral explanandum, something that both sides can agree on is something that needs to be explained, and yet that one side can explain and the other cannot. There are two candidate explananda here. First there is the claim that the invariance of the interval is generally *assumed to have* explanatory priority. And second there is the fact that the invariance of the interval *has* explanatory priority. The first is a sociological claim about, roughly, the assumptions at play in the scientific community; the second is a claim about which fact takes explanatory priority. The first, if it is indeed true, is a neutral explanandum that the fragmentalist can agree with but which is also very easily explained by the fragmentalist. The second is not a neutral explanandum, since it is false by the lights of the fragmentalist and hence not something that ought to be explained.

Let us have a closer look at these two cases. First there is the claim that the invariance of the spacetime interval is generally assumed to take explanatory priority. Let us grant that this is so. The fragmentalist can easily explain this by pointing out that the scientific community generally accepts the standard interpretation, and hence that they assume the interval to be real and the variant properties not to be real, and hence that they attribute explanatory priority to the interval. Nobody has argued that fragmentalism is plausibly what the scientific community has been thinking all along, neither Fine, nor any else I know off. It seems rather obvious that the standard interpretation is, well, standard, and that the fragmentalist interpretation goes against the status quo. In any case, the sociological claim can (and I think) should be accepted by everyone, and can be easily explained by the fragmentalist.

The second alleged explanandum is that the standard assumption is right and that the invariance of the interval *has* indeed explanatory priority.[7] This is clearly not a neutral explanandum: it is only an explanandum if the standard interpretation is correct. If the fragmentalist is right, there are fundamental variant properties, constrained by a fundamental law that underwrites the Lorentz transformations. It is this law that has explanatory priority on this view; not the invariance of the interval.

The situation here is the converse of the dialectical standoff we encountered in the discussion of the explanatory potency of variant properties. There I noted how the fragmentalist could be tempted to think that she can explain why something has a certain constant velocity in terms of earlier constant velocities, and hence that she can offer explanations that the standard interpretation cannot offer. But, as I argued there as well, the Minkowskian has

[7] I will assume that the notion of explanation here is not merely epistemological, but something that is meant to reflect a certain objective explanatory order in the world.

nothing to worry from this, because if she is right, there is no such phenomenon involving constant velocity, and hence there is nothing that could admit of the explanation given by the fragmentalist. Where there is disagreement about what phenomena there are, there will unsurprisingly be a disagreement over what explanations can be given. That each view is able to give those explanations of the phenomena that it alone postulates does not help us see which view is better when we compare them.

Hofweber and Lange further discuss various spin offs of their main objection. Most notably, they object that the fragmentalists needs to postulate 'brute' connections across the fragments without giving any reason to expect such brute connections, and that this is a substantive cost of the view (2016: 6). It is hard to see what the difference could be between laws being fundamental and them being brute: it is just that nothing explains why they hold. The Lorentz law is indeed fundamental according to the view under consideration.[8] Now if the complaint is simply that the law is taken to be fundamental while it is not fundamental according to the standard interpretation, we are back with the previous point about explanatory priority.

But perhaps the complaint is subtly different. Perhaps the objection is that the fragmentalist assumes that there this Lorentz law is fundamental even though nothing in fragmentalism gives any reason to expect that it holds (see the Bayesian argument, 2016: 6).

[8] In fact, they really do not have to be fundamental, not even on the view that takes the variant properties to be fundamental. That the lawlike-connections underwriting the Lorentz transformations take explanatory priority over the spacetime interval (and assumed variance of the variant properties), does not mean that there cannot be another explanation of the Lorentz transformations. One might offer an account along general Humean lines, for example, or one might endorse a so-called dynamical explanation of the Lorentz transformations, according to which transformations are taken to be grounded in the various forces acting on rods and clocks; see Bell (1976/1987), Brown and Pooley (2006) and Brown (2005).

