IPP-SR-7:
Relativity and conventionality of simultaneity

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HT25

The course

1. Newton's laws
2. Galilean invariance
3. The Michelson-Morley experiment
4. Einstein's 1905 derivation of the Lorentz transformations
5. Spacetime structure
6. General covariance
7. Relativity and conventionality of simultaneity
8. Frame-dependent effects
9. The twin paradox
10. Dynamical and geometrical approaches to relativity
11. Presentism and relativity
12. Acceleration and redshift

Today

Relativity of simultaneity

Conventionality of simultaneity

Arguments against conventionality

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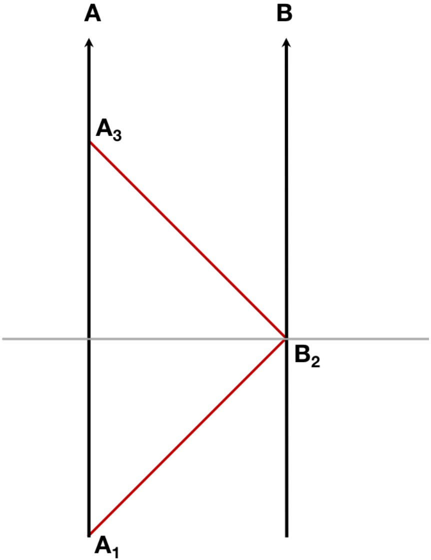
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B
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B2
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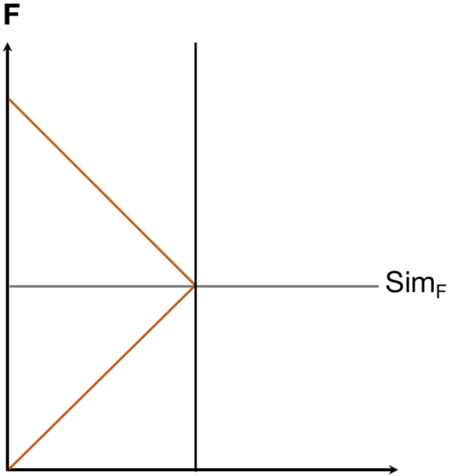
- If we apply this in all frames, the relativity of simultaneity follows.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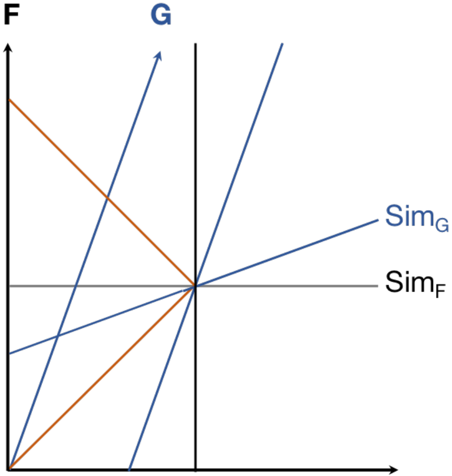
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- One who thinks this would have to say that that there are no facts about simultaneity *even in one frame*—and thus that these can be fixed by convention only.
- This is the *conventionality of simultaneity*, which is conceptually distinct from the *relativity of simultaneity*.

Today

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Conventionality of simultaneity

Arguments against conventionality

Reichenbach's ϵ-factor

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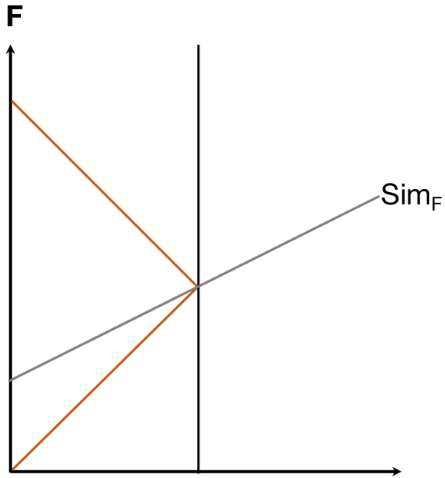
- Reichenbach's underlying thought: nothing in the formal structure of SR fixes which synchrony convention we must use; it is, rather, *an additional input choice*.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- **Question:** Why did Reichenbach bound ϵ by 0 and 1?

