

07. Interpreting Special Relativity

Topics:

1. Two Interpretations
2. Philosophical Consequences

1. Two Interpretations of Special Relativity

Basic Question: What would the world be like if special relativity were true?

I. Spacetime Substantivalist Interpretation

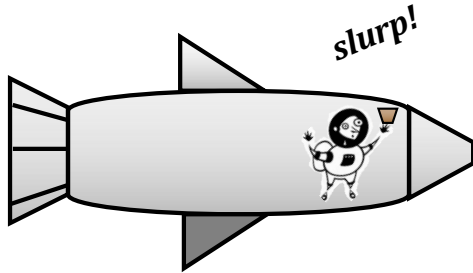
Claims:

- (a) *Special Relativity is a theory about the structure of spacetime. It says that this structure is given by Minkowski spacetime.*
- (b) *Minkowski spacetime is a real substance that affects the behavior of objects moving through it (*substantivalism*).*

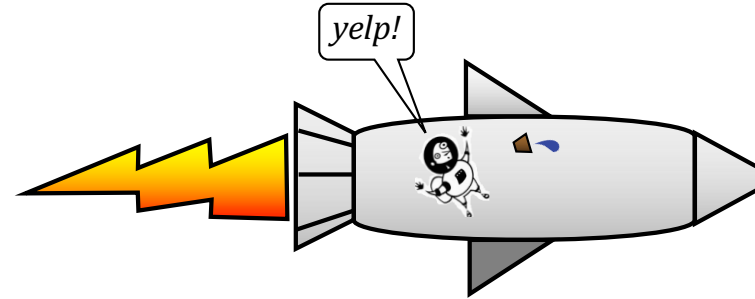
Why Claim (b)?

Offers an explanation of *inertial forces*:

Inertial force = force felt by an object when it deviates from inertial motion



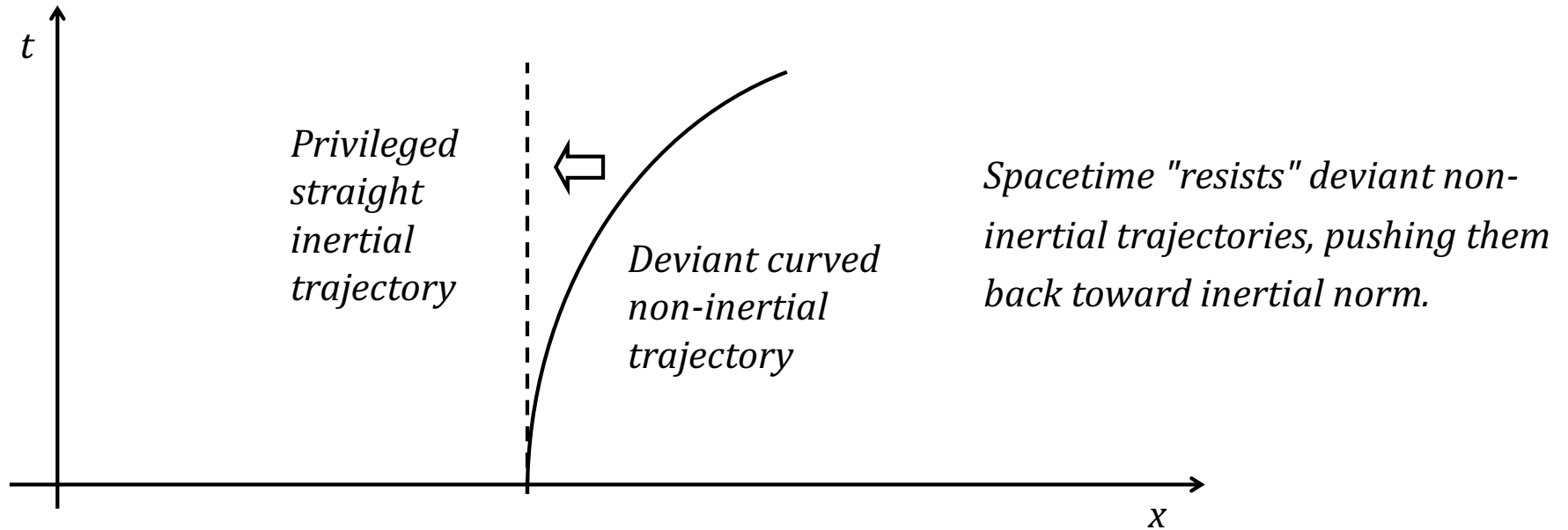
Rocket undergoing inertial motion (constant velocity)



Rocket undergoing non-inertial motion (accelerating)

Spacetime Substantivalist Explanation of Inertial Forces

- Minkowski spacetime is "resistance-free" to objects undergoing *inertial motion* (straight-line, constant velocity).
- It "resists" objects undergoing *non-inertial motion* (accelerated motion).
- This "resistance" manifests itself as inertial forces.



