

Temporal Parts and Superluminal Motion

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Abstract: Hud Hudson has recently suggested a scenario intended to show that, assuming the doctrine of temporal parts and a sufficiently liberal view of composition, there are material objects that move faster than light. I accept Hudson's conditional but contend that his modus ponens is less plausible than the corresponding modus tollens. Reversed in this way, the argument stemming from the scenario raises the cost of mereological liberalism and advances the case for a principled restriction on diachronic composition.

Is superluminal motion possible in a physically interesting sense? The usual answer based on relativity theory is no. Consider a point event p in Minkowski spacetime. The light cone centered on p imposes an objective (i.e., frame-invariant) partition of the relativistic spacetime into three regions (Figure 1): the *absolute future of p* , which contains events that are later than p in any frame of reference and thus could be causally influenced by p ; the *absolute past of p* containing events that are earlier than p in any frame and that could causally influence p ; and the *absolute*

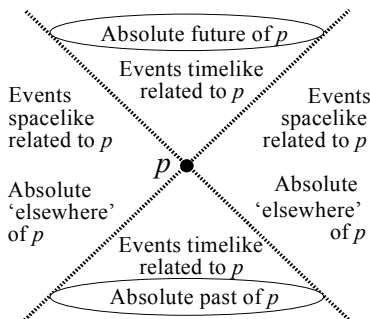


Figure 1. Objective partition of Minkowski spacetime by the light cone (dotted lines) centered on event p . Time goes from bottom up. One dimension of space is suppressed.

'elsewhere' of p , the set of events that bear no objective temporal order to p . For any such event, there is a frame of reference in which it occurs earlier than p , another frame in which it occurs later than it, and another one in which it is simultaneous with p . Such an event cannot have any causal relation to p .

Geometrically speaking, the ban on superluminal motion boils down to the requirement that any worldline of a point-like material object (such as O in Figure 2a) passing through p be confined to the absolute past and future of p . But in the 1960s and early 1970s physicists debated the notion of hypothetical particles (called tachyons) violating this restriction and moving faster than light. In Figure 2 O^* represents the worldline of a tachyon. Given what has just been said about the absence of objective temporal order between events lying in the absolute 'elsewhere' of each other, there is a frame of reference (x', t'), in which O^* moves 'backwards in time'. This could perhaps be seen more explicitly in another Minkowski diagram (Figure 2b) representing the same state of affairs from the point of view of object O .

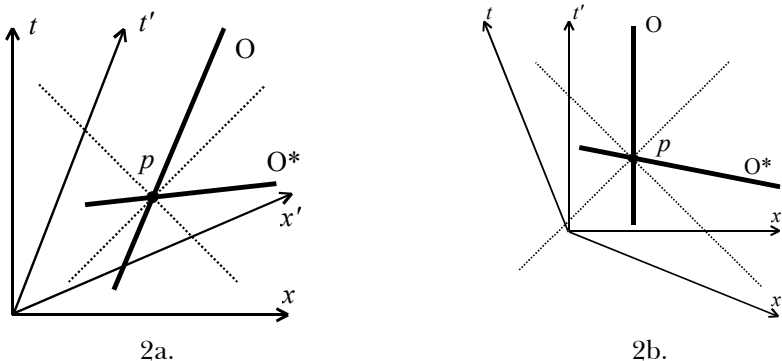


Figure 2. O is a 'normal' material object and O^* is a tachyon. The dotted lines depict the light cone centered on p . Two spatial dimensions are suppressed in these diagrams. Both diagrams represent the same situation. But (2b), which is drawn from the point of view of object O (whose worldline thus becomes vertical in this representation), makes it perspicuous that the tachyon O^* moves 'backwards in time' in reference frame (x', t') .

The interest in tachyons has since faded away, although one still comes across sporadic articles about them in the literature. But one can also approach the issue of superluminal motion from a more metaphysical angle. Hud Hudson has recently argued that a (this-worldly) possibility of superluminal motion can be demonstrated on metaphysical grounds.¹ He has suggested a thought experiment intended to show that, assuming the doctrine of temporal parts and a sufficiently liberal view of composition, there are material objects that move faster than light, in fact, as fast as you want. Furthermore, unlike tachyons, they accomplish this feat without moving backwards in time.

