Time, Relativity, and Persistence

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Metaphysics » Lecture 8

Contents

Relativity

The Commonsense/Newtonian Conception of Absolute Time

> Absolute, true, and mathematical time, of itself, and from its own nature, flows equably without relation to anything external, and by another name is called duration: relative, apparent, and common time, is some sensible and external (whether accurate or unequable) measure of duration by the means of motion, which is commonly used instead of true time; such as an hour, a day, a month, a year. (Newton 1687: 6)

- There is a recognition that common measures of time are relative to external things (as a day is keyed to the speed at which the earth happens to rotate), but that 'absolute time' is indepent of all external things.
- This is how we've been thinking of time (and space) so far.
- Even when we think of them together, in the block universe, we think of space and time as separately contributing to the locations of things.

Space, Time, and Spacetime

- Einstein's theories of special and general **relativity** involve a much more intimate connection between space and time:

  > The views of space and time which I wish to lay before you have sprung from the soil of experimental physics, and therein lies their strength. They are radical. Henceforth space by itself, and time by itself, are doomed to fade away into mere shadows, and only a kind of union of the two will preserve an independent reality (Minkowski 1952: 75)

- This view of spacetime goes beyond the block universe; in Minkowski spacetime, which underlies special relativity (our principal focus today), there aren't really separate spatial and temporal dimensions; better thought of as four **spatiotemporal dimensions**.

Frames of Reference

- It is a familiar fact that how an object's motion is described is **relative** to the observer's state of motion. On a moving train, a ball can be tossed **vertically** and caught; but when observed from a platform outside, the ball traces an **arc**.
- The ball obviously doesn't occupy different points of spacetime when differently described; rather, the different **perspectives** of observers allow a different representation of those successive locations.
- One especially useful sort of perspective corresponds to an observer who is **not accelerating**: those exhibiting **inertial** (or 'free fall') motion. All inertially moving objects move intertially according to every other inertial observer – observers differ only in the **velocities** they assign.
  - Two inertial observers who are in relative motion, but each of whom considers themself at rest, will judge the other to be moving at a constant velocity.
- To each **possible** inertial observer, there corresponds a **frame of reference**; basically, a way of assigning spatiotemporal coordinates to each event in spacetime, given an assumption about which things are at rest. Different frames will disagree on the coordinates they assign.

Reality and Frames of Reference

- Whether something is in motion or at rest **seems real** to observers; but different observers will **disagree** (and no one is getting things wrong).
  - An observer on the platform will be stationary in their own frame of reference, but moving relative to the train frame of reference – assuming the train is moving inertially.
- No experiment can determine which of two inertially moving observers is 'really' at rest – that there is motion with respect to **asbolute space** was part of Newton's worldview, but was not an essential part of his theory of motion.
  - Later physicists and philosophers of physics have tended to dispense with absolute space, and to deny that there is any fact of the matter about the reality of motion (Huggett 2010: 98–100).
- What's real, rather than apparent? **A feature in a frame of reference is absolutely real (rather than merely perspectival) iff it is a feature of *all* frames of reference.**
- So *being in motion* is merely perspectival (and obviously so is *moving at a specific speed*); but *being accelerated* is not, since an accelerated object is one that changes speed, and so is at some time at rest with respect to one inertial frame, and some time at rest with respect to another; and so **every** inertial frame of reference will represent the object as changing speed (though what speeds it is represented as travelling at will vary).

Galilean Relativity

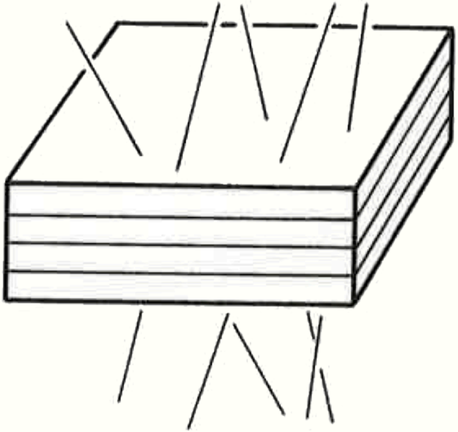

Figure 1: Galilean Relativity (Geroch 1978: 47). Any one of these lines can be treated as **at rest**; 'being vertical' is not invariant. So even **being at the same place at a different time** is not genuinely real, according to Galilean relativity.

The Non-Relativity of Light

- We've so far described **Gallilean relativity**: some notions (like speed, or sameness of spatial position over time) are perspectival, while others (acceleration, simultaneity, measures of elapsed time) are absolute (Geroch 1978: ch. 3).
- To get to Einstein's **Special Theory of Relativity (STR)**, we make one further change: **light travels at an absolute speed** – so it is the same in every inertial frame of reference.
  - The theory of relativity thus postulates that one form of motion is **absolute**.
- There is experimental evidence to support this light postulate; one easy example is provided by the motion of **double stars** (Geroch 1978: 54–57).
- Light's absolute motion has some **surprising** consequences.