Brown on bounding ϵ

I will have more to say about this Reichenbach factor ϵ shortly, but note that it is widely assumed that ϵ must be restricted to the closed set $[0, 1]$ ... This is to ensure that in one direction light does not propagate backwards in time. It is often claimed that such a possibility would violate the fundamental canons of causality, but it is a hum-drum experience for airline travellers flying East across the International Date Line.

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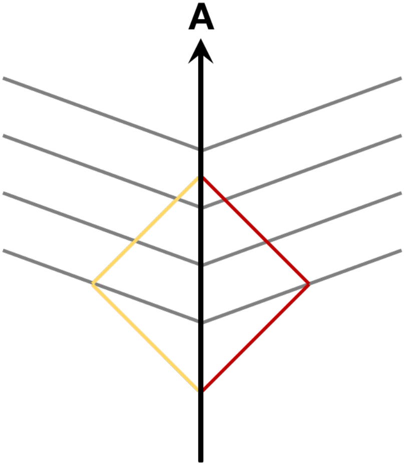
... I can testify, having flown from New Zealand to both North and South America, that arriving before you left is survivable! ... Come to think of it, every telephone call from, say Australasia to the UK, involves a signal arriving before it left, and no one seems the worse for it. (Brown 2005, p. 97)

Reichenbach's synchrony conventions

Building upon the thought that one is free to choose $\epsilon \neq \frac{1}{2}$, Reichenbach articulated two different possible synchrony conventions ('I' and 'II'), which we will now consider.

Reichenbach-I synchrony



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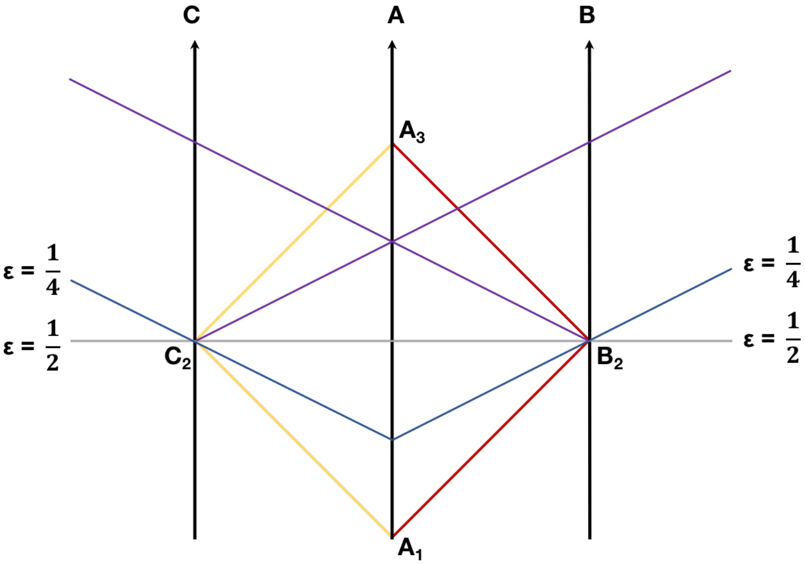

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- Simultaneity surfaces won't be flat, and there will be a preferred position in the reference frame.
- About *A*, the description of the one-way speed of light is isotropic but highly non-homogeneous due to the preferred point.
- C_2 and B_2 are simultaneous from the point of view of *A* but not from the point of view of *C* ...
- ... so what counts as simultaneous is not just frame-dependent, but position-dependent.

