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Fine's Fragmentalist Interpretation of Special Relativity

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In "Tense and Reality", Kit Fine (2005) proposed a novel way to think about realism about tense in the metaphysics of time. In particular, he explored two non-standard forms of realism about tense ("external relativism" and "fragmentalism"), arguing that they are to be preferred over standard forms of realism. In the process of defending his own preferred view, fragmentalism, he proposed a fragmentalist interpretation of the special theory of relativity (STR), which will be our focus in this paper. After presenting Fine's position, we will raise a problem for his fragmentalist interpretation of STR. We will argue that Fine's view is in tension with the proper explanation of why various facts (such as the Lorentz transformations) obtain. We will then consider whether similar considerations also speak against fragmentalism in domains other than STR, notably fragmentalism about tense.

I. Fine's fragmentalism

Fine holds that the best form of realism about tense is "fragmentalism". Fragmentalism is the view that reality is not "of a piece" (p. 262)[1], but rather fragmented into different parts that cannot be joined together without contradiction: " . . . no two [fragments] can be regarded as belonging to a single coherent whole" (p. 262). Reality is thus partly constituted by facts that are incompatible with each other. However, no true contradiction results since for some pairs of facts, their conjunction is not a fact; a conjunction is a fact only if its conjuncts are "coherent". Some facts cohere with each other in that they belong to the same fragment of reality, while other facts belong to different fragments. Any fact belongs to a fragment, and a fragment is a "maximally coherent collection of facts" (p. 281), i.e., a maximal collection of facts that all cohere with each other. That two facts "cohere" is not to be understood in terms of their conjunction being a fact; the order of explanation might need to go in the other direction in order to distinguish the facts that go together, so to speak, from those that do not.[2] Therefore, Fine says, " . . . one might want to take the notion of coherence as fundamental . . . " (p. 281). Coherent pairs of facts belong to a common fragment, while other pairs of facts belong to no common fragment. Nonetheless, all of these facts make up reality and all of these fragments are real.

Let's illustrate fragmentalism with Fine's primary example: realism about tense. Reality consists of tensed facts such as the fact that 2014 is the present year, that 1975 is a past year, and so forth. These facts are not relative to some time, as would be the fact that 2014 is the year present in 2014, or that 2014 is the year of this very utterance. Rather, tensed facts are absolute facts such as the fact that

2014 has the property of being present (simpliciter!). A standard realist about tense holds that only one fact of the form "X is the present year" is among the facts that constitute reality. By contrast, the fragmentalist holds that all facts of the form "X is the present year" are partly constitutive of reality: 2014 is the present year, 2015 is the present year, 1785 is the present year, and so on. The same applies to all facts of the form "X is a past year" and "X is a future year". Reality contains all of these. However, that 2014 is the present year and that 2015 is the present year are incompatible facts in that they do not "cohere" with each other. But instead of concluding that reality is contradictory, Fine's fragmentalist accepts that reality is instead "not of a piece", but rather fragmented in being broken into smaller, coherent pieces that cannot coherently be joined together. Fragments correspond to maximal sets of facts that can be coherently joined together. One fragment contains the facts that 2014 is present and that 2015 is future (and many other facts), while a different fragment contains the facts that 2015 is present and that 2014 is past (and many other facts). Thus the fragmentalist picture consists in an "über-reality" (p. 281) that contains a myriad of tensed facts, many of which are incompatible with each other. This über-reality fragments into parts such that any two facts in the same fragment are compatible with each other. All of the tensed facts in every fragment are absolute facts, not relative to a time or a fragment or anything else. Fragmentalism thus is a radically non-standard form of realism about tense and, Fine argues, is the best form of realism about tense.[3]