Further Claims:

- (i) Length contraction and time dilation are *purely kinematical* effects due to the structure of Minkowski spacetime.
 - *Due to disagreements over how inertial observers take spatial and temporal cross-sections of the world-tube of a physical system.*
- (ii) Space and time are different inertial-frame-dependent aspects of the invariant frame-independent property of *spatiotemporal length*.
- (iii) Mass and energy are different inertial-frame-dependent aspects of the invariant frame-independent property of *energy-momentum*.

II. Dynamical Relationalist Interpretation.

Claims:

- (a) *Special Relativity is a theory about the form that dynamical laws must take. It says that such laws must be Lorentz invariant.*
- (b) Spacetime does not exist independently of physical objects; rather, it consists merely in the *dynamical* relations between physical objects (*relationalism*).

Why Claim (b)?

- What kind of substance would spacetime be?
- What is the mechanism by which it interacts with (resists) moving objects?
- If it acts on objects without objects acting on it, wouldn't it violate Newton's 3rd Law (for every action there is an equal and opposite reaction)?

But: What about inertial forces? How can inertial forces be explained *relationally*?

Further Claims:

- (i) Time dilation and length contraction are *real dynamical* effects.
- *Moving objects contract and moving clocks slow down due to physical molecular forces that govern their constituents.*
 - *A real dynamical effect due to Lorentz-invariant laws.*
 - *Not due to motion with respect to a stationary physical rest frame (like the aether); nor is it due to the (kinematic) structure of Minkowski spacetime.*
- (ii) Time and space are distinct quantities. So are mass and energy.

2. Philosophical Consequences of Special Relativity

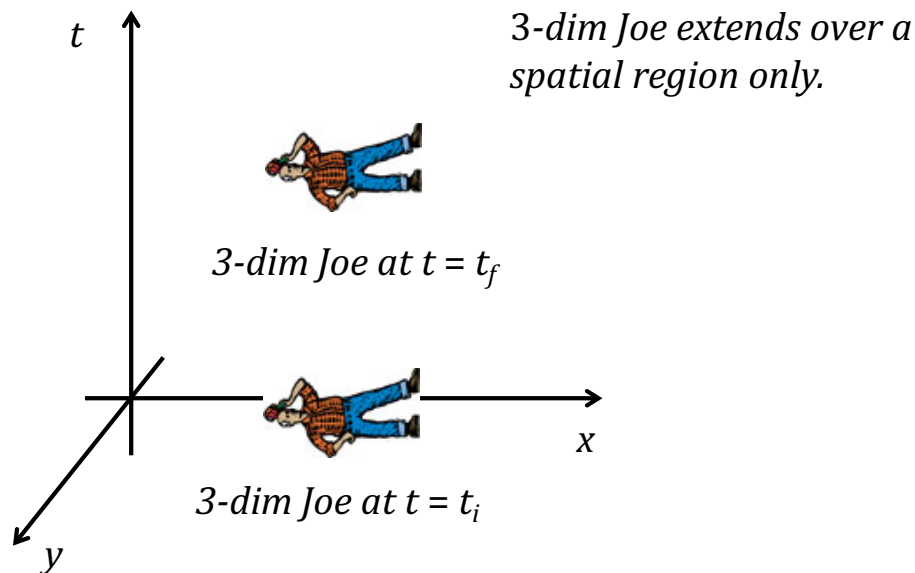
- A. Ontological Status of Objects With Respect to Time
- B. Ontological Status of Time
- C. Ontological Status of Change