I accept, with a minor amendment (explained below), Hudson's conditional statement but am inclined to turn his reasoning around: given that his thought experiment does not support any non-trivial or physically objectionable sense in which superluminal motion is possible, we have little reason to regard Hudson's superluminal objects as genuine entities. In my mind, a welcome outcome of this turn-about is that it bolsters the case for restricted diachronic composition.

To set these claims in context, I begin by giving a simplified version of Hudson's scenario. This will help to make it explicit that the scenario is indeed physically innocent.² I will then provide my reasons for turning Hudson's argument on its head.

1 In a paper first read at the session of the Philosophy of Time Society in Seattle, Washington, USA, in March 2002. A version of this paper has since been published as Hudson (2002).

2 Hudson (2002) does not deny that his superluminal objects do not present any threat to the well-known relativistic restrictions. But he does not make it explicit either. In fact, his opening statement is intriguing enough to produce (if only for a moment) an impression to the contrary:

Any schoolchild will tell you that nothing moves faster than light. ... Notwithstanding this cloud of witnesses ... I would like to offer a reason to think that not only are there material objects that move faster than light (without moving backwards in time), but also that, for any multiple of the speed of light you might care to specify, there are materials objects that move at that speed (Hudson 2002, p. 203).

The schoolchild's conviction that nothing moves faster than light comes, of course, from the bits and pieces of relativity picked up at school and on public television. And this, in

I.

Imagine a Flatland world in which material objects are extended in at most two spatial dimensions. Add another dimension for time. Assume, with Hudson, the doctrine of temporal parts, the view that objects persist through time by having distinct temporal parts at different moments (rather than by being wholly present at multiple moments). Statements about n -dimensional objects of the familiar world can be translated into corresponding statements about $(n-1)$ -dimensional objects populating Flatland but with the advantage of having a vivid graphic illustration. (It's hard to draw diagrams in four dimensions.)

Consider a rectangular, 'solid', material object ABCD (call it 'Rectangle'). Assume that it is composed of non-denumerably-many, one-dimensional, cross-sectional, thread-like spatial parts, some of them represented by the lines filling ABCD in Figure 3. (This assumption, and especially its real-world three-dimensional version, is, as Hudson notes, genuinely controversial, but I am not concerned to take issue with it here.) Rectangle persists over time by having a distinct temporal part at every moment of its existence and, in the course of its career, fills up the spatio-temporal region ABCDEFGH (Box).

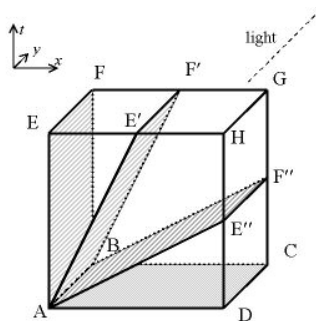


Figure 3. Thread, SlowThread, FastThread.

turn, makes it natural to suspect an anti-relativistic overtone in Hudson's opening statement.

Now focus on one of Rectangle's threads, AB, and the complete series of AB's temporal parts lined up along the rectangle ABFE. This rectangle represents an object (call it "Thread") extended in one spatial and one temporal dimension. Thread is a fusion of its temporal parts, each occupying exactly the same region of space. This means that Thread is at rest (in the given reference frame (x, y, t)). Another thing to note about Thread is that it occupies a timelike slice of Box.

Next consider a different timelike slice ABF'E' of Box. It is occupied by another persisting object, SlowThread, which is a fusion of non-denumerably-many one-dimensional objects, each of them being a temporal part of a distinct thread of Rectangle ABCD. At every instant SlowThread occupies a different region of space. This means, on what Hudson calls 'a reasonably orthodox view' (I fully subscribe to it), that SlowThread is in (subluminal) motion. This motion is obviously continuous.

Finally, consider a third object, FastThread, occupying a *spacelike* slice ABF''E'' of Box and composed, again, of one-dimensional temporal parts of different threads of Rectangle. FastThread is also in continuous motion, but unlike its slow partner, it moves faster than light. Clearly, there are lots of objects like FastThread. There are also objects that start out slowly and then accelerate beyond the speed of light, thus breaking the light barrier, something that even tachyons cannot do.³

One residual worry may be that FastThread and its ilk are only two-dimensional objects (counting one temporal dimension), not full-blown three-dimensional objects populating Flatland. It would be good to find a relative of FastThread that was just as fast but occupied a two-dimensional region of space at each moment of its existence. (Its real-world counterpart would occupy a three-dimensional volume of space at each moment.) Figure 4 depicts such a relative, ThickThread. It is

³ The latter are *always* in the superluminal domain. According to relativistic physics, no material object can accelerate to the speed of light (let alone break the light barrier) as this would require an infinite amount of energy. In this respect Hudson's proposal appears to be especially provocative.

constructed by slightly extending the rectangle $ABF''E''$ in the x dimension of space. At every moment ThickThread occupies a different region of space and thus moves as fast as FastThread, ‘despite dragging a tail behind’ (in Hudson’s apt expression (2002, p. 205)). Unlike FastThread, it is a genuine Flatland analog of four-dimensional ‘thick’ perduring objects of the real world.

