In Defence of a Fragmentalist Interpretation of Special Relativity

Fragmentalism was first introduced by Kit Fine, in his ‘Tense and Reality’ (2005). It is the view that reality is an inherently perspectival place that exhibits a type of fragmented structure. The current paper motivates and defends the fragmentalist interpretation of the special theory of relativity, which makes room for genuine yet conflicting 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 an even stronger motivation for a fragmentalist account of variant properties. One might think that positing such variant properties is a turn for the worse as they are not involved in physical explanations and hence redundant. But this is mistaken. If variant properties are instantiated, they will also be involved in straightforward physical explanations. The paper concludes with a discussion of objections offered by Hofweber and Lange in ‘Fine’s Fragmentalist Interpretation of Special Relativity’ (forthcoming). Their objections are based on the claim that the fragmentalist interpretation is in tension with the right explanation of why the Lorentz transformations hold. It will be argued that this claim is motivated on question-begging grounds and that their objections fail.
Consider some faraway place in the universe. There is no fact of the matter about what things over there are happening at the same time as 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. Consider also your direct surroundings. It is not the case that the things you see have intrinsic mass, or intrinsic shapes or lengths. These are merely ways things appear to you. Things can also not be divided 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 highly revisionist metaphysics. As we all know though, this is the story being told to us by our physics textbooks, at least by the chapter on special relativity. The story simply lists the standardly accepted metaphysical consequences of the special theory of relativity. These metaphysical consequences are nicely 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 that is standardly drawn from it. These considerations involve metaphysical assumptions that are 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 in a better position to account for the passage of time and for the stable truth of tensed token utterances, and 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 salvaging a tense realist view of time. The focus of this paper will rather be on the
interpretation of special relativity as such, and its independent motivation.\footnote{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 argument that fragmentalism about tense is superior to standard realism about tense. This will however not be discussed explicitly.} Given the radical nature of the standard Minkowskian conception of the world, it is reasonable to step back at least once and a while, and consider the possibility of embedding the theory in a different metaphysical picture. This paper discusses in some detail how fragmentalism affects the apparent metaphysical implications of the special theory of relativity.

It will be argued first of all that the considerations that motivate a standard Minkowskian conception of spacetime point instead 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 take on explanatory roles. The paper will then discuss objections against the fragmentalist interpretation that have recently been made by Hofweber and Lange (forthcoming). They offer objections based on the claim that fragmentalism is in tension with the right explanation of why the Lorentz transformations hold. This claim turns out to be motivated on question-begging grounds.

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 (cf. Fine 2005: 261). 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 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 relativization, 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, 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 $\mathcal{R}(\ldots)$, which is governed by various formal and 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 $\mathcal{R}p$. Tense-realism, on this approach, becomes the claim that various tensed sentences are embedded under the reality operator $\mathcal{R}$ 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.

Fragmentalism can also be formulated without building into it Fine’s metametaphysical views (see [suppressed]). One might think this is preferable. It seems that any view of the way in which facts hang together is independent from a view about which of those facts are also part of reality or not. In saying that certain facts coalesce together to form a single unified bit of world, it is unclear to me why this should imply anything about the fundamental reality of the relevant facts. There is no reason why the derivative or non-fundamental world could not be as fragmented as the fundamentally real layer.\(^2\) This changes slightly how we think of the relation that structures the fragmented world. To avoid confusion, I will not speak of coherence, but rather of a non-standard notion of co-obtainment which does not convey the fundamental reality of whatever it relates and which can apply indiscriminately to the mere facts and the fundamentally real facts of Fine’s view. This notion of co-obtainment consists in a primitive bit of metaphysical ideology, expressed with a sentential connective ‘∘’. When the fact that \(A\) and the fact that \(B\) co-obtain in the fragmentalist’s sense, this consists in it being the case that \(A∘B\). Fragmentalism holds in particular that not all facts that obtain also co-obtain, i.e. from ‘\(A\)’ and ‘\(B\)’ we cannot infer ‘\(A∘B\)’. Incompatible facts are precisely those matters that cannot co-obtain in this sense, i.e. it is metaphysically impossible that \(A∘B\) if and only if ‘\(A\)’ and ‘\(B\)’