The complaint is in this case that the law is a substantive addition by the fragmentalist's own light. But it is a misguided worry. Outside the law, there is indeed nothing to expect such a Lorentz law but this precisely why they it is a fundamental law. It is a fundamental law precisely because it does not follow from anything else that we already have. This is generally the case for fundamental laws. For any fundamental law one could complain that nothing else gives us a reason to expect that they hold. But this is wrongheaded. It is simply a characterizing feature of *fundamental* laws. So the complaint that nothing in the fragmentalist framework would make one expect that such laws hold is really quite hollow. It would similarly be hollow to complain that nothing in a unified, non-fragmentalist metaphysics makes one expect that only intervals are real and that the Euclidean shape properties and duration and so on, are not real. This clearly does not make it a cost that, in offering an adequate interpretation of special relativity, the Minkowskian needs to assume that this how things fundamentally are. The non-separation of space and time is taken to be a 'brute' fact about the world in the Minkowski interpretation, but it would be odd to consider this a cost in the context of offering an interpretation of the special theory of relativity. In offering an adequate interpretation of special relativity, the fragmentalist assumes instead that there is a law-governed regularity across fragments in order to give the right interpretation of the special theory of relativity. Starting with a neutral metaphysical framework, anyone will need to add certain fundamental facts in order to capture what we learn from the special theory of relativity. The cross-fragment Lorentz law that the fragmentalist assumes to hold *just is* the law of nature captured by the special theory of relativity, according to the fragmentalist. It is a surprising fact to the extent that the special theory of relativity is surprising.

A related criticism targets not the fundamentality of the needed Lorentz law, but rather its being *sui generis*. They point out that the usual natural laws track causal relations across time, such as those relating forces to caused accelerations, or spell out ways in which structural features ground certain dispositions to behave in certain circumstances, such as that the chemical structure of sugar disposes it to dissolve in water (2016: 5-6). In contrast, the fragments are obviously not related by causal relations or structure-disposition relations, and so the laws seem *sui generis*. This might be right, but even if it is, it is unclear why this should count against the view. It is unclear why a theory's introduction of new kinds of physical laws should somehow be a sign of its incorrectness. The only relevant question is whether the proposed revisions are good or not.

Yet another related criticism targets the tension between the fragmentalist approach as such and certain widespread basic assumptions in the scientific community. They offer various quotes (by Eddington, Mermin, Einstein and Holton) which express adherence either to the standard interpretation or to the basic assumption that different perspectives always present us with mere appearances of an underlying unified reality (2016: 4-7). This assumption of taking reality to be unified behind the mere perspectival appearances, they claim, is 'alien to the spirit behind fragmentalism' (2016: 7). As I already argued, it is not really the unifying impulse that goes against fragmentalism. More precisely, it is the related impulse to deny the reality of what is perspectival. Hofweber and Lange (2016) may well be right that there is a widespread assumption in the scientific community to deny the reality of what is perspectival and that fragmentalism goes against this. But this is to say little more than that fragmentalism is not currently the dominant view in the scientific community. Of course it isn't. It would be rather dogmatic to hold this against the view. Many of us think that philosophy is precisely of interest when it identifies implicit general assumptions, and explores what happens to our understanding of the world if we drop them. We do not dismiss metaphysical views just because they happen to explore things outside the familiar assumptions.

I conclude that Hofweber and Lange (2016) have failed to offer us any good reason to think that the fragmentalist interpretation must be false. The fragmentalist interpretation offers an original response to the sort of scenarios that otherwise motivate the Minkowskian conception of spacetime, one that preserves the properties in terms of which we like to think about the world around us. For what we know thus far, it is a well-motivated view that deserves further work and further discussion.

*References*


Baker, D. (2010). 'Symmetry and the Metaphysics of Physics', *Philosophy Compass* 5: 1157–66.

Bell, J. S. (1976/1987). 'How to Teach Special Relativity', in *Speakable and Unspeakable in Quantum Mechanics*. Cambridge: Cambridge University Press.