A. Ontological Status of Objects with respect to Time

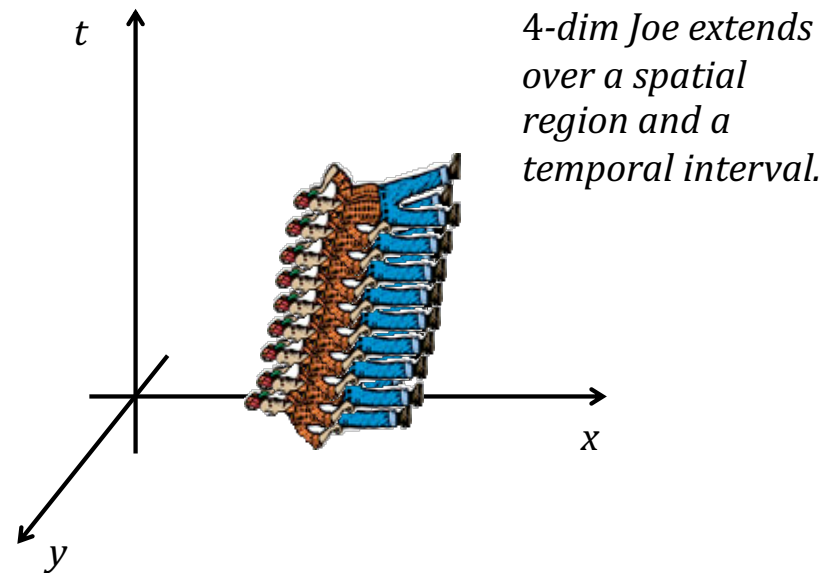
Basic Question: How do objects exist with respect to time?

(a) *Endurantism*: Objects are 3-dimensional and endure through time.

(b) *Perdurantism*: Objects are 4-dimensional and "perdure" (extend) over time.



Endurantism



Perdurantism

- *Endurantism*: What identifies Joe-at- t_i with Joe-at- t_f ?
 - *Are they the same Joe: Is Baby Joe the same 3-dim object as Coffin Joe?*



Baby Joe at $t_i - 50$



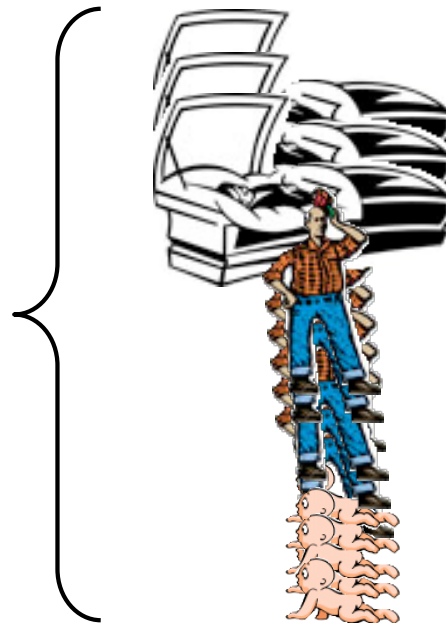
Joe at t_i



Coffin Joe at $t_i + 50$

- *Perdurantism*: How temporally extended is 4-dim Joe?
 - *Does he extend only over the interval $[t_i, t_f]$? A larger/smaller interval?*

The Complete 4-dim Joe?



Coffin Joe slice

Baby Joe slice

Typical Claim: Special Relativity supports perdurantism.

Why?

- Minkowski spacetime is 4-dim.
- The Lorentz-invariant quantities associated with Minkowski spacetime (like spatiotemporal length and energy-momentum) are 4-dim quantities.

But:

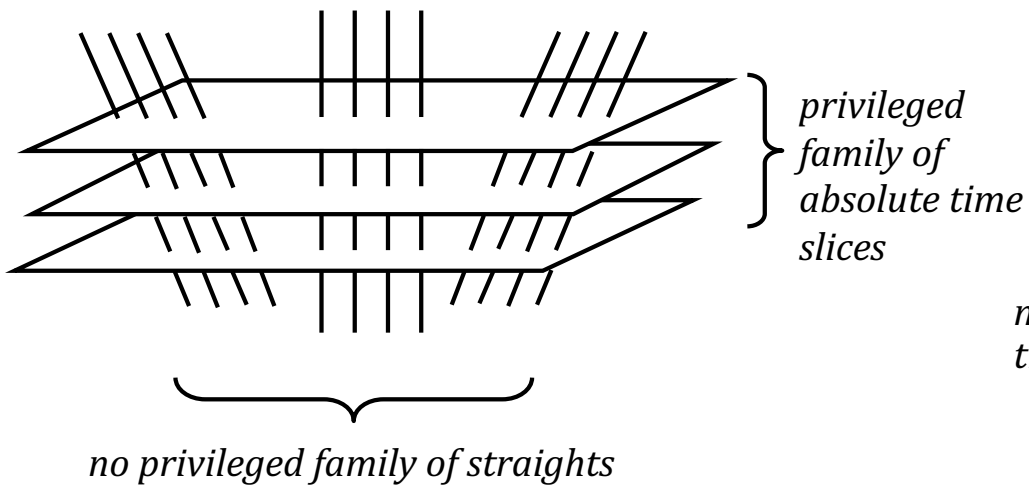
- Dynamical relationalist interpretation of SR is compatible with endurantism.
- Newtonian physics can be formulated in a 4-dim spacetime ("Galilean" spacetime); hence there is nothing special about Special Relativity with respect to 4-dim spacetimes.
- Perhaps 3-dim objects can have 4-dim properties (spatiotemporal length, energy-momentum, *etc*) and *still* remain 3-dimensional.