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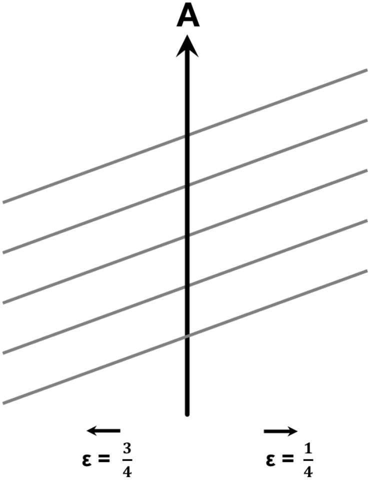
- A timescale (i.e. an assignment of time coordinates to spacetime points) is *inertial* iff, relative to that timescale, free particles have (or would have) constant velocity.

Reichenbach-II synchrony



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- Around *A*, space will be anisotropic but homogeneous: light travels faster in the rightwards direction.
- Note that Torretti's objection does not apply in this case.

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(Anderson *et al*. 1998, Winnie 1970.)

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- For example, the time read by two clocks when reunited after a ‘twin paradox’ journey will have to be the same, given any synchrony convention (see lecture 9).

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Is simultaneity conventional?

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1. Arguments from slow clock transportation.
2. Malament's 1977 (purported) proof of non-conventionality.

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- Bridgman (1962, p. 26) uses the 'self-measured' velocity, determined by using the transported clock to measure the time interval, to avoid this problem.
- But, like Eddington, he does not see this scheme as contradicting the conventionality thesis:

  > *What becomes of Einstein's insistence that his method for setting distant clocks—that is, choosing the value* $1/2$ *for* ϵ*—constituted a 'definition' of distant simultaneity? It seems to me that Einstein's remark is by no means invalidated.* (Bridgman 1962, p. 66)

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- The point is that using the slow clock method to synchronise distant clocks *is itself just another synchrony convention*.

Introducing Malament

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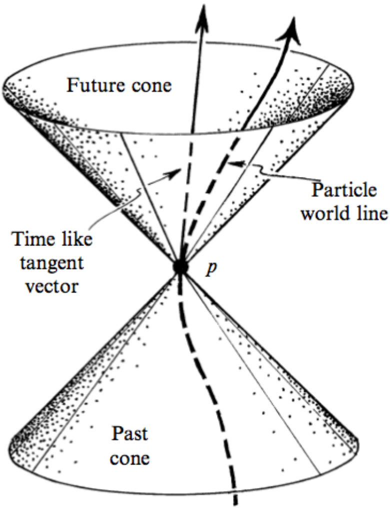
As Brown puts it, this is

> *a result which virtually single-handedly managed to swing the orthodoxy within the philosophy literature from conventionalism to anticonventionalism.* (Brown 2005, p. 98)

Norton on Malament

Contrary to most expectations, [Malament] was able to prove that the central claim about simultaneity of the causal theorists of time was false. He showed that the standard [$\epsilon = \frac{1}{2}$] simultaneity relation was the only nontrivial simultaneity relation definable in terms of the causal structure of a Minkowski spacetime of special relativity. (Norton 1992, p. 222)

Causal structure of Minkowski spacetime



(Penrose 2004, p. 403.)

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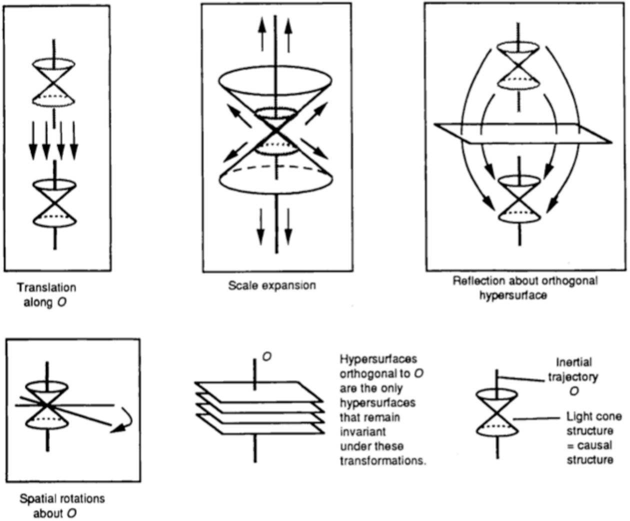
(d) which is not the universal relation.