\(^2\)There are also reasons to think that the required notion of coherence must exhibit formal features that make it a bad candidate for doing double-duty as the notion of reality. There are for example reasons to think that the structuring relation should be non-factive (so that one thing can cohere with another without obtaining), whereas the notion of reality is naturally taken to be factive (so that if something is in reality the case, it is also the case simpliciter).
state incompatible facts. Of course there is much more to say about the inferential role of co-obtainment (for which, see [suppressed]); but this should suffice for the present discussion.

A complete description of the world must tell us which fact co-obtains 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:

\[(t_1 \text{ is present} \circ t_2 \text{ is future} \circ t_3 \text{ is future}) \& (t_1 \text{ is past} \circ t_2 \text{ is present} \circ t_3 \text{ is future}) \& (t_1 \text{ is past} \circ t_1 \text{ is past} \circ t_3 \text{ is present})\]

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 and states that \(t_1\) is present \(\circ\) \(t_2\) is future \(\circ\) \(t_3\) is future. As Fine argues (2005: §11), the relativization of the facts would undermine the tensed or A-theoretic character of the supposed facts of the A-theory, which is in turn responsible for their underwriting 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; the conflicting appearances might be the manifestation of genuine facts regardless of their incompatible character. 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’ would be here. 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

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3 I will write: ‘\((A \circ B \circ C \circ \ldots)\)’ to express that each of the expressed facts obtains with every other.
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 across the relevant perspectives about which events succeed one another, about the duration of a given event, as well as about the intrinsic spatial shapes and intrinsic masses of objects. They are the so-called variant (or ‘frame-dependent’) properties of special relativity. The fragmentalist interpretation of the special theory of relativity denies the relativization and takes the incompatible facts at face value, requiring not a radical revision of the way we think about space, time and their occupants, but requiring rather a radical revision of the general structure we attribute to reality: taking there to be various collections of co-obtaining 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).

The fragmentalist interpretation contrasts with the Minkowskian conception of spacetime. The Minkowskian conception effectively rejects anything that differs across the

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4 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.
relativistic perspectives, and only takes that which is invariant to obtain. 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 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 the textbook considerations in favour of the Minkowskian picture.

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 rehearse these well-known considerations with a typical scenario.

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, 

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5 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.
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.

There is more. 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 originates from. Moving from a Newtonian to a Minkowskian conception of spacetime eradicates the 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):

\[
\begin{align*}
t' &= \gamma(t - vx/c^2) \\
x' &= \gamma(x - vt) \\
y' &= y \\
z' &= z
\end{align*}
\]

\[\gamma = (1 - v^2/c^2)^{-1/2}\]

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 becomes questionable due to the possibility of an alternative treatment of our empirical evidence. Taken at face value, we have two observations that, together, provide empirical evidence for incompatible assignments of variant properties. Variant properties feature squarely in our empirical observations of the world; we observe a world with objects with intrinsic shapes and lengths and we observe certain definite events occurring at the same time. If variant properties did not feature in our observations, the observations of the sketched scenario above would not disagree; but they do. When you observe me as moving by and I observe myself as being at rest, we really observe the world in different ways; such observations have a different content. The Minkowskian conception undermines the apparently irresolvable conflict between two pieces of equally good evidence, but it does so by going against both of these observations in a rather radical way, deeming any apparent qualitative differences between such observations to be merely apparent differences.
Those deeply entrenched in the standard Minkowskian view might want to deny that we even observe any of the variant properties. They might deny for example that we observe constant velocity, and insist that we only experience relative velocities. But this seems to me implausible, especially when generalized to all variant properties. You know very well what it is for things to be at rest (cf. Lewis 1986: 204) and I submit that you can decide whether the things you observe around you are at rest or moving without needing to regard yourself or surrounding objects as well. Variant properties more generally feature in our empirical observation of the world: we plausibly observe definite objects with definite lengths and shapes, and events of definite durations following each other in a definite order. 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 (obtained from a Lorentz transformation of the first frame). It is highly implausible that our observations will be indiscriminate between square and oblong shapes. 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 is clearly 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. And similarly for other variant properties: there is the possibility of conflicting observations of the variant properties of things.