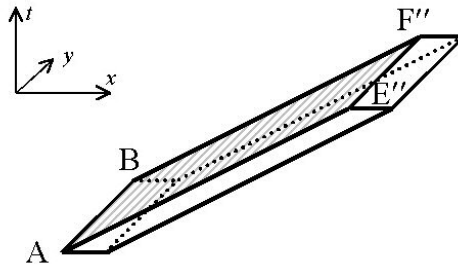


Figure 4. ThickThread.

II.

As already mentioned, the scenario does not violate the physical ban on superluminal motion. Making it explicit, however, leads to an important ontological lesson. Or so I shall argue. But first, I wish to correct a minor error in Hudson’s description of his *Gedankenexperiment*. Contrary to Hudson, FastThread and its thick partner do *not* pull off the trick of moving faster than light *without* moving ‘backwards in time’. In fact, they do the latter in precisely the same way as tachyons would, if they existed: Since FastThread sweeps a spacelike slice of Box, all points on this slice are pairwise spacelike separated. This means that their temporal order is not objectively defined. In particular, there are inertial reference frames in which the end of FastThread’s spatio-temporal career, $E''F''$, occupies

an earlier moment of time than its beginning, AB.⁴ But this is a minor point.

The real worry about the scenario comes from the fact that it entirely turns on putting FastThread, SlowThread, and Thread on the same ontological footing: all three (and more of their ilk) count as bona fide material objects. What sanctions this is a rather liberal theory of composition cast in the spatio-temporal context, which underlies the argument. More precisely, any spatio-temporally continuous fusion of temporal parts of material objects drawn from different instants is taken to constitute a further (perduring) object. This does not go as far as mereological universalism (which rules in scattered as well as continuous objects), but it comes fairly close. Hudson notes that although this assumption is controversial, it is quite popular. The pressures to adopt it are, indeed, familiar. It is becoming more and more difficult to sail unscathed between the Scylla of nihilism and the Charibdis of universalism.⁵ Nonetheless, I believe that here we have one of those cases where a sobering *modus tollens* is more plausible than the sweeping *modus ponens*.

4 Just as later stages in the tachyon O*'s career occur before its earlier stages in reference frame (x', t') in Figure 2.

5 Mereological *nihilism* is the view that there are no composite objects having other objects as proper parts. On this view, only mereological simples (or 'atoms'), objects having no proper parts, exist. Mereological *universalism* is the doctrine that any arbitrary collection of objects constitutes a further object, no matter how scattered, heterogeneous, gerrymandered, or even cross-temporal (assuming the temporal-parts view of persistence). The common sense view of composition falls between these two extremes. Mereological *liberalism* could then be characterized as a view that is more promiscuous than common sense but, in general, more restrictive than universalism. Such a view endorses many sufficiently arbitrary (in the intuitive sense) mereological sums—more than common sense does, but stops short of allowing all arbitrary sums into one's ontology. In our non-philosophical attitudes, we are inclined to count atoms and molecules, as well as tables and chairs, and even galaxies as genuine objects, but rule out such obviously 'unnatural' fusions as that consisting of my left ear and the right rear tire of your car. However, recent work instigated by van Inwagen's influential book (van Inwagen 1990) has shown that drawing a principled distinction between such cases is a difficult and, according to many, so far unresolved problem.