Fine's primary aim in his (2005) is to discuss fragmentalism and other standard and non-standard forms of realism about tense. In this connection, he notes that any such realism seems to be incompatible with the special theory of relativity (STR) for well-known reasons: STR denies absolute simultaneity and with it an absolute notion of the present. The notion of the present seems to makes sense only relative to an inertial frame and a time—that is, Fine says, only relative to a "frame-time". But such a relativity seems to be incompatible with realism about tense, be it standard or non-standard realism. To avoid this incompatibility, Fine proposes not merely a fragmentalist realism about tense, but also a fragmentalist interpretation of STR according to which reality fragments into parts each of which corresponds to a particular frame-time. Each of these fragments has a traditional "Newtonian"[4] separation of time and space, allowing for absolute simultaneity and thus an absolute notion of the present. Instead of reality forming one unified Minkowski spacetime, it fragments into many Newtonian parts, each fragment corresponding to what traditionally would be regarded as holding relative to a given inertial frame at a given moment.

Furthermore, instead of the spatial and temporal features of objects being the appearances (relative to a frame) of 4-dimensional objects in spacetime, fragmentalism takes objects in each fragment to have absolute spatial (3-dimensional) and temporal features, where the objects have different spatial and temporal features in different fragments. Just as the year 2014 has in one fragment the absolute property of being the present year and in another fragment the absolute property of being the past year, so likewise a given piece of paper has in one fragment the absolute property of being square and in another fragment the absolute property of being

a non-square rectangle (where the latter fragment corresponds to an inertial frame that is moving relative to the inertial frame corresponding to the former fragment, thereby yielding length contraction of two sides of the object parallel to the direction of motion). The fragmentalist interpretation of STR thus takes fragmentalism further than fragmentalism merely about tense. It is a non-standard form of realism about the features of objects that are not invariant among inertial frames. Fragmentalism about tense is congenial to and naturally associated with this fragmentalist interpretation of STR, and Fine suggests that a combination of both is the best form of realism about tense.

Fragmentalism is a radical and intriguing view.[5] We cannot hope to assess comprehensively here whether fragmentalism in general is a live option[6] or, in particular, whether fragmentalism about tense is correct, although we will return to these questions in sections 3 and 4. Instead we will focus on Fine's fragmentalist interpretation of STR. We will argue in section 2 that the fragmentalist interpretation of STR is problematic, since it is at odds with the best explanation of why various relations (notably the Lorentz transformations) hold between inertial frames. Fragmentalism must regard as brute certain relations between "fragments" that have explanations on the standard interpretation of STR. Because such relations would not be expected if fragmentalism obtained, these relations count as empirical evidence against fragmentalism. In section 3, we will examine a potential fragmentalist reply to our argument. In section 4, we will consider whether our objection to the fragmentalist interpretation of STR applies to fragmentalism more generally.

II. A problem for the fragmentalist interpretation of STR

As Fine notes about his fragmentalist interpretation of STR, "The resulting metaphysical view is quite remarkable" (p. 306). It is indeed strikingly different from the standard interpretation of what reality under STR is like. However, there is reason to think that the fragmentalist position is wrong and a more standard view is right.

On the standard interpretation of STR, descriptions made from different inertial reference frames are equally accurate and are on a par as descriptions of reality. For instance, that a given body moves uniformly with speed s1 in inertial frame f1 and moves uniformly with speed s2 (unequal to s1) in inertial frame f2 are both true. They are on a par as descriptions of reality because neither of these reference frames is privileged in being at absolute rest, so neither of these speeds is the body's absolute speed (since there are no absolute speeds), so a description from neither reference frame captures the body's absolute speed. Absolute speeds, while logically compatible with STR, could not have any role in the laws of nature and so would be undetectable even in principle, according to relativistic mechanics. They would be surplus ontological structure; we are justified in believing them not to exist. This is a familiar interpretation of STR and accordingly Fine (2005: 298) is concerned to render fragmentalism compatible with it.