Conclusion: *By itself*, Special Relativity says nothing about the ontological status of objects with respect to time.

- *In order to say it does, we have to provide it with an interpretation, and we may have to engage in speculative metaphysics with respect to properties and dimensionality.*

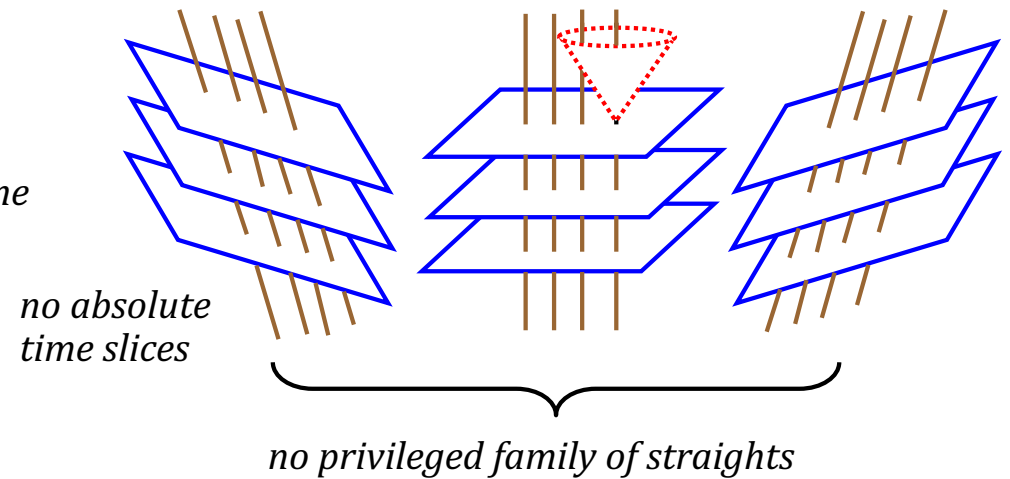
How the 4-dim spacetime of Newtonian physics (Galilean spacetime) differs from the 4-dim spacetime of Special Relativity (Minkowski spacetime).

Galilean Spacetime



1. Many inertial frames; none privileged.
2. Velocity is relative.
3. Acceleration is absolute.
4. Simultaneity is absolute.