The Structure of Spacetime

- The **absolute** speed of light means we can use the trajectories of light beams as a **framework** for spatial and temporal measurement.
- Every frame agrees on that speed, so every frame agrees on what locations are 'reachable' by a light ray from a given point.
  - If two points p, q are not able to be connected (because intuitively they are too far away in space for light to reach them in time), they are said to be **spacelike separated**.
  - If two points p, q are able to be connected by a signal travelling exactly at the speed of light, they are said to be **lightlike separated**. If the signal connecting them leaves p and reaches q then q is on the **future light cone** of p; if the converse, q is on p's **past light cone**.
  - If two points p, q are able to be connected by a signal travelling slower than light, they are **timelike separated**. If the signal leaves p, then q is in the **causal future** of p; otherwise it's in the **causal past**.

The 'Light Cone' Structure of Spacetime

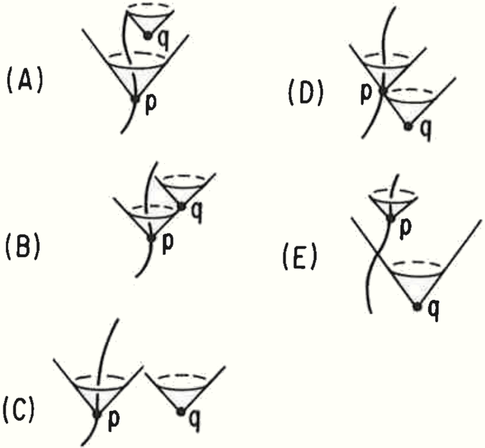

Figure 2: p and q are **spacelike** separated in (C), **lightlike** separated in (B) and (D), and **timelike** separated in (A) and (E). (Geroch 1978: 89)

Spacetime Without Frames of Reference

- We could have given STR as a theory of physics in a different sort of spacetime, **Minkowski spacetime**.
- In Minkowski spacetime, the fundamental distance relation isn't the familiar Euclidean one, but rather the **spacetime interval** (Geroch 1978: chs. 5–6; Eagle 2021: 88).
  - If you think of each point of spacetime being associated with a collection of **vectors**, each of which is directed at another point of spacetime, you can think of the interval as the 'length' of such a vector (though it's a weird notion of length, since it can be negative, and many non-trivial vectors can have 'length' zero).
  - The spacetime structure is given by the points and the vectors, including their interval; the spatial and temporal distances between points in a frame are derivative, resulting from a certain **decomposition** of the interval into spatial and temporal components.
- The mathematical details need not detain us; what matters is that the spacetime interval grounds the lightcone structure (Eagle 2021: 89), e.g., points with a **negative** interval are spacelike separated.
- The interval is invariant, but it lacks a unique spatial and temporal decomposition – different frames correspond to different possible decompositions.

Consequences of Relativity

The Relativity of Simultaneity

Suppose I [in the middle of the train] send a radio message to the driver at the front and to the guard at the back. From my perspective – the frame of reference centred on the train – the driver and the guard receive the message simultaneously. After all, their messages each have the same distance to travel, and each travels at the same speed. …
From [the platform] perspective, the train carries the guard forward to meet his message, and carries the driver away from hers. But the driver's message doesn't travel any faster than the guard's: like light, radio signals travel at the same speed with respect to every non-accelerating frame of reference. The driver's message travels further, at the same speed, so it arrives after the guard's message. (Hawley 2009: 508)

Einstein's Account of Simultaneity

- The standard approach to defining simultaneity in relativity is **operational**: we give a procedure that, were it performed correctly, would classify all points of spacetime as simultaneous with a given point or not.
- The procedure is this: while at rest (in some inertial frame) the observer P sends out a light beam towards a candidate event m from p. The light reflects from m and returns at p''.
- Then m is simultaneous with the event p' midway along the line of free fall (P's intertial trajectory, or **worldline**) between p and p''.
- This is frame-dependent, though: suppose another freely falling observer Q is moving along a worldline at some speed relative to P, and also passes through p. They send a light signal to m; and also to p': and for Q, those events will **not** be simultaneous; they will regard m as occuring before p'.