What is radical about fragmentalism (in the STR context) is not that it regards the collection of tensed facts associated with one (frame-)time as ontologically on a par with the collection of tensed facts associated with another (frame-)time. So

far, this is just part of the standard interpretation of STR. Rather, what is radical about fragmentalism is that it regards both of them as *fundamental* rather than as derivative from a more fundamental reality consisting of facts that are invariant across different (frame-)times:

> It is very tempting to want to explain away the contradiction that the fragmentalist claims to find in the facts. The facts themselves, one wants to say, cannot be incompatible; and so lying behind the "facts" that the fragmentalist takes to be incompatible must be facts that are compatible and that are what are really in question. Thus it is not the fact that I am sitting and the fact that I am standing that belong to reality but the fact that I am sitting at t and the fact that I am standing at t′; and if not that, then something else of that same sort. But the fragmentalist, like all realists about tense, is animated by a robust sense of the inviolably tensed character of the facts. In relativizing them, they are destroyed. Combine this sense of what the facts are like with an egalitarian and undifferentiated view of what they are and her position is forced upon one. (Fine 2005: 282)

Fragmentalism's "egalitarianism" is problematic, it seems to us, only when it is combined with such "a robust sense of the inviolably tensed character of the facts" that it takes frame-dependent facts to be fundamental rather than derivative from frame-invariant facts such as facts about the spacetime intervals between various events. The standard interpretation of STR is not merely that the facts associated with different inertial reference frames are on a par, but also that they are not fundamental. Instead, "tenseless" facts about four-dimensional Minkowski spacetime are fundamental, and their "tensed" projections onto various reference frames are derivative from them. Here is a typical expression of this interpretation of STR:

> [A]n observer on the earth sees and measures an oblong block; an observer on another star contemplating the same block finds it to be a cube. Shall we say that the oblong block is the real thing, and that the other observer must correct his measures to make allowance for his motion? All the appearances are accounted for if the real object is the four-dimensional, and the observers are merely measuring different three-dimensional appearances or sections; and it seems impossible to doubt that this is the true explanation. (Eddington 1920: 181)

We regard this view as very plausible and (not coincidentally) embodied in various features of scientific practice in connection with STR. Insofar as fragmentalism sets its face against this view, it is implausible and in tension with scientific practice.

Why is this interpretation of STR plausible? At STR's heart are laws of nature specifying relations between the "tensed" facts in different inertial reference frames. The most famous of these relations are the Lorentz transformations, which specify the relations between spacetime coordinates in different inertial frames; there are similar relativistic transformation equations for every other physical fact (e.g., the electric field at a given spacetime coordinate, the pressure there, the charge density there). If reality consists fundamentally of "fragments" corresponding to the facts that hold relative to frame-times, then there is no reason for there to be laws relating the facts that these different fragments contain. On the other hand, if the tensed facts in these fragments are instead projections onto various reference frames of

tenseless facts about four-dimensional Minkowski spacetime, then there is every reason to expect there to be laws relating facts in different frames, since those laws govern the way in which the four-dimensional reality is projected onto different spacetime coordinate systems.[7]

Here is one way to put this point. Two events (that do not take place at the same place at the same time in an inertial frame) have a spatial separation and a temporal separation that differ in different inertial frames. On STR's standard interpretation, these separations in any frame have only derivative reality; they are grounded in the spacetime interval between these events. That real quantity is decomposed differently into spatial and temporal components in different frames, and that is why the events' spatial and temporal separations are frame-dependent. The spacetime interval is frame-invariant and is more fundamental than any frame-dependent fact (such as a tensed fact associated with some "frame-time"). This is the standard view:

> Invariants—quantities that everybody agrees on regardless of their frame of reference—play a more important role in our understanding of the world than quantities that vary from one frame of reference to another. (Mermin 2009: 79)

On this view, the tensed facts are mere appearances of a tenseless underlying reality. Two events' spatial and temporal separations in different frames have a common explanation in the spacetime interval separating the events; the former hold partly in virtue of the latter. Because the tensed facts have a common explainer, there is good reason for there to be a law relating them: the Lorentz transformations. By contrast, fragmentalism says that there is no such common explainer; the tensed facts relative to each frame are all fundamental. So there is no reason for there to be a coordinate transformation law relating them.[8]

This argument does not show that fragmentalism is somehow metaphysically impossible. The coordinate transformation laws could be brute, i.e., have no explanation. Some laws are presumably fundamental, and the coordinate transformation laws could be among them. Nevertheless, it seems implausible for them to be brute. We might expect the laws governing, say, the various fundamental interactions (or the "grand unified field") to be brute. But none of these laws includes the coordinate transformation laws.