Given the possibility of worldly fragmentation, the Minkowskian conception of spacetime seems based on an unnecessarily radical treatment of the possibility of irreconcilable conflicts between observations. What motivates the Minkowskian conception is not the

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6 I am here employing what Siegel (2010: Ch. 3) calls the method of ‘phenomenal contrast’ to figure out the contents of our experience. She argues that this is the most reliable method of figuring out the contents of experience, as it only requires rough introspective judgments about whether there is a difference in what it is like to undergo the relevant experiences.
absence of variant properties from our observations, it is the need to avoid an empirically arbitrary choice between incompatible observations. Our observations do not suggest that these variant properties are not instantiated in the world; our observations suggest a world richly imbued with variant properties. Fragmentalism opens up the possibility of taking the observations at face value whilst still avoiding a parochially privileged observer.

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. One might be tempted to dismiss the other’s observation by digging one’s heels in and discredit the other’s observation based on its disagreeing with your own observation. But this solipsistic privileging of one’s own observation seems objectionably parochial: if asked why I privilege my own observations, all I could say, it seems, is that it is because I am having these observations. But that is only a good explanation of privileging my own observation if we already have a reason to think that I am special; and we do not. We clearly do not have independent, neutral grounds for privileging one of the conflicting observations. So between us, 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. Between us, we do not have evidence that the facts that you observe co-obtain with the facts that I observe. We have good reasons between us to think that your movement at a constant velocity co-obtains with the light beams arriving one after the other and that your being at rest co-obtains with the light beams arriving simultaneously. So we have good reasons to describe our imagined case as follows:
(your shuttle is at rest \(\circ\) my shuttle moves with 5 km/h to the east \(\circ\) the light beams arrive at the front and back simultaneously) \& (your shuttle moves with 5 km/h to the west \(\circ\) my shuttle is at rest \(\circ\) 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 favours a fragmentalist conception that matches the overall pool of empirical evidence better than the Minkowskian treatment that regards the observed differences to be merely apparent differences. We therefore have the striking situation that the very considerations that normally motivate a Minkowskian conception of spacetime turn out to favour the fragmentalist interpretation over a Minkowskian interpretation of special relativity.

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

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7 How should we think of the observations themselves in this picture? There are a range of options here. One possible option is that each of us, strictly speaking, observes only unified bits of world, i.e. only observes the co-obtainment of various facts involving the various variant properties. If this is right, then each observation can be included in each fragment and true in each fragment. Another possible option is that each observation tells of what singular individual facts co-obtain with the observation itself. This might give reason to include each observation only in one fragment, or alternatively to include them in both so that their veridicality is itself one of the variant properties. There are yet other possible construals of the observations within the fragmentalist context. Further work is needed to tell what the most plausible construal is of the observations themselves.
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 the fragmentalist sets her face against this widely adopted 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 descriptions of all the facts. Treating invariance amongst arbitrary incomplete representations as a guide to reality would clearly lead to disaster, as any independent intrinsic feature could be filtered out. If the relevant descriptions are always only equally good complete descriptions, of all the facts, then 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 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.