O-causal automorphisms



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1. Why postulate that the simultaneity relation must be an equivalence relation? Doesn't this rule out e.g. the Reichenbach-I scheme by fiat?
2. "Malament's theorem leads to a unique (but different) synchrony relative to any inertial observer, [but] this latitude is the same as that in introducing Reichenbach's ϵ, and thus Malament's theorem should carry neither more nor less weight against the conventionality thesis than the argument that standard synchrony is the simplest choice." (Janis 2018)

Extra structure

Generally, supporters of Malament (e.g. Friedman 1983) argue that to use a non-standard synchrony scheme in a given frame would involve importing extra structure, supererogatory to that of SR.

Friedman's argument

So we cannot dispense with standard simultaneity without dispensing with the entire conformal structure of Minkowski space-time. Second, it is clear that if we wish to employ a nonstandard [simultaneity] ... we must add further structure to Minkowski space-time. ... This additional structure has no explanatory power, however, and no useful purpose is served by introducing it into Minkowski space-time. Hence the methodological principle of parsimony favors the choice of Minkowski space-time, with its 'built-in' standard simultaneity, over Minkowski space-time plus any additional nonstandard synchrony.

These considerations seem to me to undercut decisively the claim that the relation of [simultaneity] ... is arbitrary or conventional in the context of special relativity. (Friedman 1983, p. 312)

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- Thus, Friedman is stating that while we *could* articulate non-standard synchrony conventions in a given frame, this would involve introducing extra structure, and we have an Occamist norm to not do so.
- *This* is the import of Malament's result, for Friedman.

Brown's response

Brown's response is very different:

> *Why should we consider defining simultaneity just in terms of the limited structures at hand in the Grunbaum-Malament construction, namely an inertial world-line W and the causal, or light-cone structure of Minkowski space-time?* (Brown 2005, p. 100)

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The thought is: in the real world, there are *multiple* observers, each with an associated worldline. What’s wrong with saying that O is to use the standard simultaneity relation of O'—which need not be a standard simultaneity relation for O?

(So Brown is echoing here Janis’ point considered above.)

A geometrician's response?

Here's how Malament/Friedman might reply:

> *There's an important conceptual distinction between a world in which there is only one inertial observer (which is what Malament is countenancing) and a world with many observers (such as our own). In the latter case, we do indeed have sufficient structure to 'push' a non-standard simultaneity relation onto O's worldline (we just declare that O is to use the standard simultaneity relation of O'). But in the former case, we are not able to make this move—in this sense, simultaneity is non-conventional in SR.*

A Brownian comeback?

And here's a response which could be offered, in turn, on behalf of Brown:

> *In the former case, it's not obvious that we have enough physical structure to set up coordinates* at all *(how, operationally, is one to 'spread time through space' with only one worldline—that of O?). There would, for example, be no way to set up 'radar coordinates' in such a world. So, given an operational understanding of coordinates, it's not clear that it is legitimate to speak of simultaneity relations* at all *in that world. And in the latter case, there are many observers and much physical structure, which should afford ample opportunity to define non-standard simultaneity relations for O, as the Malamentarian has already acknowledged. Either way, Malament's proof fails to show what is claimed.*

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4. One might question certain assumptions in the proof—e.g., why assume that simultaneity must be an equivalence relation?
5. Even setting this aside, there are questions of (i) why Malament can't help himself to more structure, and (ii) whether it makes sense to speak of simultaneity at all, in the impoverished Malament-world.

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