Belot, G. (2013). 'Symmetry and Equivalence', in R. Batterman (ed.), *The Oxford Handbook of Philosophy of Physics*, Oxford: Oxford University Press.

Brown, H. R. (2005). *Physical Relativity: Space-Time Structure from a Dynamical Perspective,* Oxford: Oxford University Press.

Brown, H. R. and Pooley, O. (2006). 'Minkowski Space-Time: A Glorious Non-Entity', in Dieks, D. (ed.), *The Ontology of Spacetime*. Elsevier: 67-89.

Chalmers, D. (2012). *Constructing the World*. Oxford: Oxford University Press.

Dasgupta, S. (2016). 'Symmetry as an Epistemic Notion (Twice Over)', *The British Journal for the Philosophy of Science* 67: 837-78.

Earman, J. (1989). *World Enough and Space-Time: Absolute versus Relational Theories of Space and Time*, Cambridge, MA: MIT Press.

Epstein, P. F. (forthcoming). 'Shape Perception in a Relativistic Universe', *Mind*.

Einstein, A. and (transl.) Lawsom, R. W. (1920). *Relativity: The Special and General Theory*. New York: Henry Holt Company.

Einstein, A. and (transl.) Beck, A., and (ed.) Stachel, J. (1905/1986). 'On the Electrodynamics of Moving Bodies', in *The Collected Papers of Albert Einstein, volume 2, supplement*. Princeton: Princeton University Press: 140–171.

Fine, K. (2001). 'The Question of Realism', *Philosopher's Imprint* 1: 1-30.

Fine, K. (2005). 'Tense and Reality' in *Modality and Tense: Philosophical Papers*. Oxford: Oxford University Press: 261-320.

Galileo, Drake S. (ed.) (1632/1967): *Dialogue Concerning the Two Chief World Systems*. Berkeley: University of California Press.

Hofweber, T. and Lange, M. (2016). 'Fine's Fragmentalist Interpretation of Special Relativity', *Noûs*.

Ismael, J. and van Fraassen, B. (2003). ‘Symmetry as a Guide to Superfluous Theoretical Structure’, in K. Brading and E. Castellani (eds.), *Symmetries in Physics: Philosophical Reflections,* Cambridge: Cambridge University Press: 371–92.

Lipman, M. A. (2015). ‘On Fine’s Fragmentalism’, *Philosophical Studies* 172 (12): 3119-3133.

Loss, Roberto (2017). ‘Fine's McTaggart: Reloaded’, *Manuscrito: Revista Internacional de Filosofía* 40 (1): 209-239.

Minkowski, H. (1964/1908). ‘Space and Time’ in J. J. C. Smart (ed.), *Problems of Space and Time*. New York: Macmillian Company: 297-312.

Mermin, N. D. (2005). *It’s About Time*. Princeton: Princeton University Press.

Moore, A. (1997). *Points of View*. Oxford: Oxford University Press.

Naber, G. (1988). *Spacetime and Singularities: an Introduction*. Cambridge: Cambridge University Press.

Newton, I., and (transl.) Motte, A. and (ed.), Cajori, F. (1689/1934). *Philosophiae Naturalis Principia Mathematica*. Berkeley: University of California Press.

Roberts, J. (2008). ‘A Puzzle about Laws, Symmetries, and Measurability’, *The British Journal for the Philosophy of Science* 59: 143–68.

Siegel, S. (2010). *The Contents of Visual Experience*. Oxford: Oxford University Press.

Simon, J. (forthcoming), ‘Fragmenting the Waves’, *Oxford Studies in Metaphysics*.

Sklar, L. (1977). *Space, Time and Spacetime*. Berkely: University of California Press.

Stein. H. (1968). ‘On Einstein-Minkowski Space-Time’, *Journal of Philosophy* LXV (1): 5-23.