According to fragmentalism, the coordinate transformation laws connect fundamental, distinct "fragments" of reality. Of course, laws of nature typically relate distinct events or facts, so fragmentalism's depicting the coordinate transformation laws as doing so does nothing to make fragmentalism implausible. But when laws of nature relate distinct events or facts, they generally do so for certain familiar reasons. Some laws relate causes to their effects, as when laws relate electric charges to the forces they cause or relate forces to the accelerations they cause. But fragmentalism does not depict events in one "fragment" as causes of events in another. Similarly, some laws specify the correlation between joint effects of a common cause, but once again, fragmentalism does not depict events in different fragments as having a common cause. In addition, some laws relate the ground of a disposition to the disposition it grounds, such as a law relating an element's atomic

structure to its chemical activity. But this is obviously not the way to understand the transformation laws. That laws relating ontologically fundamental fragments would be *sui generis* does not show that they are impossible. But it does show that fragmentalism has an explanatory weakness compared to a rival view according to which the "fragments" are mere appearances of a common underlying reality.

Here is another way to put our point. Since fragmentalism (F) offers us no reason to have expected that C (that there are coordinate transformation laws), our rational subjective credences are such that cr(C | F) is low.[9] On the other hand, if it is the case that A (that the "fragments" are mere appearances of a common underlying reality), then we would expect there to be coordinate transformation laws since the fragments would be manifestations of a common explainer; hence, cr(C | A) is high. By the law of likelihood, C supports A over F.

We believe that for related reasons, fragmentalism runs contrary to scientific practice. Scientists do not treat the coordinate transformation laws as brute facts. Rather, scientists explain why the transformation laws hold by deriving them from more fundamental laws. These explanations typically work by showing how the transformations result from the invariance of the spacetime interval.[10] Why does the spacetime interval's invariance count as explanatorily prior to various other facts, such as the transformation laws?[11] 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?[12] 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.[13] 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.

That is why the spacetime intervals' invariance takes explanatory priority in scientific practice over the Lorentz transformations, the relativistic velocity addition law, and the relativity of simultaneity, for instance. Fragmentalism would have to offer a different account of the order of explanatory priority in these cases. Alternatively, fragmentalism could deny that scientific practice is correct in taking the coordinate transformation laws, the relativistic velocity addition law, and the relativity of simultaneity as explanatorily posterior to the spacetime interval's invariance. But ordinarily we need a very powerful reason for rejecting such an element of scientific practice.[14]

In doing violence to scientific practice, fragmentalism sets itself against some of the most powerful original motivations for STR. Consider, for instance, Einstein's opening argument in his first paper on STR—the argument that, Einstein later wrote, "led me directly to the Special Theory of Relativity" (Holton 1973: 285). The argument begins with the fact that (according to Maxwell's electromagnetic theory, as interpreted in classical physics) the electromotive force produced when an electrically conductive wire moves uniformly through a uniform unchanging magnetic field (as exists inside a solenoid at rest, through the coils of which a constant current flows) is equal to the electromotive force produced when the wire

and field (that is, the solenoid) have exactly the same relative motion as before, but now the field (that is, the solenoid) is moving while the wire is at rest. What (Einstein asks) explains the fact that the two forces (a magnetic force in the former case, but an electric force in the latter) are equal? Of course, it could simply be a brute fact about the fundamental laws of electricity and magnetism, as classical physics must say. But Einstein found this interpretation "unbearable" (Holton 1973: 363–4). On his view, a much more plausible explanation is that what appear to be two distinct cases are in fact the same single reality as seen from different frames. On this interpretation, the frame-invariant reality of an electromagnetic field is explanatorily prior to the frame-dependent appearances of various combinations of electric and magnetic fields in different frames. It is not clear to us how a fragmentalist could do justice to Einstein's argument here.[15]

For these reasons, fragmentalism seems remote from the unifying impulses that motivate STR. As Wilhelm Wien put the argument for STR in 1909:

> What speaks for it most of all is the inner consistency which makes it possible to lay a foundation having no self-contradictions, one that applies to the totality of physical appearances. (as quoted in Holton 1980: 58)

These strengths of STR seem alien to the spirit behind fragmentalism.