Minkowski Spacetime



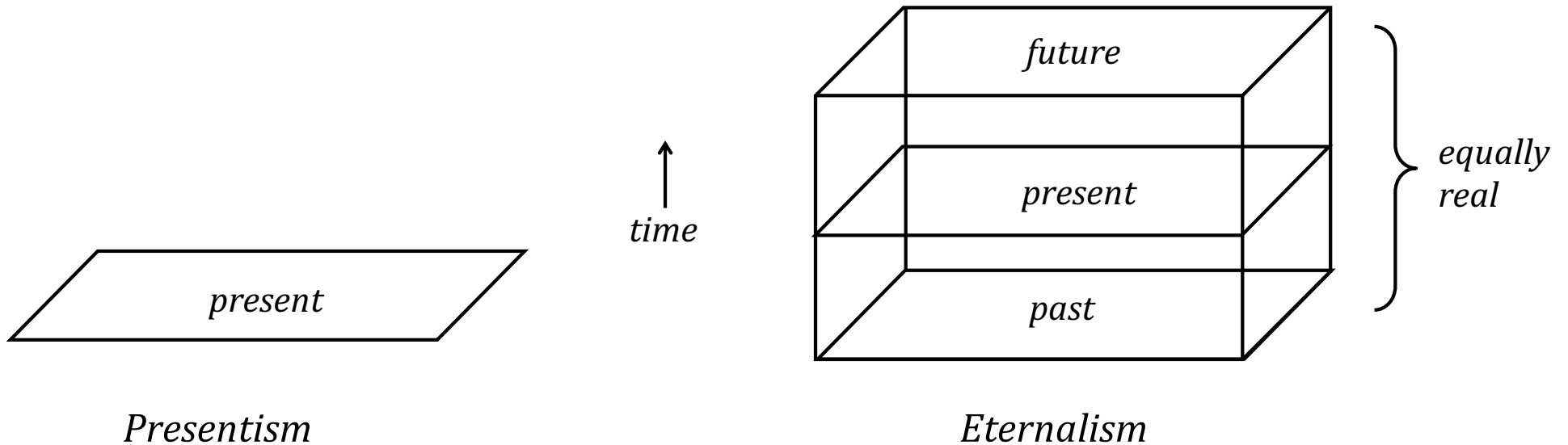
1. Many inertial frames; none privileged.
2. Velocity is relative.
3. Acceleration is absolute.
4. Simultaneity is relative.
5. Light-cone structure at each point.

B. Ontological Status of Time

Basic Question: What is the ontological status of times *other than the present*?

(a) *Presentism*: Only the present is real.

(b) *Eternalism*: All times, past, present and future, are equally real.

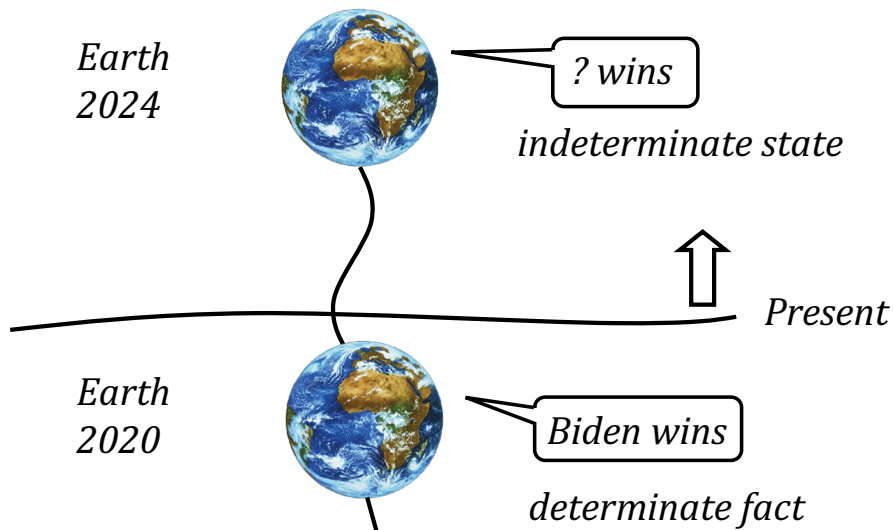


Typical Claim: Special Relativity supports eternalism.

Argument #1

- Special Relativity entails space and time are not separate but combined into spacetime.
- In spacetime, all events have the same ontological status.

According to presentism (and common intuition)...



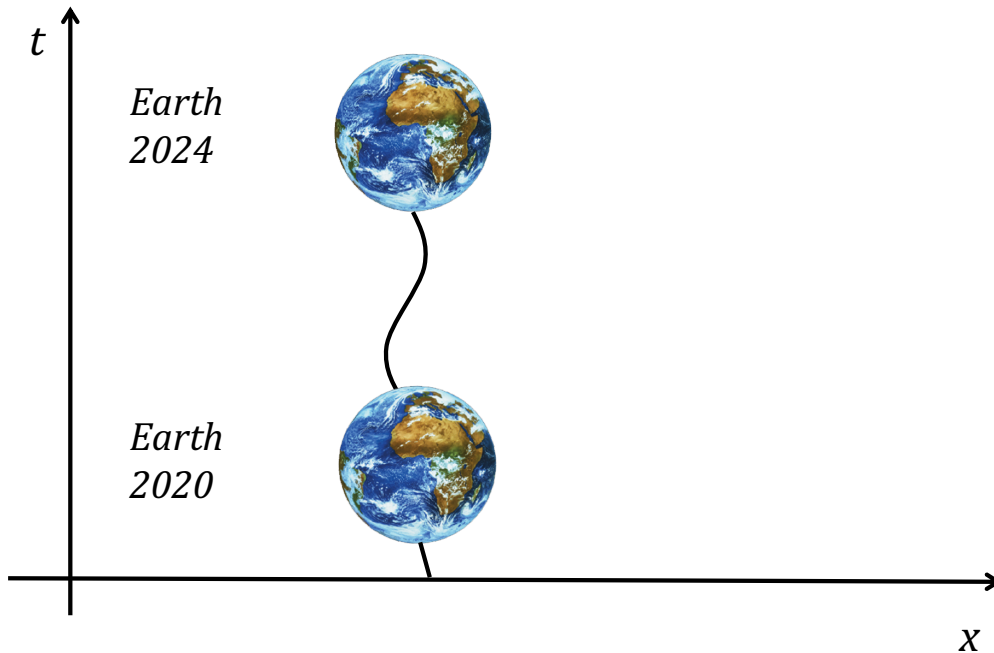
The "Present" advances and produces determinate facts out of indeterminate states.