The Relativity of Simultaneity

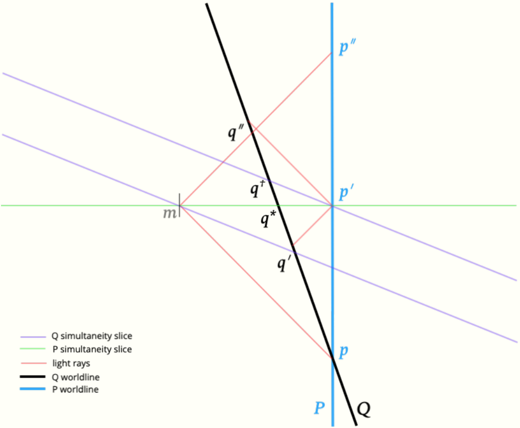

Figure 3: Relativity of simultaneity. Two observers, P and Q, meet at p; a light signal is sent to m; reflection is received by P at p'', by Q at q''. Each judges m to occur halfway between send and receive: according to P, simultaneous with p'; according to Q, simultaneous with q'. But according to P, p' is simultaneous with q^*; according to Q, p' is simultaneous with $q^\dagger$.

The Relativity of Time and Distance

- The spatial distance between two points isn't invariant.
- For observer P, the spatial/temporal distance between p and q^* might be 1 year (the time elapsed between p and p') and 500km; for observer Q, who moves at high speed relative to A, it might be 11 months and 0km, as she passes through both p and q^* – this is the phenomenon of relativistic **time-dilation**.
  - It's called 'time dilation' because from the P reference frame, a clock carried by Q would be seen to tick more infrequently than a clock carried by P, thus the gap between successive ticks of Q's clock would seem to P to expand (or dilate), so less time would seem to Q to pass.
  - The phenomenon is symmetric; for Q, obviously, p' is simultaneous with $q^\dagger$, which may be more than a year, according to Q, after p.
- Time dilation is paired with **length contraction**: objects that are in motion are measured to be smaller than they are in their own rest frame – this is a product of the relativity of simultaneity, since different points on the object are regarded as simultaneous, and hence relevant to measurements of extension.

Length Contraction and Simultaneity

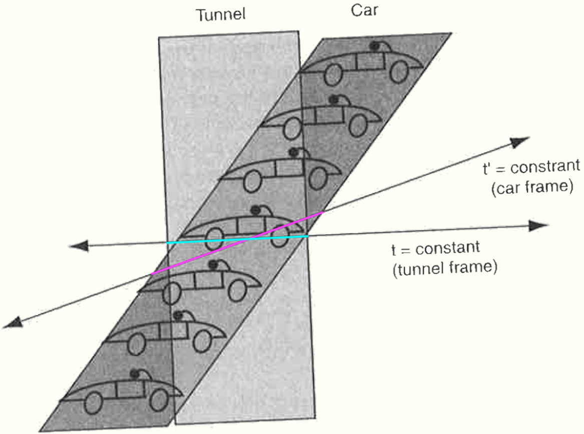

Figure 4: Length contraction: the car is longer than the tunnel in the Car frame (pink span), and shorter in the Tunnel frame (blue span) (Maudlin 2011: 54).

Relativity and the A-theory

The A-theory Revisited

- Obviously two events are simultaneous iff they are happening at the same moment of time. A **moment of time** is thus a class of points that are all simultaneous with each other (Eagle 2021: 90).
- The relativity of simultaneity thus leads directly to this thesis:

  Many Moments Any given event belongs to many different moments of time.
- Recall that the A-theory is the view that the present is privileged; that there is just one moment such that the events of that moment are **truly happening**.
- Suppose we can identify one event e as truly happening: which other events are also happening – which moment of time to which e belongs is how things 'really are'? The A-theory seems to be committed to there being a definite answer to this question.
- A privileged moment will yield a class of events that are **absolutely simultaneous** with e. And the **problem** this poses for the A-theory is simple:

  > it is of the essence of the theory of special relativity that absolute simultaneity as such does not exist. (Saunders 2002: 280)

Presentism and Relativity

- This problem for the A-theory takes a particularly sharp form when applied to presentism, the view that the present is privileged **ontologically**.
- The presentist wants to link absolute simultaneity with existence.
- If absolute simultaneity doesn't exist, should the presentist link relative simultaneity with existence?
- But how could **what exists** depend on an observer's state of motion?
  - This is particularly sharply felt if we do not approach relativity via frames of reference, seeing them as only pedagogical tools; it will be very hard to accept that a **conventional** choice of how to represent the spacetime interval in terms of spatial and temporal coordinates could have **ontological** consequences.
- In fact, if the simultaneity of two events does indicate their joint existence, as the presentist wants to argue, then the relativity of simultaneity seems to provide a direct argument against presentism.