Although we have been critiquing fragmentalism in the context of STR (where the "fragments" are indexed to frame-times), our arguments apply *mutatis mutandis* to fragmentalism in the context of classical physics (where the fragments are indexed simply to times). The Galilean transformations in classical physics are generally taken to be explained in precisely the same way as the Lorentz transformations are in STR (see Lange 2013). The invariants among the various fragments in classical physics (such as the temporal order and separation among events) are obviously different from the invariants in STR. But the same issues arise concerning the explanation of the relations among the fragments. Fragmentalism would seem to have difficulty accounting for any kind of coordination among the fragments.

III. Fragmented reality as explainer?

Our main argument in the previous section concerned the possibility of explaining why the fragmentalist's fragments are coordinated in certain ways and the order of explanatory priority in these explanations—for instance, the order of explanatory priority in accounts of why the Lorentz transformations hold. Facts about reality explain why frame-dependent facts in different frames stand in certain relations.[16] And this, we argued, is contrary to fragmentalism, where the explanatorily basic parts of reality are the coherent fragments, not reality as a whole (since this whole is not coherent). But could the fragmentalist also accept that the order of explanation is as we claim it is? To do so, the fragmentalist would have to hold that über-reality explains why the coherent fragments of it stand in certain relations. In particular, in the case of STR, the fragmentalist would have to hold that the explanation of the Lorentz transformations given above is compatible with reality being fragmented.

On this view, a fragmented reality can explain why the fragments stand in certain relations.

However, there is reason to think that this reply is not available to the fragmentalist. Whether this is in the end correct will depend on how fragmentalism is to be understood more precisely—in particular, how to understand certain aspects of it that Fine did not spell out completely. As we will argue in the next section, these issues also affect fragmentalism about tense directly. But let's first look at why it would seem that fragmentalism cannot accept the proposed order of explanation in accounting for why the Lorentz transformations hold between two fragments.

To better appreciate the obstacle that Fine's fragmentalist faces, let's think about how über-reality in STR could explain a relation among the fragments, such as that the spacetime coordinates of a given event e1 in two fragments (f and f′) conform to the Lorentz transformations. Über-reality consists simply of an enormous incoherent collection of facts, including various assignments of spacetime coordinates to e1 and to other events. For the Lorentz transformations to relate all of the events' spacetime coordinates in f to all of the events' spacetime coordinates in f′, über-reality's collection of facts would have to divide into fragments in a very particular way. After all, if a given fragment f contained the event e1 with its spacetime coordinates from one inertial frame and another event e2 with its spacetime coordinates *from some other inertial frame*, then we would not in general expect the Lorentz transformations to hold between these events' f-coordinates and their coordinates in another frame f′. So to explain why the Lorentz transformations hold, we would need to explain why certain facts but not others belong to the same fragment. Presumably, the notion of coherence carries this explanatory responsibility: various facts belong to the same fragment because they cohere. But if coherence is primitive, then the explanation is bound to be rather thin, if it would count as an explanation at all. One might explain why two facts cohere by pointing out that each of these facts is derivative from certain other, more fundamental facts, which in turn cohere. But why fundamental facts cohere will have no explanation or, at least, it is hard to see how the fragmentalist who takes "the notion of coherence as fundamental" (p. 281) could give one.