Thread, I want to argue, is a genuine material object, whereas FastThread and SlowThread are not. The distinction between them is physically robust and perspicuous. To set it in a larger context, recall another distinction, due to Wesley Salmon (1984), between two types of processes, genuine causal processes and pseudo-processes. A genuine process, such as the propagation of light, is capable of *transmitting a mark*. Put a small figure in the light ray between the source and the screen, and the image of the figure will be projected onto the screen. In contrast, a pseudo-process is so called because it is not a real physical process propagating in space and time. Although pseudo-processes often masquerade as real processes, they are distinguished from the latter by their inability to transmit marks. Suppose a laser gun points to the eastern horizon. High overhead the sky is completely overcast. At some time the laser beam is switched on and the laser pivots in the vertical plane, sweeping the beam across the bottom of the overcast to the western horizon. Consider the circular motion of the light spot across the overcast. If the laser pivots sufficiently fast the spot will travel faster than light—a result found in physics textbooks. But the motion of the spot, very unlike the propagation of light from the laser to the clouds, does not constitute, in Salmon's terms, a genuine physical process. One cannot use it to transmit a mark or information. For this reason, the superluminal motion of the spot is entirely unproblematic and does not conflict with relativity theory. The distinction between Thread and its slow and fast partners is quite similar.⁶

Indeed, perduring objects are a lot like processes. What binds a series of temporal parts of Thread into a robust material object is not just spatio-temporal continuity but a stronger relation of a broadly causal sort. Following W.E. Johnson and David Armstrong, one could call it

⁶ The similarity is close as well as enlightening. Consider the pseudo-process just described, on the one hand, and FastThread, on the other. Different stages of the former and different temporal parts of the latter are equally spacelike separated. And there are pseudo-processes more akin to SlowThread, which do not produce the appearance of superluminal motion but are not real causal processes either. The moving spot of light cast by a car on a row of houses is an example.

immanent causality, a form of causality confined to a single perduring particular and welding its temporal parts together ‘to constitute the single thing that exists through time’ (Armstrong 1997, p. 74). Alternatively, one could call this relation *genidentity*, following another venerable tradition (see Reichenbach 1957, pp. 270-271). Whatever one calls it, the presence of such a relation makes a series of temporal parts of a robust object different in kind from a juxtaposition of its contemporaneous spatial parts, such as the sum of cross-sectional parts of ABCD. A mark put on a temporal part persists through later parts, whereas a mark in a spatial part does not ‘persist’ through space. Quickly spray some red paint on AB. You will find later temporal parts of Thread stained too. Nothing similar happens to cross-sectional parts of ABCD. The difference could be analyzed in counterfactual terms, if one wished.

The important thing to note about SlowThread and FastThread is that they are, in this respect, closer to fusions of spatial parts (Rectangle being a key example) than to causally cemented (in the sense of immanent causality) series of temporal parts, such as Thread. Whereas the red color of AB is transmitted to later temporal parts of Thread, it is not transmitted to later temporal parts of either SlowThread or FastThread. Instead, the color instantly disappears. The behavior of painted ThickThread is even more peculiar: its red color mysteriously ‘fades away’ over a short period of time. The reason, of course, is that the temporal parts of such objects are causally (or genidentically) unrelated.⁷

7 Cf. Reichenbach:

If this decisive difference did not exist ... we could consider the continuation of yesterday’s Mr. A to be today’s ... Mr. B, and we could construct the world-line of a human being running through several different individuals. ... (Reichenbach 1957, p. 270)

The concept of genidentity is, consequently, closely related to the concept of causality. Different states can be genidentical only if they are causally related. This conception agrees with our definition of causal connection, which considers the causal chain a signal, i.e., the transmission of a mark. To speak of recognition of the *same* mark implies a striation of the space-time manifold. Not all world-lines can be interpreted as lines of the progress of a mark. (Reichenbach 1957, p. 271)

They do not form a whole in a way the temporal parts of Thread do. And for this reason they do not conflict with relativity—not any more than Salmon’s pseudo-processes do.

In fact, Salmon’s pseudo-processes are so called precisely because their shadowy nature disqualifies them from playing the usual physical roles assigned to real processes, such as transporting energy, causal influence, or information. There is a sense in which pseudo-processes do not occur *at all*. A typical pseudo-process is nothing over and above a peculiar superposition of stages of real physical processes, which combine to produce a false impression that something more is going on. But the question of whether pseudo-processes are an inferior class of processes or no processes at all may not be as ontologically important as the question of whether what I earlier called ‘SlowThread’ and ‘FastThread’ belong to an inferior category of objects (‘pseudo-objects’) or are no objects at all. If pressed, I would opt for the latter.

III.