Putnam's Argument Against Presentism

(I) I-now am real. …

(II) At least one other observer is real, and it is possible for this other observer to be in motion relative to me. …

And, the most important assumption, which will be referred to (when properly understood) as the principle that There Are No Privileged Observers:

(III) If it is the case that all and only the things that stand in a certain relation R to me-now are real, and you-now are also real, then it is also the case that all and only the things that stand in the relation R to you-now are real. (Putnam 1967: 240–41)

- Given the additional assumption that 'All things that exist now are real' is true for every observer (Putnam 1967: 243), we see that simultaneity of x and y is **sufficient** for Rxy to hold.
- Then some past and future events are real, **contrary to presentism**.
  - This is an objection just to presentism; it can be extended to target the A-theory if we adopt an analog of Putnam's principle III stating that any **events** standing in the R relation are real, i.e., really happening.

Resisting Putnam: Can We Read Metaphysics Off Of Physics?

- Putnam thinks 'the problem of reality and determinateness of future events is … solved by physics and not by philosophy' (Putnam 1967: 247). Yet…

  > Such a naive view is as wrong as can be. … one can only extract so much metaphysics from a physical theory as one puts in. While our total world vie must, of course, be consistent with our best available scientific theories, it is a great mistake to read off a metaphysics superficially from the theory's overt appearance, and an ever graver mistake to neglect the fact that metaphysical presuppositions have gone into the formulation of the theory. (Sklar 1985: 291–92)

Simultaneity and Co-Presentness

- The key metaphysical ingredient going in to Putnam's argument is the operational account of simultaneity or **co-presentness** (the relation that holds between events in the A-theoretically privileged moment) we saw earlier.
- The account of simultaneity is a **bridge principle** connecting the physics with our ordinary notions. The A-theorist must reject that account. There are a couple of broad families of approaches to doing so (Eagle 2021: 92).

Conciliatory
: A conciliatory approach agrees that the A-notion of co-presentness must be relativistically definable, and wants to offer a different relativistically definable relation as the correct analysis.

Supplementing
: Agrees that simultaneity is to be defined as Einstein does, but denies that simultaneity is co-presentness; the latter notion is not necessarily relativistically definable, though we may have good reason to impose it on relativity, a theory which is A-theoretically incomplete.

Revisionary
: STR is wrong; its future successor will feature a well-defined absolute simultaneity relation. This is purely **speculative**.

Supplementing Approaches

- Supplementers want to **distinguish** simultaneity from co-presentness.
  - The former is the frame-dependent relation; the latter is the relation important to the A-theory.
- The A-theory is the thesis that if x and y are really occurring, then x and y are co-present. At most one frame of reference f is such that simultaneous-in-f is coextensive with co-presentness. This is a **privileged** frame: metaphysically special through having a special connection with **what exists**.
  - There are no relativistically privileged observers; but there are **metaphysically** privileged observers,
- This approach starts with the A-theory, and **adds structure** to STR – a privileged frame that isn't relativistically specifiable.

A Privileged Frame?

- The A-theory adds ‘surplus geometrical structure’ (Gilmore, Costa, and Calosi 2016: 109); it’s argued that this is methodologically objectionable, much as Newton’s absolute space is regarded as methodologically objectionable.

  > This objector is saying, in essence, ‘If fundamental physics can’t see a distinction between two classes of things, there is no distinction to be made.’ But we all believe in lots of distinctions physics ‘can’t see’. Arguably, … all [fundamental physics] needs to describe the events with which it concerns itself are things like tiny particles, gigantic fields, and space-time. Is there no difference, then, between groups of particles that make up larger wholes, and groups that do not? Should we conclude that, since physics does not mention things like dogs, there is no reason to believe in such things – as opposed to mere swarms of particles arranged in various canine shapes. (Zimmerman 2008: 219)

Is a Privileged Frame Acceptable?

- Zimmerman's response is well-taken, if we are thinking about entities that **supervene** on the physics but aren't reducible to it. But the privileged frame isn't like that; it doesn't supervene on the contents of the spacetime manifold.
- Moreover, our apparent evidence for the privileged present – temporal experience – does seem to supervene on the physical. The privileged present seems **explanatorily idle** (Savitt 2000: S570; Eagle 2021: 95)

  > [M]any people … think that the philosophical reasons to believe in such a frame are far outweighed by our empirical grounds for thinking it does not exist. Why? First, there is the idea that if there were a privileged reference frame, this would show up in our best scientific theories:… this is just the sort of thing you'd expect science to tell you about. Second, there is the idea that an empirically undetectable distinction between past, present, and future, whilst not incoherent, cannot form the basis of a philosophical theory which is supposed to explain or vindicate our pre-theoretical ideas about time and existence. (Hawley 2009: 511)

Options for the Conciliatory A-theorist

- The conciliatory A-theorist must try to find an **invariant** but relativistic notion of co-presentness; several options suggest themselves, all related to the invariance of the **lightcone structure**.