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 in favour of the standard Minkowskian interpretation, which razors the unneeded variant properties away. Contrary to the worry, though, it turns out that variant properties will naturally slot into various kinds of physical explanations, due to their exhibiting 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 govern the distribution of variant properties across different fragments in the way that dynamical laws govern the distribution of temporal properties across
different times. But there is also an important difference: 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 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, along the lines of the Lorentz transformations.\(^8\)

This does not mean that variant properties do not feature in physical explanations at all. 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; 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. Say we observe things as follows: Rocket I and Rocket II are initially at rest and then they start to move

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\(^8\) 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, 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 \(A \circ B\) physically necessitates it also being the case that \(C \circ D\), where \(A, B, C, D\) state facts involving variant properties.
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. Observing things this way, 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.

As it happens, someone else observes things differently: 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, when observing things in this way, 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 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:}
If in one fragment an object remains at rest, its being at rest at $t_1$ may be explained by it being at rest at $t_0$ and its 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.\(^9\) 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.

That said, from the perspective of the fragmentalist, 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 absolute velocities over time. It is precisely because of this

\[^9\] 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).
that a uniform velocity boost (giving everything in a system an added constant velocity of 5 km/h in the x directions, say) seems to make no difference to what a set of dynamic laws that only involve invariant properties tell us about the system. But the moment we recognize an object’s being at rest as a genuine observable phenomenon, its dynamic explanation must appeal to the object’s constant velocity at an earlier time. If absolute velocities are instantiated, no real spontaneous velocity boosts occur from one moment to the next; there is rather a lawlike evolution of absolute velocities over time. A set of laws is naturally considered to be the complete laws of motion when they capture everything about the dynamics of a physical system, i.e. everything there is to say about the way systems evolve over time, ruling out exotic evolutions. If the fragmentalist interpretation is true, a sudden uniform velocity boost would constitute an exotic evolution of variant properties of time and hence should be ruled out. But such velocities boosts are not ruled out by any set of dynamic laws that have the velocity boosts as symmetries (that is precisely why such uniform velocity boosts are symmetries of the given set of laws) and hence any such set of dynamic laws should be deemed incomplete to the very extent that we accept the object’s being at rest as a genuine phenomenon, exhibiting a law-like evolution over time. Capturing the law-like evolution of absolute velocities requires dynamic laws governing absolute 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, considering two particles both rest to be one worldly phenomenon and two particles both travelling with 5 km/h in the x direction to be a different worldly phenomenon. 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 (forthcoming) argue that the fragmentalist interpretation of special relativity ‘is in tension with the proper explanation of why various facts (such as the Lorentz transformations) obtain’ (forthcoming: 1). They offer subtly different objections revolving around this claim. But the central claim can only be supported on question-begging grounds and the alleged problems they see are not really problems for fragmentalism.

According to Hofweber and Lange, the Lorentz transformations arise from what we take to be the admissible ways of projecting the Minkowski spacetime onto different coordinate systems (together with the structure of those coordinate systems). 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. The fragmentalist cannot offer this explanation of why the Lorentz transformations hold.

Hofweber and Lange offer various explanations of why they think this is a problem for the fragmentalist. The main worry seems to be that ‘fragmentalism must regard as brute certain relations between “fragments” that have explanations on the standard interpretation of STR’ (forthcoming: 3). As was discussed above, the Lorentz transformations indeed gain the status of laws of nature that underwrite a law-like relation between the distributions of variant properties in the different fragments. But the situation is not simply one of taking as brute relations that can be explained on the Minkowskian view, the situation is merely one of a reversal of explanatory priority. We can only explain the Lorentz transformation in the way that Hofweber and Lange envisage if, amongst other things, we make the brute assumption that the spacetime interval is an invariant quantity and that absolute simultaneity, spatial shape, and so on, can freely vary between equally good assumptions. If we make this assumption, then we
can derive all the different frame descriptions on the basis of the spacetime intervals of things by figuring out all the possible ways in which the spacetime intervals can be factored into spatial and temporal components whilst keeping the spacetime interval constant. It is because we assume that only the spacetime interval should come out as constant in all complete frame descriptions, that the Lorentz transformations hold in the class of relevant reference frames. The Lorentz transformations are thus explained in terms of the assumed invariance of the spacetime interval.