What is at stake here is the issue of restricted material composition. The above analogy between Salmon’s pseudo-processes and candidate entities such as SlowThread and FastThread suggests that it may be easier to come up with a principled restriction on spatio-temporal material composition (in the framework of the temporal parts theory) than on purely spatial material composition. One useful restriction comes from a principle of unity cast in terms of immanent causality or genidentity (and revealed in the phenomenon of mark transmission), which grounds the distinction between robust (four-dimensional) objects such as Thread and loose collections of temporal parts such as Slow- and FastThread. In fact, speaking of ‘loose collections of temporal parts’ may be misleading as it smacks of second-class citizenship, which, despite being second-class, is a citizenship nonetheless. It is more in line with contemporary policy to say that such temporal parts do not compose anything at all.

But why not adopt a third option, along the lines of mereological liberalism?⁸ Why not maintain that Thread and FastThread are on the same ontological level, as being concrete objects—material, thread-shaped at any moment, and located in space and time—and chalk up the entire difference between them to their ability or inability to play certain physical roles normally assigned to material objects and to their willingness or unwillingness to abide by physical laws?

I don't think such a proposal has much to recommend it. The difference between Thread and candidate entities such as Fast- or SlowThread is just too substantial to treat them on a par, even if such a treatment promises certain advantages.⁹ My disinclination to do so owes much to the fact that Hudson's scenario is explicitly cast in this-wordly terms and does not appeal to possible worlds governed by different physics. Indeed, such an appeal would trivialize the whole point of the scenario. And as long as our reasoning about objects is thus constrained by the physics of the actual world, it seems natural to require that any candidate physical object allowed in our ontology be capable of passing at least a minimal test of physicality. This surely includes conforming to the relevant physical laws. And neither SlowThread nor FastThread do. Applying a net mechanical force orthogonal to their direction of motion will have no effect whatsoever on this 'motion'. Putting an electric charge on any of them will not result in any familiar electrodynamical effects at

8 The third option was suggested by Hud Hudson in his comments on an earlier version of this paper. See note 5 on mereological liberalism.

9 Hudson has indicated in correspondence that one such advantage would be avoiding a questionable sort of vagueness associated with restricted composition. But I don't think that genidentity brings with it any *new* sort of vagueness *in addition* to that involved in accepting *spatial* macroobjects such as Rectangle (or Cone, from Hudson's original argument) into one's ontology. And this more familiar issue of spatial composition is quite *orthogonal* (!) to the problem of diachronic composition. Why doesn't the relation of genidentity create any additional vagueness? Briefly, the reason is that, unlike spatial composition *at a moment of time*, genidentity is a broadly *causal* relation connecting items from different times and susceptible to regimentation grounded in robust physical dispositions such as the capacity for transmitting energy, momentum, and other conserved fundamental quantities.

any later time, such as generation of a magnetic field due to motion. And so on.

Suppose an entity did not behave like the electron is supposed to do—suppose its motion was not deflected by the magnetic field and it did not interact in the prescribed way with the positron. Could such an entity be an electron nonetheless? Not unless we adopted a framework in which the specific identity of a physical object were separate from its behavior and, hence, from the laws of nature that applied to it. Could such an entity be a physical object of any sort? This depends on whether its actual behavioral traits were identical to those of any existing kind of physical object and, hence, whether its behavior was constrained by the appropriate laws of nature. And if we suspected that the behavior of our entity did not conform to any actual physical laws whatsoever, we would have, I think, a strong reason to deny a physical status to it. Perhaps what we had before us was a microphysical version of a non-entity such as `FastThread`.

To be sure, `Thread` and its problematic partners are not like electrons in that their specific identity is not tied up so closely to their particular behavioral traits. Yet they are constrained in their behavior by more universal physical laws, such as the laws of mechanics and electrodynamics. The upshot then is that the ontological credentials of a candidate material entity whose behavior did not comply with the relevant laws of nature are suspect.

IV.

If the above analysis is correct, it boosts the case for restricted diachronic composition. ‘Separate and loose collections of temporal parts’ can sometimes masquerade as objects moving faster than light, but that is no more shocking than the peculiar behavior of Salmon’s pseudo-processes. A genuinely controversial claim would defend the existence of robust material objects moving faster than light. And Hudson’s thought experiment does not support this stronger claim.

One last remark: what about tachyons? Are they in the same family with what we earlier called FastThread? No. If tachyons exist, they are robust objects. But then, how does their hypothetical existence square with causality? Would tachyons be capable of transmitting marks, energy, and so forth, while moving (in sense explained above) backwards in time, thus leading to causal paradoxes? Yes, they would, and that is one familiar reason to doubt their existence.¹⁰

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