Duration in Relativistic Spacetime

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In 'Location and Perdurance' (forthcoming), I argued that there are no compelling mereological or sortal grounds requiring the perdurantist to distinguish the molecule Abel from the atom Abel in Gilmore's original case (2007). The remaining issue Gilmore originally raised concerned the 'mass history' of Adam and Abel, the distribution of 'their' mass over spacetime. My response to this issue was to admit that mass histories needed to be relativised to a way of partitioning the location of Adam/Abel, but that did not amount to relativising any fundamental natural intrinsic properties—the latter are all had unrelativised, and (so most perdurantists would say) the distribution of instances of these properties suffice to fix all the facts about Adam and Abel. No threat to perdurantism, or the argument from temporary intrinsics, comes from this direction.

My response was too hasty, as it relied naively on the thought that proper time in the Adam/Abel case could be explained away in terms of external time. In his reply (forthcoming), Gilmore points out, entirely correctly, that this cannot be done. Proper time along a trajectory is the only unrelativised (i.e., reference frame invariant) measure of duration. My original discussion at the end of section 5 was at best misleading.

However, my basic mistake was to think that the case of Adam/Abel required a different treatment than the case of Cell/Tubman. But in fact the two cases can be treated in a completely parallel way.

In the Cell/Tubman case, there is no preferred duration that it 'really' has. There is, unrelativisedly, the *volume* of spacetime it occupies. There are two distinctive patterns of causal relations instantiated through that volume—patterns that, were they instantiated by intrinsic duplicate parts differently distributed through spacetime, would in one case constitute a three-year-long person, and in the other a $3n$-year-long cell (where n is the number of cells in any timeslice of Tubman). Of course, given the existence of an external time in the classical spacetime I used in the discussion of Cell/Tubman, there is a strong temptation to say that the volume of spacetime occupied by Cell/Tubman has an unrelativised duration of three years, but I see no real significance as to whether perdurantists succumb to this temptation.

In the Adam/Abel case, for some reason, I succumbed to the analogous temptation, and identified the duration of Adam/Abel with the apparent duration of Abel. This was an error, which I now retract—there is no requirement to pick a preferred duration in the classical case, and even less reason to do so in a relativistic spacetime.

But the account then is just as for Cell/Tubman. Adam/Abel occupies a single volume (collection of points) in spacetime. The perfectly natural intrinsic properties instantiated at these points fix the intrinsic character of Adam/Abel. These properties suffice to establish that Adam/Abel is a molecule *and* that it is an atom—we now see, thanks to Gilmore's cases, that these are not incompatible properties, and that a persisting object can have both, in virtue of the causal relations that its parts stand in.

The particular way that Adam/Abel's parts are distributed over spacetime causes some confusion when it comes to evaluating temporal *duration.* As mentioned above, the proper time is duration *along a trajectory.* What a trajectory is may be disputed; I will assume with Gilmore that they are not simply regions of spacetime, but rather trace the history of a persisting kind of object, an atom or molecule in this case, by tracing the causal connections among its stages.[1]

Because Adam/Abel satisfies both the properties of being a molecule and an atom, there are two ways of tracing continuous identity-constituting causal chains (trajectories) through the volume of space it occupies—the atomic way, giving a sequence of those parts of Adam/Abel which are atom-parts linked by the same-atom-as relation, and the molecular way, giving a sequence of molecular-parts linked by the same-molecule-as relation.[2] Thus there will be two proper time durations assignable to the volume of spacetime occupied by Adam/Abel, 1 billion years and 2 billion years. It is again true that intrinsic duplicates of Adam/Abel's parts might be distributed through spacetime in such a way as to make, e.g., a molecule that is not an atom, and which has a 1 billion year long proper time along its molecular trajectory, and no other candidate proper time. In that case we would be justified in saying that the molecule had a duration of 1 billion years, and that may tempt us erroneously into saying that Abel has that duration. We can and should resist that temptation.

This is, as Gilmore points out, a 'relativising' response to this problem. But, as before no fundamental natural property is relativised. The situation thus remains quite different to what must happen in the case of endurantist intrinsic change, which does involve relativising such properties. Since perdurantists can treat all facts in relativistic spacetimes—including all facts about the location and identity of persisting objects—as supervening on the distribution of perfectly natural intrinsic properties over spacetime, no fact in the supervenience base is relativised. (That is why fundamentality matters.) I see no weakening

[1] Compare, e.g., 'The world-line [trajectory] provides us with the information of where the particle was (and is, and will be) at every possible time...' (Geroch, 1978: 18).