  Past-lightcone-ism
  : What's present to an observer are those events on the past light cone, from which light is reaching them here-now (Godfrey-Smith 1979).

  Here-now-ism
  : Only a single spacetime point is present to an observer located there (Sklar 1985: 302).

  Spacelike separation
  : Those events which are not causally connectible to a an observer's location are present to that observer.

- This last idea takes *present* to mean 'simultaneous according to some inertial frame'. Yet sufficiently distant events can be spacelike separated from us and yet **causally connected** to each other – the whole span of an alien civilisation, from origin to collapse, can count as present. The metaphysics of the A-theory don't mesh well with such a view.

Past-lightcone-ism

> When we gaze into the night sky, I suggest, what we observe is the actual state of the universe, not some causal remnant of its former state. We gaze at the star Sirius and observe its state; not some Sirius-trace which is the antecedent of its actual present state. The latter supposition would suggest that there is some actual contemporaneous state which we cannot know now, but will know later, and I think that special relativity shows us that this is mistaken. (Godfrey-Smith 1979: 241)

- Again, many causally linked events count as co-present. (Suppose a light ray travels through a coloured filter on its way from Sirius to us; the view would say the emission of the light ray and the filtering are both really happening.)
- Moreover, this is **asymmetric**; we are not present to any event which is present for us.
- This privileges our temporal experience; but does it do so in the right way?

Here-Now-ism

- The past-lightcone-ist privileges the apex of the lightcone, but goes awry when the present is extended to distant events.

  > Now, in the theory of relativity, the only reasonable notion of "present *to a space-time point*" is that of the mere identity-relation: present to a given point is that point alone—*literally* "here-now"…. (Stein 1991: 159)

- This is invariant (and an equivalence relation), but again – does it give the A-theorist a viable theory of tense?
- Perhaps a supplementing theory is more defensible, or A-theorists can pin their hopes on some future science. But STR is pretty unfriendly territory for the A-theory.

Relativity, Time-Travel, Coincidence, and Persistence

Relativity and Persistence

- Many have thought the B-theoretic/eternalist view favoured by relativity makes it a natural home for perdurantism .
- Moreover, some of the novel features of relativity favour perdurance over its rivals.
  - For example, it has been argued that perdurance explains **length contraction** more readily, because they can explain the different spatial cross-sections in different frames as derived from an underlying 4D shape, whereas endurantists must somehow synthesise 3D shapes into a 4D whole (Balashov 2010: ch. 8).
- But some have tried to make relativity amenable to B-theoretic endurantism (Gibson and Pooley 2006; Gilmore 2006).
- I will focus here on a very specific argument, due to Cody Gilmore, that suggests an argument for endurantism from some broadly relativistic considerations.

Anti-Coincidence

> It is impossible for numerically distinct material objects to *coincide* – that is, to be (i) wholly present in exactly the same location and (ii) composed, at some level of decomposition, of all the same parts or all the same matter at a given location. (Gilmore 2007: 178)

- We've already discussed some coincidence cases.
- It already emerged previously that coincidence cases seem to involve a **difference without a difference-maker**. Why are there two things, if nothing makes them distinct?
- The standard dialectic has it that cases of temporary coincidence, like Body/Body-minus, favour perdurance (because distinctness can be grounded historically, and sharing of parts is then not problematic coincidence); and that in cases of permanent coincidence, like Goliath/Lumpl, are problems for both perdurance and endurance. On balance, perdurance is favoured.
- Gilmore (2007) argues that time-travel and relativity allows another kind of coincidence case; one easy for endurance to explain, but tricky for perdurance.

Locations, Paths, and S-Regions

Let us say that spacetime region R is a *location* of object O just in case R exactly contains the whole of O, or, synonymously, just in case O *exactly occupies* or is *wholly present* at R. … Let us say that spacetime region R is an *S-region* of object O just in case R corresponds to what we would ordinarily think of as a spatial location of O at some instant in O's career. Only instantaneous spacetime regions can be S-regions of objects. … Let us say that spacetime region R is the *path* of object O just in case R exactly contains O's complete career or life-history. An object's path is the union of its S-regions. …
philosophers *disagree* about … which regions are O's *locations*. Perdurantists will say that O has only one location – namely, its path – and that none of O's S-regions are locations of O. Endurantists, on the other hand, will say that O has many locations – namely, its S-regions – and that O's path is not a location of O. (Gilmore 2007: 179–80)

Two Types of Coincidence Scenario

- Gilmore uses this terminology to classify coincidence scenarios:

  Type-A: O and O' are distinct material objects that share an S-region, but do not share a path. (**Temporary coincidence**: Body and Body-minus are an example.) Problem for endurance, no problem for perdurance.