As we saw in the previous section, the standard explanation of why the Lorentz transformations hold appeals to the fact that the spacetime interval between a given pair of events is frame-invariant; it is equal in all inertial frames. But according to fragmentalism, the interval between e1 and e2 in f is equal to the interval between e1 and e2 in f′ by virtue of each event's spacetime coordinates in f and f′.[17] If e1's spacetime coordinates are those it has in f and e2's spacetime coordinates are those it has in f′, then the interval between e1 and e2 in the resulting fragment will not equal the interval between e1 and e2 in a genuine fragment. Once again, then, for the spacetime interval's invariance to be available to help explain why the Lorentz transformations hold, über-reality must divide into fragments in a particular way, and to explain why it does so, there seems nowhere for fragmentalism can turn except to the notion of coherence. But it is hard to see how the division of über-reality into fragments can be anything but a brute fact if the notion of coherence is unanalyzed.

To repeat our main point for a simple case, consider a square object at rest in one frame and the same object in uniform motion parallel to two of its sides in another frame. In the frame where it is in motion, the length of its sides parallel to its motion will be contracted, and thus the object will not be square. What explains this systematic connection between length and relative movement? The standard explanation is that a single 4-dimensional reality with an invariant spacetime interval presents itself in different frames as separating differently into space and time. But fragmentalism does not have the resources to give this or any similar explanation. For fragmentalism, there simply is an association between the coherence of the fact that x is a square with the fact that x is at rest, which thus both occur in one fragment, and the coherence of the fact that x is moving with the fact that x is not a square, which thus both occur in a different fragment. But why there is such an association between the coherence of the one pair of facts and the coherence of the other pair cannot be explained further. Since Fine's fragmentalist takes the notion of coherence as fundamental, there is little hope for more of an explanation.

Although coherence is a fundamental notion (i.e. is not to be spelled out in other, more basic terms) in Fine's articulation of fragmentalism, perhaps there are general constraints on coherence. Fine briefly mentions that there might be rules of coherence, analogous to logical principles, and he gives the transitivity of the coherence relation as a possible example (p. 281). It seems entirely plausible that the coherence relation in general is governed by such principles, and its being fundamental does not conflict with its being constrained by general principles such as transitivity. But such general principles concerning the coherence relation are not likely to help our fragmentalist in the cases we have discussed here. These cases do not concern the general "structural" features of the coherence relation, but rather the substance of which particular facts do and do not cohere. That a certain fact does not cohere with another one (thereby avoiding an exception to the Lorentz transformations) is not about the logical properties of coherence, but instead about instances of the coherence relation directly. Although logical principles are unproblematic, they will not help the fragmentalist to explain why the Lorentz transformations hold. An incoherent über-reality together with a fundamental coherence relation does not seem to give the fragmentalist sufficient resources with which to do this.

We could stipulate that a scheme succeeds in grouping various facts into "coherent" fragments only if those fragments obey the invariance of the spatiotemporal interval. But this stipulation would merely insert "by hand" into the notion of coherence what that notion was supposed to help to explain.

IV. A problem for fragmentalism generally?

Our target in this paper was Fine's fragmentalist interpretation of STR. But the problem we found there can naturally be seen to afflict many other forms of fragmentalism, including Fine's main concern: fragmentalism about tense. The problem seems to arise as long there must be some harmony between the fragments, that is, some general coordination between the various aspects of reality that the fragmentalist would like to place in different fragments. On a standard realist account

(as on a standard interpretation of STR), this coordination has an explanation: the whole of reality is a certain way that leads to some general relations among times, or tensed facts, or locations, or selves, etc. But a fragmentalist will have few resources to explain why there is this harmony across the fragments, that is, why there is a particular restriction on which facts cohere with which facts.