Typical Claim: Special Relativity supports eternalism.

Argument #1

- Special Relativity entails space and time are not separate but combined into spacetime.
- In spacetime, all events have the same ontological status.

Claim: Special Relativity denies this view...



Both events are equally determinate in spacetime (i.e., both are present in a spacetime diagram).

Typical Claim: Special Relativity supports eternalism.

Argument #1

- Special Relativity entails space and time are not separate but combined into spacetime.
- In spacetime, all events have the same ontological status.

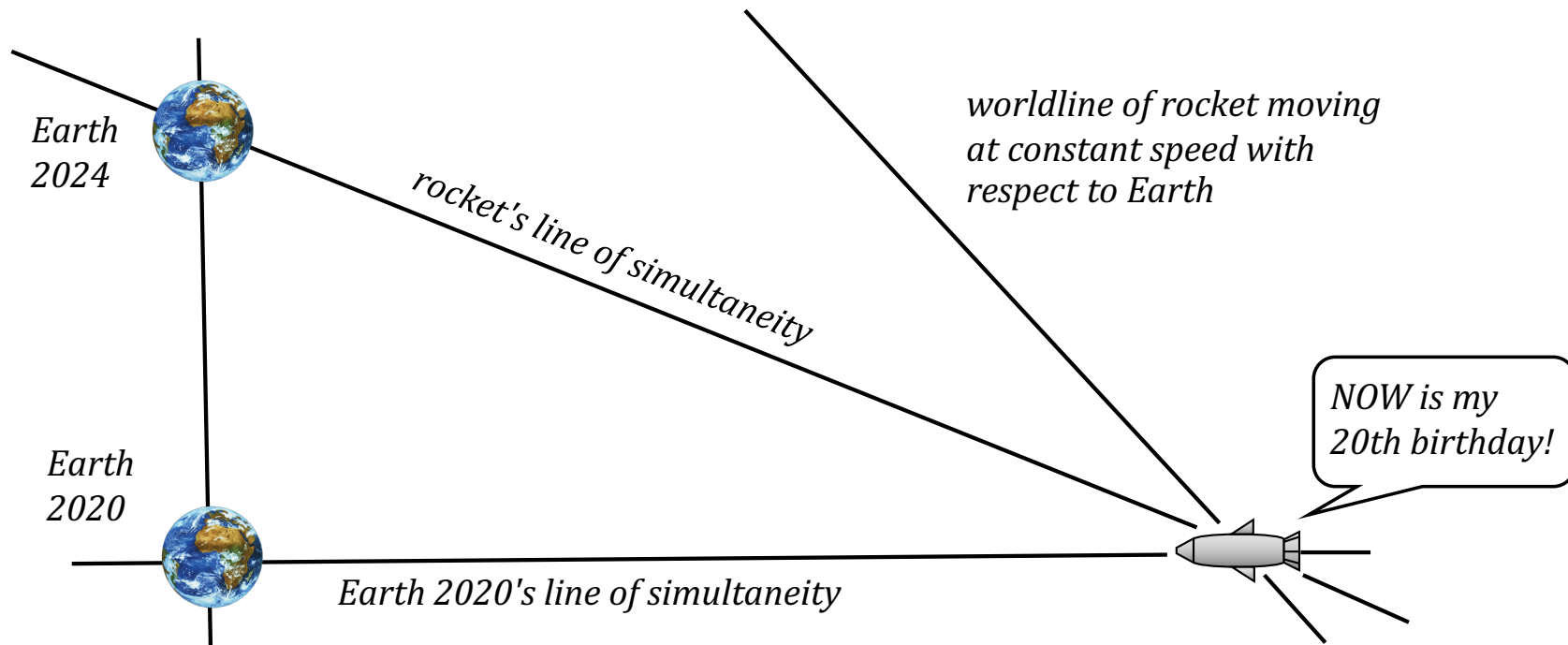
BUT!