Fragmentalism turns the order of explanation around. On the fragmentalist story, the spacetime intervals are naturally explained as consisting in a ratio of the variant properties (namely, $\Delta s^2 = \Delta x^2 + \Delta y^2 + \Delta z^2 - (c\Delta t)^2$), in particular, given how $\Delta s^2$ is defined, it is grounded in different spatial and temporal distances in different frames. So, in each frame, it has the status of a mere ratio, derivative from that which it is a ratio of. The fact that it is invariant across frames is, in turn, grounded in the fact that the distribution of these spatial and temporal relations is constrained by the Lorentz transformations. We do not have a simple loss of explanatory power on the fragmentalist story, we have at most a reversal of the order of explanation. Put roughly: instead of explaining the Lorentz transformation on the basis of the invariance of the spacetime interval, we can explain the invariance of the spacetime interval on the basis of the Lorentz transformations.\textsuperscript{10}

\textsuperscript{10} That the Lorentz transformations cannot be explained from the assumed invariance of the spacetime interval (and assumed variance of the variant properties), does not mean that there cannot be another explanation of the laws. The fragmentalist interpretation could for example quite naturally combine with the 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). Following this approach, the fragmentalist would say for example that the length of a rod is contracted insofar as it moves, not because we describe it in a certain way in the reference frame that moves with it, but because the forces acting on the atomic structure of the rod are different in a fragment in which the rod moves.
Hofweber and Lange are in fact aware that the issue is really just the direction of explanation. They try to motivate why the spacetime interval’s invariance should count as explanatorily prior, writing the following:

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. (forthcoming: 10-11)

The idea that ‘how things are explains how things appear from a perspective’ motivates an explanatory direction from the spacetime intervals between entities to the supposed appearance of those entities’ constant velocities, rest mass, and so on. But the issue under discussion is not the relation between intervals and variant properties; the issue is the relation between the invariance of spacetime intervals and the holding of the Lorentz transformations. Presumably the relation between the offered motivation and the issue under discussion is that, because spacetime interval is real and the variant properties unreal, 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. So, because only spacetime intervals are instantiated out here, and because the relevant frame descriptions are all meant to be equally good renditions of all the
facts, all frame descriptions must agree on the spacetime intervals of things (otherwise they would not be equally good renditions of the facts) and hence spacetime interval must be invariant across all the relevant frame descriptions. Conversely, because all variant properties are not instantiated out there, but constitute mere appearances, the relevant frame descriptions can differ in their descriptions of the variant properties and yet be equally good descriptions of the true facts out there, viz. facts concerning spacetime intervals. Employing the definition of the spacetime interval, we can figure out all the equally good ways in which the spacetime intervals are factored into purely spatial and purely temporal separations between things.

This motivation for why the standard order of explanation is right is clearly question-begging in the current dialectical context.\(^{11}\) It assumes exactly that which is meant to be shown, namely that the variant properties are unreal. It is precisely the defining claim of fragmentalism that what differs across equally good frame descriptions of the Lorentz transformations does not automatically have to be deemed mere appearance. What the explanatory connection is between the invariance of the spacetime interval and the Lorentz transformations depends on whether the Lorentz transformations merely relate different descriptions of the same thing, or rather specify ways in which certain patterns of property instantiation determine other such patterns (in the way that dynamic laws formulate ways in which temporal states constrain one another). The discussion between the Minkowskian and fragmentalist interpretation is precisely a discussion about whether the incompatible matters that appear to obtain from different perspectives must be considered mere appearances, and according to fragmentalism what varies across these perspectival representations can be every bit as real as what is invariant.