  Type-B: O and O' are distinct material objects that share their S-regions, and share their path. (**Permanent coincidence**: Statue and Clay when both are formed simultaneously.) Problem for both endurance and perdurance.

- These scenarios motivate many endurantist (Wiggins 1968) to embrace coincidence; this deflates the potential challenge from these cases by denying that coincidence is a problem.

Another Sort of Coincidence

- But if there are coincidence scenarios that were problems for perdurance and not endurance, we deflate the challenge by showing that everyone faces it, and hence that anti-coincidence provides no special support for any particular theory of persistence.

  Type-C — O and O' are distinct material objects that share **no** S-regions, but **do** share a path. (Gilmore's own cases.) Problem for perdurance, no problem for endurance – though some think otherwise (Effingham and Robson 2007).

- To get these cases up and running, we need to have judgements about S-regions that are **independent** of our preferred theory of persistence.
  - If we accept the possibility of Type-C coincidence, we cannot **define** an S-region in terms of paths (i.e., as R is an S-region of x iff it is the intersection of x's path with some time), since the shared paths would entail shared S-regions.

Case 1: Cell and Tubman

- Gilmore's first case involves backward time-travel of a Lewisian sort:

  some cell ['Cell'] is originally created at the beginning of the year 2000 and that it jumps back in time over and over again, never venturing further back in time than the moment of its original creation, and never progressing beyond the end of the year 2002. The cell's entire career is confined to this three-year interval. Suppose also that the cell never leaves the immediate vicinity of my bathtub. If this cell's trips were structured properly, if it made enough of them, and if it underwent the right sorts of intrinsic changes along the way, the cell might compose some macroscopic object that sits in my bathtub for three years. Indeed, the cell might compose an object that by all appearances is a conscious, intelligent human being ['Tubman'], one who exhibits the strange behavior of living in my bathtub, and whose constituent cells seem to pop into and out of existence, but who is otherwise quite normal. (Gilmore 2007: 182)

Cell and Tubman is a Type-C case

> The fact that Cell and Tubman have different S-regions entails that they are numerically distinct. However, their distinctness can be shown in other ways as well. (1) Tubman is conscious, but Cell is not. (2) Unlike Cell, Tubman will never travel backward in time. No one will ever see older and younger versions of him in the same room at once. Thus the case of Cell and Tubman seems to be an example of a type C situation: it seems to involve distinct material objects that share their path but have none of their S-regions in common. (Gilmore 2007: 183)

- Yet compared to the obviousness of cases like Body/body-minus, a case requiring convoluted backwards time travel is hardly compelling – the scales don't really balance between type-A and type-C cases.

Relativity and Closed Timelike Curves

- Relativity theory permits another kind of time travel, along a physically possible trajectory (a **timelike curve**) – not so easily set aside as a fringe case.
- One way to construct closed timelike curves is take a Minkowski spacetime and 'wrap it up' into a cylinder (**compactify** it), taking some past and future simultaneity slices and identifying them (Maudlin 2012: 157–62).
  - This spacetime is locally like flat Minkowski spacetime, but allows a physically possible trajectory into the future to eventually intersect itself: a **closed timelike curve**, or CTC.
- Another way to construct CTCs is to move to the context of **general relativity** (Arntzenius and Maudlin 2013: §§4–5).
- Unlike special relativity, in which spacetime is still conceived of as a container (like Newtonian space), in general relativity the **distribution of matter** and the lightcone structure of spacetime are interdependent.
- Distribute matter in the right way, and you can locally 'tilt' the lightcone structure so that an entity can have its overall trajectory in spacetime forming a CTC – even if the whole spacetime isn't wrapped up.
  - One example is Gödel's rotating universe model of GR (Huggett 2010: 175–76).

Almost-Closed Timelike Curves

The General Theory of Relativity (GTR) permits the occurrence of … closed timelike curves. … A timelike curve is a continuous path through spacetime corresponding to the possible life-history of a massive particle. Unlike our time-traveling cell, a particle whose path is a timelike curve is 'always oriented towards its local future' (Smith 1998: 156): at no point in its career does the object travel backward in time with respect to its immediate neighborhood in spacetime. A timelike curve is closed just in case it forms a loop, thus 'ending where it began', so to speak. A particle that traces out an almost closed timelike curve would, just by lasting long enough and taking the appropriate trajectory, return to its own past and coexist with a younger version of itself.
… similar time-travel scenarios can be constructed in … spacetimes [that] could be 'cylindrical,' with a closed, circular, temporal dimension. (Gilmore 2007: 185–86)