- The dynamical relationalist interpretation of SR is compatible with presentism.
- SR is not unique in its use of spacetime diagrams. (Can be used in Newtonian physics, too.)

Typical Claim: Special Relativity supports eternalism.

Argument #2

Claim: The *relativity of simultaneity* entails that all events in spacetime *coexist* with each other.



- (1) Earth judges rocket's 20th B-Day as happening in 2020. *Therefore*, the rocket's 20th B-Day *coexists* with Earth 2020.
- (2) Rocket judges Earth 2024 as simultaneous with her 20th B-Day. *Therefore*, Earth 2024 *coexists* with the rocket's 20th B-Day.
- (3) So: The Earth at 2024 *coexists* with the Earth at 2020!

Typical Claim: Special Relativity supports eternalism.

Argument #2

Claim: The *relativity of simultaneity* entails that all events in spacetime *coexist* with each other.

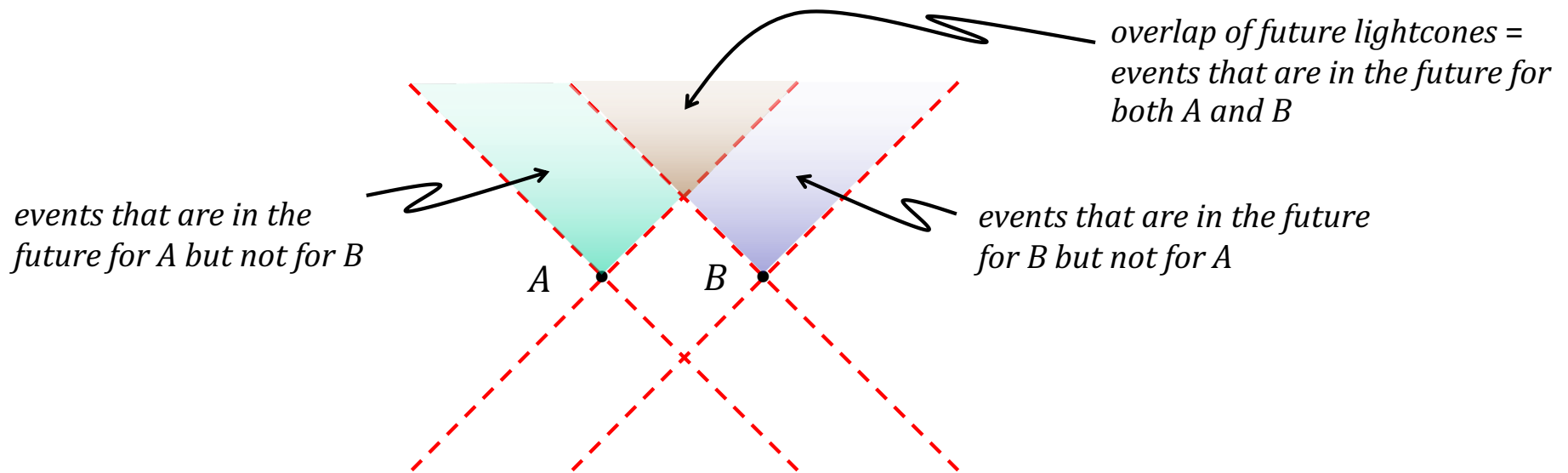
BUT!

- This conflates "being simultaneous with" with "coexisting with".
 - *Is it the case that if Event A is simultaneous with Event B, then B coexists with A?*
 - *What does it mean for one event to coexist with another?*

Typical Claim: Special Relativity supports eternalism.

Argument #3

Claim: Presentism minimally requires everyone to agree on what the present is at any given time. But since simultaneity is relative in special relativity, there is no way this can be done.