\(^{11}\) To be sure, Lange (forthcoming) appeals to the same sort of reasoning in motivating the explanation of the Lorentz transformation based on the invariance of spacetime interval. Here the reasoning is not question-begging because it is not under discussion whether what differs across frame descriptions can still be real. Invoking the reasoning against the fragmentalist is what is question-begging.
between them. When Hofweber and Lange motivate the standard order of explanation on the
grounds that ‘the facts related by the coordinate transformations are frame-dependent facts and
hence are appearances of that reality’, they are motivating the standard order of explanation
based on the presumed falsity of fragmentalism, even though this is what the objection is meant
to show.

Hofweber and Lange also argue that the standard explanatory order is preferred because
it is the explanatory direction adopted by current scientific practice. That the current scientific
community adopts the standard order of explanation is of course true. The scientific community
has of course not even considered the fragmentalist alternative. We all know that the scientific
community has adopted the Minkowskian interpretation, and hence it is entirely unsurprising
that they follow the explanatory directions they do. The only dialectically relevant issue is
whether they are right in doing so. On the assumption that the Minkowskian interpretation is
true, they are right in doing so. But the question under discussion is whether the Minkowskian
interpretation is true, or whether the fragmentalist interpretation might be better motivated.
Given that this is the question under discussion, to point out that, as a matter of fact, the current
scientific community adopts the Minkowskian interpretation is a red herring.

Hofweber and Lange also object to the fact that the Lorentz transformations come to
have the status of natural laws that are unlike the laws that we are accustomed to. Hofweber
and Lange point out (forthcoming: 5-6) 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). In contrast, the fragments are
obviously not related by cause-effect 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 introducing new kinds of physical laws would somehow be
a sign of its incorrectness. It would be odd if we evaluated new scientific theories in such a way. Being revisionary should not as such count against a view, the real question is whether the proposed revisions are good or not. As we saw, the offered reason for thinking that the revisions in explanatory directions is not good assumes what we are trying to figure out. We resist revisions until we have been given good reasons to adopt them; but I tried to spell out some positive reasons for fragmentalism in section 2.

Besides attacking the fragmentalist interpretation of the special theory of relativity, Hofweber and Lange finally argue that the lawlike coordination between fragments is a general problem for fragmentalism, including for fragmentalism about tense. The worry for the case of tense is as follows. They ask us to consider the following three facts:

(1) $e_1$ is present
(2) $e_1$ is earlier than $e_2$
(3) $e_2$ is future

They then ask:

[W]hy is every fragment such that it contains a fact of kind (3) when it contains facts of kind (1) and (2)? Why does reality fragment only in such a way that the present is earlier than the future? Why is there this uniformity among fragments? This, one might think, should be explained. On a standard realist picture of time and tense, (...) one possible explanation comes from the single temporal reality in which all temporal and tensed facts are related a certain way. But no such explanation seems open to the fragmentalist (Hofweber and Lange: 10).
It is not clear to me that there is a philosophically interesting explanatory demand of this kind, for any metaphysical theory of time. The explanatory demand effectively asks why the present is (always) earlier than the future. That the present is earlier than the future is either metaphysically necessary or it is not. If it is metaphysically necessary, then the answer is that it could not be otherwise, or that it follows from what it is for things to be present, future and earlier than another event. The question is then like asking why all triangles are trilateral. If it is not metaphysically necessary but contingent, then the question is like asking why \( F = ma \) holds in the actual world (if physical necessitism is false), or why the initial conditions of the universe are the way they are. There might then be some scientific explanation in terms of deeper contingent matters, or it is just how things happen to be in the actual world, in neither case of which the philosopher has much of interest to say. So, it is unclear why there is an interesting explanatory demand for any metaphysical view along these lines.