Case 2: Adam and Abel

Consider … the career of a hydrogen atom, which we shall call 'Adam'. Adam is spatially bi-located throughout its two-billion-year- long career. For any given moment of external time (or 'global simultaneity slice') t in the relevant universe, Adam is present at t 'twice over:' i.e., there are two different moments p_t and p_{t^*} of Adam's proper time such that, at p_t, Adam is present at t, and at p_{t^*} Adam is present at t. Suppose that, at each moment of Adam's proper time, Adam is chemically bonded to itself at a different moment of its proper time, thus forming a molecule of H_2, which we shall call 'Abel'. Abel is spatially mono-located throughout its career (which is only one billion years long). For any given external time t, Abel is present at t only once: i.e., there is only one moment of Abel's proper time at which Abel is present at t. (Gilmore 2007: 186–87)

Picturing Adam and Abel

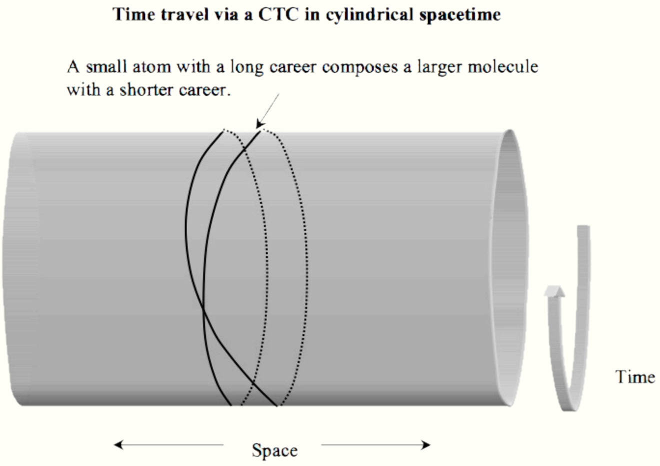

Figure 5: Adam and Abel, inhabitants of a compactified spacetime (Gilmore 2007: 186).

Mass Histories

- Gilmore invites us to consider the **distributional property** of a **mass history**: 'a property that reflects the way in which the object's mass changes, or stays constant, over the course of its career' (Gilmore 2007: 187).
- He argues that Adam and Abel differ in their mass history.
- But consider any two mass histories:

  > each seems to be *intrinsic* in the sense … that whether or not a thing has the property depends only on what the thing is like in itself, and is independent of how that thing is related to anything else. They seem to be *incompatible* in the sense that it's impossible for a single thing to have both of them. (Gilmore 2007: 187–88)

- So Adam and Abel, too, is a type-C case according to Gilmore.

The Argument Against Perdurance

(1) Type-C situations are possible: there are possible worlds in which they occur.

(2) For any possible world *w*, if a type-C situation occurs in *w*, then either:

a. there are numerically distinct material objects that coincide in *w* (in which case the anti-coincidence principle is false) or

b. perdurantism is not true in *w*.

(3) The anti-coincidence principle is true: it is impossible for numerically distinct material objects to coincide.

(4) Perdurantism is not a necessary truth: there are possible worlds in which it is not true. (1, 2, 3)

- This already leaves open the idea that **our world** is one where perdurance is false; and if it's true only if necessary, then its possible falsehood **entails** its actual falsehood.

Options: Reject (3)? (2)?

- We can **accept coincidence**, and deny (3).
  - As Gilmore points out, this undermines arguments from type-A coincidence against endurance, such as the Body/Body-minus argument offered by Heller (1984) that we have considered.
- And denying (2) doesn't look like an option: type-C cases are **defined** as those in which there is sharing of path and yet non-identity. If it is correct that perdurantists should take the location of a persisting object to be its path, then this entails coincidence. And what would the location of a four-dimensional spacetime worm be, but the path (modulo some worries about multiple location and perdurance – Eagle (2010a: 60–62))?

Denying (1): some unpromising ways

- So it looks like (1) must be the scapegoat. But what can a perdurantist reject?
- They should not reject **backwards time travel**.
  - After all, it was supposed to be one of the **successes** of Lewis' framework, in which perdurance plays a crucial role, that it can accomodate time travel in an unproblematic way.
  - And even if armchair time travel cases don't move you, the relativistic models that Gilmore explores give physically possible models of time travel that cannot be dismissed as idle speculation (Arntzenius and Maudlin 2013).
- They could adopt **nihilism**: Abel and Tubman don't exist, just simples arranged them-respectively-wise.