Let us see how this problem arises for fragmentalism about tense because of the harmony it requires among fragments. Fragmentalism about tense is a form of realism about tense, although a non-standard one. In particular, properties like the property of being future are *sui generis* properties of events, and not simply to be understood as the property of being later than this very inscription or the like. Consider now these three facts:

(1) e1 is present
(2) e1 is earlier than e2
(3) e2 is future

Any fragments, according to Fine's fragmentalist about tense, that includes (1) and (2) will also include (3). Among the basic tensed facts concerning e2, only (3) is coherent with all the other facts in the fragment; for instance, the fact (by the fragmentalist's lights) that e2 is past (or that e2 is present) is incoherent with (1) and (2). This captures, in a way, that the direction of time is uniformly from the present to the future. But why is every fragment such that it contains a fact of kind (3) when it contains facts of kinds (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, as well as on various relativist pictures (including Fine's external relativism), 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 to be open to the fragmentalist. There is no single coherent reality, only coherent fragments. To explain why these fragments are harmonious in this way comes down to explaining why coherence always includes (3)-type facts when it builds a maximal collection of facts that includes (1)- and (2)-type facts. Or to put differently: why is it the case that in each and every fragment in which events are ordered by the earlier-than-relation, all those earlier than the ones that are present are past, and those later are future? Why do only those cohere with each other? Since coherence is fundamental, it seems that no such explanation can be forthcoming from a fragmentalist. A non-fragmentalist, on the other hand, can give such an explanation. Therefore, fragmentalism is worse than standard forms of realism in that they can explain what it cannot, but should.[18]

Notes

[1] All page references are to Fine (2005), unless otherwise noted.

[2] Fine does not settle on whether it is the case that for any two facts that cohere, there is also their conjunctive fact. Even if a conjunctive fact obtains only if its conjuncts cohere, Fine suggests that

conjunctive facts may not be fundamental, but instead "may disappear from reality ... in favor of their conjuncts" and the coherence of the conjuncts (p. 281). Thus coherence would be more fundamental than the obtaining of conjunctive facts.

[3] See pp. 286–307 for Fine's arguments that non-standard realism is to be preferred, and especially pp. 307–10 for his discussion of why fragmentalism is the preferred form of non-standard realism.

[4] Fine uses "Newtonian" to characterize each fragment's space-time (p. 308). By this, we take it, he means that each fragment's spacetime separates cleanly into space and time, unlike Minkowski spacetime where the fundamental facts involve both space and time. Fine's characterization of spacetime in fragmentalist STR as "Newtonian" does not involve the claim that Newton's laws of motion hold in any fragment. Relativistic rather than Newtonian dynamics would prevail; the speed of light would be a limiting speed for initially sub-luminal material bodies, for example.

[5] For more on fragmentalism in general, see also Lipman (2015).

[6] See Hofweber (2015) for some worries about fragmentalism.

[7] The notion of a "reference frame" may be taken more broadly—as including a coordinate system (a certain kind of assignment of four numbers to events)—or more narrowly (so that a mere shift in the origin or spatial rotation of the coordinate axes does not count as a change in the reference frame). In relating the spacetime coordinates in different inertial frames, the Lorentz transformations concern relations among inertial frames in the broader sense. (However, confusion is mitigated by the usual practice of taking the coordinate systems to which the usual form of the Lorentz transformations apply as having to be in the "standard configuration": the corresponding primed and unprimed coordinate axes are parallel, the origin of the spatial coordinates in the primed frame is moving uniformly in the unprimed frame with speed v in the +x direction, the spatial origins of the two frames coincide when the times at each are zero, the frames are equivalent when $v = 0$.) Of course, a coordinatization is conventional. Nevertheless, we will speak of the "facts" in a given reference frame with the understanding that these include facts about events' coordinates in two frames in the broad sense—or, equivalently, in two frames in the narrow sense *under a given pair of coordinate systems* (in "standard configuration"). The Lorentz transformations thus specify relations between frame-dependent *facts* in different inertial frames. Of course, on the fragmentalist picture in which reality consists of fragments indexed by frame-times, there are distinct fragments corresponding to distinct frame-times in the narrower sense of "frame" (but not for two frames in the broader sense that are not distinct in the narrower sense). Nevertheless, for a given frame in the narrower sense, there are facts in this fragment about events' coordinates *under a given coordinate system*. The Lorentz transformations are relations among the facts in different fragments where these are facts about events' spacetime coordinates there under certain coordinate systems.