More important for the current dialectic, however, there is no asymmetry between the fragmentalist view of time and other views of time in the way it may answer this sort of explanatory demand. Each of the mentioned answers above are legitimate answers for the fragmentalist as well. She too may answer that things could not be otherwise or, alternatively, that this is just what the course of time is actually like. If we ask a standard tense realist why (3) is true whenever both (1) and (2) are true, imagine that her answer is that it just is. Of course she could also appeal to some kind of general fact instead, that for all events \( x \) and \( y \), if \( x \) is present and \( x \) is earlier than \( y \), then \( y \) is future. But the general fact itself just reports that this is how events, including \( e_1 \) and \( e_2 \), happen to be related in the world. I take it that this is what it would be for a standard tense realist to answer by appealing to ‘the single temporal reality in which all temporal facts are related a certain way’. The fragmentalist can legitimately offer the very same answers, this time appealing to the single fragmented reality in which all temporal facts are related a certain way. She too may appeal to a generalized fact, such as the fact that
for all events \( x \) and \( y \), if \( x \) is present \( \circ x \) is earlier than \( y \), then \( y \) is future \( \circ x \) is present. There is absolutely no reason why the fragmentalist is somehow restricted to describing single fragments, when stating general facts like these. The fact that the overall collection of facts exhibits a fragmented structure in no way means that we suddenly cannot appeal to the general patterns that, we assume, happen to hold amongst the overall collection of facts. The patterns in property distributions we find across fragments are the same sort of patterns of property distributions that we find across spatial regions or across different moments in time.

There will of course be generalizations within a fragmentalist view that involve the notion of co-obtainment, whereas no such generalizations are involved in other views simply because these other views have no use for the concept of co-obtainment. Indeed, there will be metaphysical laws that involve co-obtainment (such as that it is metaphysically impossible that an object’s being square co-obtains with its being round), whereas there are no such metaphysical laws on other views. But this is just the typical situation of different metaphysical views admitting different sorts of facts in their picture. To compare, say we have a view on which we accept relativized tensed facts. Such a view will posit facts concerning the assumed patterns of such temporally relativized facts. In this case we might for example assume a generalized fact of the form: for all events \( x \) and \( y \), and for all times \( t \), if \( x \) is present at \( t \) and \( x \) is earlier than \( y \), then \( y \) is future at \( t \). It would clearly be misleading to argue that other views do not need to assume this particular pattern concerning relativized facts and hence that this view is inferior to these other views. These other views will in turn have their own assumptions concerning the general coordination between contents across time.

If we ask how we know that these generalizations about the fragmented world hold, the answer here is the exact same as for any view and the generalizations it appeals to about the ways things are related in the world. We posit the generalizations on the same sort of evidential grounds as any view posits such generalizations: patterns in our observations, our grasp of the
nature of the properties involved, and so on. There is also no asymmetry between fragmentalist views and other metaphysical views of time in this epistemic regard, and hence no special epistemic problem for fragmentalism in taking the fragments to be coordinated in the way that other views assume the contents of moments of times are coordinated. There is therefore no reason to think that there is a general problem for fragmentalism in the assumed coordination of fragments. Hofweber and Lange have not offered any such reason.

The fragmentalist interpretation offers a new response to the sort of scenarios that otherwise motivate the Minkowskian conception of spacetime, one that preserves the properties in terms of which we seem to observe the world around us. If the variant properties are indeed instantiated, then they are not theoretical danglers but will naturally take on explanatory roles, filling out a meshwork of law-like patterns. Amongst these law-like patterns will be the patterns that underwrite the Lorentz’ transformations. The distribution of variant properties according to the Lorentz transformations grounds the invariance of the spacetime interval, on this view, and not vice versa. The resulting picture is clearly quite different from what we are used to, changing the standard explanations of things, and bringing the contents of the world in closer correspondence with how we experience things to be. Though different, I am not yet aware of any good reason to dismiss the view. The view seems clearly worthy of further attention. Standing out amongst the topics for further study is an investigation of fragmentalism’s bearing on the general theory of relativity and its standard interpretation as a theory that ‘geometrizes’ gravity. Perhaps this is where we will find good reasons in favour of the status quo.
References