Denying (1): Relativising

The thing that we're calling 'Adam' can be exhaustively partitioned into instantaneous temporal parts in different ways. On one way of being partitioned – call it the 'atomish' way – each of the relevant parts has the size, shape, and mass of a hydrogen atom. On a different way of being partitioned into instantaneous temporal parts – call it the 'moleculean' way – each of the relevant parts has the size, shape, and mass of a molecule of H_2. All of this is true of the thing we're calling 'Abel' as well … [so] it becomes plausible to say that Adam has mass history … only relative to the atomish way of being partitioned into instantaneous temporal parts, and that Abel has the contrary mass history … only relative to a different way of being partitioned…[So] none of the facts about Adam's and Abel's mass histories entails that Adam ≠ Abel. (Gilmore 2007: 192–93)

Does Relativisation have a Cost?

- Gilmore considers a response that denies (1): this is to deny the possibility, on the basis that the supposedly distinguishing properties (mass history, personhood, time-traveller-hood, etc.) are not genuine grounds for distinctness. The move here is to **relativise properties**. But:

  > if the perdurantist makes this move, he will no longer be in a position to fault the endurantist who makes a parallel relativizing move in response to David Lewis's 'problem of temporary intrinsics'. (Gilmore 2007: 194)

- I agree. But note there is apparently a crucial **disanalogy**: namely, that while normally we relativise to render **apparently incompatible** properties nevertheless compatible, the way in which mass histories are relativised to partitions seems to show that the mass histories are, after all, compatible – because they are each derived from the same underlying fundamental arrangement of qualities (Eagle 2010b).

The Perdurance Strategy

for a persisting entity to be an F is for it to have temporal parts connected by the same-F-as causal relation. [It could be] that the same-A-as relation and the same-B-as relation both hold amongst the parts of a and b. … if those identity-constituting causal relations conflict with each other, then a (and b) is at most one of an A or a B, [but] they need not necessarily conflict. It is quite possible that (in virtue of the same-A-as relation holding among its parts in one way) a is an A; and (in virtue of the same-B-as relation holding … in a different way), a is also a B. Finally, note that many other properties – like being conscious, or having a certain mass history – are properties had in virtue of being a certain kind of thing. So if C is some property a has in virtue of being an A, but not in virtue of being a B, that might explain initially why it might seem that a and b, though identical, are distinct with respect to C. (Eagle 2010a: 77–78)

Denying (1): Mereology

- **Weak supplementation** and standard mereology entail that type-C cases are impossible:

  What are the parts of Tubman in Gilmore's cases? According to the perdurantist, those parts at least include an instantaneous temporal part Tub_t at each moment t of Tubman's existence. And each Tub_t also has parts: because they are made of Cell, they have the temporal parts of Cell as their parts. Indeed, each Tub_t is just the fusion of those temporal parts of Cell that exist at t; and Tubman is the fusion of all the Tub_t's. So, by transitivity, all the temporal parts of Cell are parts of Tubman; Tubman has no parts that are not parts of Cell, by construction. So by the definition of 'fusion', Tubman is a fusion of the temporal parts of Cell, and by uniqueness, Tubman is the fusion of the temporal parts of Cell. But Cell is obviously the fusion of the temporal parts of Cell; therefore, Cell is Tubman. (Eagle 2010a: 73)

Denying (1): S-regions revisited

- Gilmore supposes that perdurantists agree with endurantists on the S-regions:

  > philosophers on both sides of the endurance v. perdurance dispute can all agree on two things: they can all agree about which region is *O*'s *path*, and they can all agree about which regions are *O*'s *S-regions*. (Gilmore 2007: 179)

- Why? S-region is a derivative, and fairly uninteresting, notion according to the perdurantist: it is straightforwardly defined as the maximal **intersection** of the location of a perduring object with a time (Donnelly 2011: 33).
  - There is no reason for perdurantists to accept S-regions as primitives, particularly if 4D location/shape is the most fundamental geometric property of a persisting thing.
- But if Cell and Tubman share a path, then (since intersection is a function) they must **share** their S-regions, contrary to Gilmore's assertion.

A Familiar Perdurantist Story

consider what the perdurantist says about the familiar kind of time-travel case, in which an older stage of a person visits a younger stage (perhaps to pass on some sage advice). In these cases, both stages are parts of a person, but they are not temporal parts, because they are not maximal (neither overlaps every part of the person existing at that time, because neither overlaps the other). The object that is the temporal part of the person at that time is a scattered object, which has both stages as its only parts. And it is the location of this temporally unextended scattered object which is the person's S-region at that time. Nothing different from this case goes on in the Cell/Tubman case or the Adam/Abel case: and in each of those cases, the S-regions of the two purportedly distinct objects should be maximal objects also (though, given the description of the case, they will not be scattered) (Eagle 2010a: 68)

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