Rather than focusing on relations among events' coordinates in different frames (or different fragments, according to fragmentalism), we could have focused our attention instead on relations among other kinds of frame-dependent facts in different frames—facts that hold independently of the choice of coordinates, such as lengths in different frames. However, we will focus on the Lorentz transformations, since they explain phenomena such as length contraction. (After all, the transformations also hold independently of the choice of coordinates.)

[8] Of course, even on a fragmentalist picture, there remains a reason *to believe* that there are coordinate transformation laws—in particular, the Lorentz transformation laws. (The empirical evidence for the Lorentz transformations includes the experimental fact that light's speed is the same in all inertial frames.) But it is important to distinguish a reason for us to *believe* that there are coordinate transformation laws (or the Lorentz transformations in particular) from a reason for there to *be* coordinate transformation laws (or the Lorentz transformations in particular). Our argument fundamentally concerns scientific explanation, not empirical evidence. Although the standard and fragmentalist interpretations agree on the empirical evidence for the transformation laws, they differ on those laws' scientific explanations (just as Darwinism and creationism agree on the empirical evidence for the anatomical similarities among various mammals, but differ on the scientific explanations of those similarities). This disagreement over explanations is to be expected considering that the standard and fragmentalist interpretations disagree on whether the invariant quantities (such as the spacetime interval between two events) are ontologically prior to the frame-dependent quantities (the events' spatial and temporal separation) or vice versa.

[9] Here we are assuming that the "problem of old evidence" has been solved so that our $cr(C \mid F)$ can be low despite the fact that C is "old evidence".

[10] For a fuller account of the history of these explanations and how they work, see Lange (2013).

[11] Colyvan (2001: 50–1), following Smart (1990: 17), also says that the spacetime interval's invariance helps to explain (noncausally) why the Lorentz transformations hold.

[12] This question is analogous to other famous questions about the order of explanatory priority, such as why the height of the flagpole explains the length of its shadow rather than the other way around, when either (together with the same additional premises) entails the other. The standard answer to the flagpole question is that the height of the flagpole causes the length of its shadow, not the other way around. Of course, this answer does not carry over to the question about the spacetime interval's invariance and the transformation laws since these are both laws, not events in spacetime, so neither is a cause of anything.

[13] This is the answer offered in Lange (forthcoming).

[14] See note 12; it would be a courageous account of scientific explanation that held that in fact, contrary to scientific practice, the height of the flagpole is explained by the length of its shadow.

[15] For a fuller discussion of Einstein's argument, see Lange (2002: 186–99).

[16] Our argument above is similar in style and spirit, but different in target, from Yuri Balashov's argument, in Balashov (1999), that special relativity supports perdurance over endurance as the correct metaphysics of persistence. Balashov argues that the correct explanation of why the 3D shapes of objects in frame-times are coordinated across frames is that these 3D shapes are appearances of an underlying 4D object, as perdurance would have it. Balashov's argument, in particular, is an explanatory argument, like ours. In case of Balashov's argument, endurantists could attempt to give a different explanation of why this coordination occurs across frames, or at least argue that endurantists are no worse off here than perdurantists. Several authors have attempted to do this, in particular Sider (2001: 79–87), Gibson and Pooley (2006: section 6), and Sattig (2006). See Gilmore (2008) for more on this general debate, and Balashov (2010: chapter 8) for his replies. The present section of the main text hopes to make clear that no similar strategy for responding to our argument in the previous section is open to Fine's fragmentalist.

[17] If space and time were instead unified into a single entity (Minkowski spacetime) that was more fundamental than its spatial and temporal appearances in a particular frame, then it would not be the case that the interval between e1 and e2 in f holds in virtue of e1's and e2's spacetime coordinates in f. But according to fragmentalism, the fragments are not derivative from a more fundamental coherent reality; space and time in each fragment are "Newtonian".

[18] Our thanks to Yuri Balashov, Cody Gilmore, and Martin Lipman for comments on an earlier version.

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