[2] One complication Gilmore mentions is that, strictly speaking, only one-dimensional trajectories will have proper times associated with them, so the molecular trajectory will be a 'center of mass' trajectory, and may not fall entirely within the region filled by Adam/Abel. I will ignore this complication.

of the argument from temporary intrinsics in making this move.

One potential concern might come from the thought that because proper times are Lorentz invariant, they are fundamental, and so not the kind of thing that a (non-hypocritical) perdurantist should relativise. But this thought is mistaken. Consider the purely existential claim that there exists some region of spacetime that is occupied. The truth-value of this claim is Lorentz invariant, yet the facts of unspecific occupation aren't fundamental, depending as they do straightforwardly on the occupation of specific particular regions. Fundamental properties are invariant, but not vice versa.

Finally, one might consider an analogous case in purely spatial terms, without the confounding persistence issues, invented by Oliver Pooley. Consider a physical 3-torus made of three-stranded rope. It turns out that the three 'strands' are in fact a single loop of cord wrapped around itself (like that pictured in Figure 1).[3] So while the torus in cross section has three strands, and a single cut would yield three small pieces of cord, the torus is actually composed only of one long twisted cord.[4]

This 'Pooley torus' occupies a given volume of 3-space, unrelativisedly. All the properties of the Pooley torus supervene on the distribution of properties through that spatial region. On this both endurantists and perdurantists agree. But what is the *length* of the Pooley torus? There seem two natural candidates:

1. The length of the rope, i.e., the diameter of the torus. A cut of the rope would yield a piece this long, so the Pooley torus, measured rope-wise, is

[3]In the figure, the single cord is black at one 'end' and white at the other. Incidentally, this variation in colour poses a problem of spatial intrinsics for those who think a Pooley torus might be a extended simple, which must be solved, unlike the problem of length below, by relativising intrinsic properties at points.

[4]Mathematically speaking, this is therefore a *torus knot* (or a *closed braid*), a knot on the surface of a 3-torus obtained by wrapping a cord through the hole of a 3-torus p times, and looping the cord q times around the torus before joining it up, where p and q are relatively prime; this gives the (p,q) torus knot. Such a torus knot is hard to physically make, but it is clear which points of space it would fill, so simply consider the Pooley torus to be a filled region consisting of just those points.

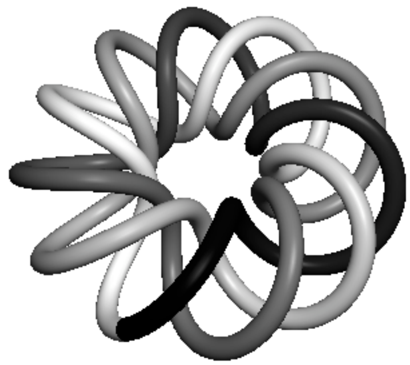

Figure 1: A Pooley torus, with the rope threads shown separated (the (11,3)-torus knot).

this long.

2. The length of the cord, something somewhat larger than three times the diameter of the torus. A single cut of one strand would yield a cord this long; so the Pooley torus, measured cord-wise, is this long.

One conclusion might be that the cord is not the rope on the basis of these different length properties; anti-coincidence prohibits this conclusion for both endurantists and perdurantists. To preserve our judgements, we should accept that the cord is the rope, and relativise length to sortals, so we have rope-length and cord-length. This relativising move seems natural and plausible in the spatial case; all I have argued is that it can be consistently and coherently extended to the temporal case by perdurantists, without undermining other perdurantist arguments.[5]

[5]Thanks to Oliver Pooley for discussion.

References

Eagle, Antony (forthcoming), 'Location and Perdurance'. *Oxford Studies in Metaphysics*, this volume.

Geroch, Robert (1978), *General Relativity from A to B*. Chicago: University of Chicago Press.

Gilmore, Cody (2007), 'Time Travel, Coinciding Objects, and Persistence'. *Oxford Studies in Metaphysics* 3, 177–98.

Gilmore, Cody (forthcoming), 'Coinciding Objects and Duration Properties: Reply to Eagle'. *Oxford Studies in Metaphysics*, this volume.