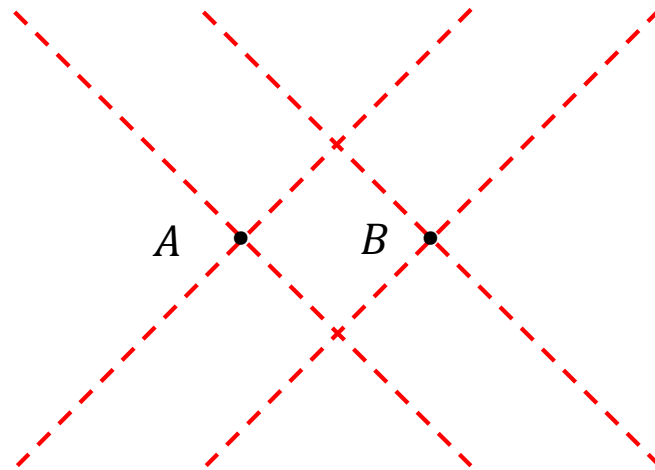
- Lightcone structure in Minkowski spacetime entails that no two events will agree on the *totality* of events that count as the future, the *totality* that count as the past, and the *totality* that count as the present.
- If the "present" is the boundary between past and future, then the present exists only at a point in Minkowski spacetime!

Typical Claim: Special Relativity supports eternalism.

Argument #3

Claim: Presentism minimally requires everyone to agree on what the present is at any given time. But since simultaneity is relative in special relativity, there is no way this can be done.

Contrast with Galilean spacetime:

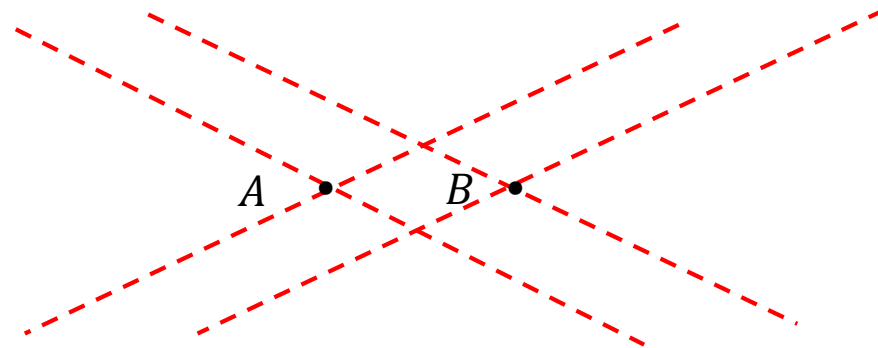


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Constrast with Galilean spacetime:

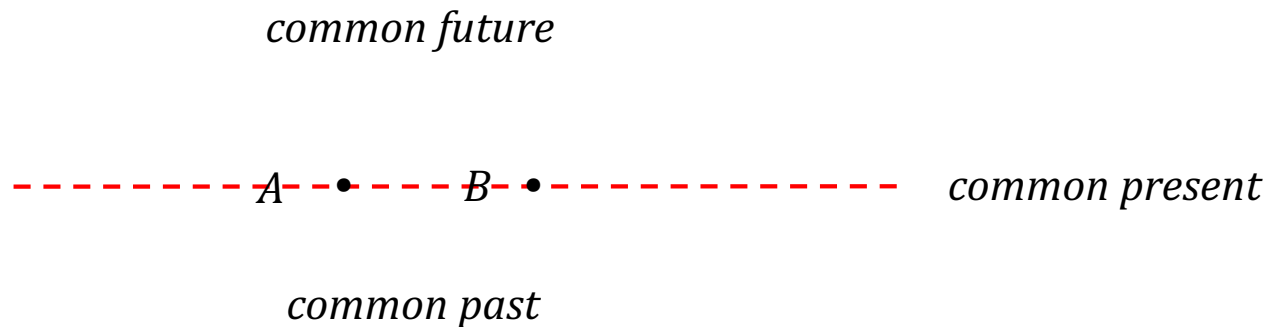


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Argument #3

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Constrast with Galilean spacetime:



- "Flattening out" lightcones corresponds mathematically to taking the "Newtonian limit": letting $c \rightarrow \infty$ (or $v/c \rightarrow 0$).
- Newtonian present = global instantaneous surface of simultaneity.

Typical Claim: Special Relativity supports eternalism.

Argument #3

Claim: Presentism minimally requires everyone to agree on what the present is at any given time. But since simultaneity is relative in special relativity, there is no way this can be done.

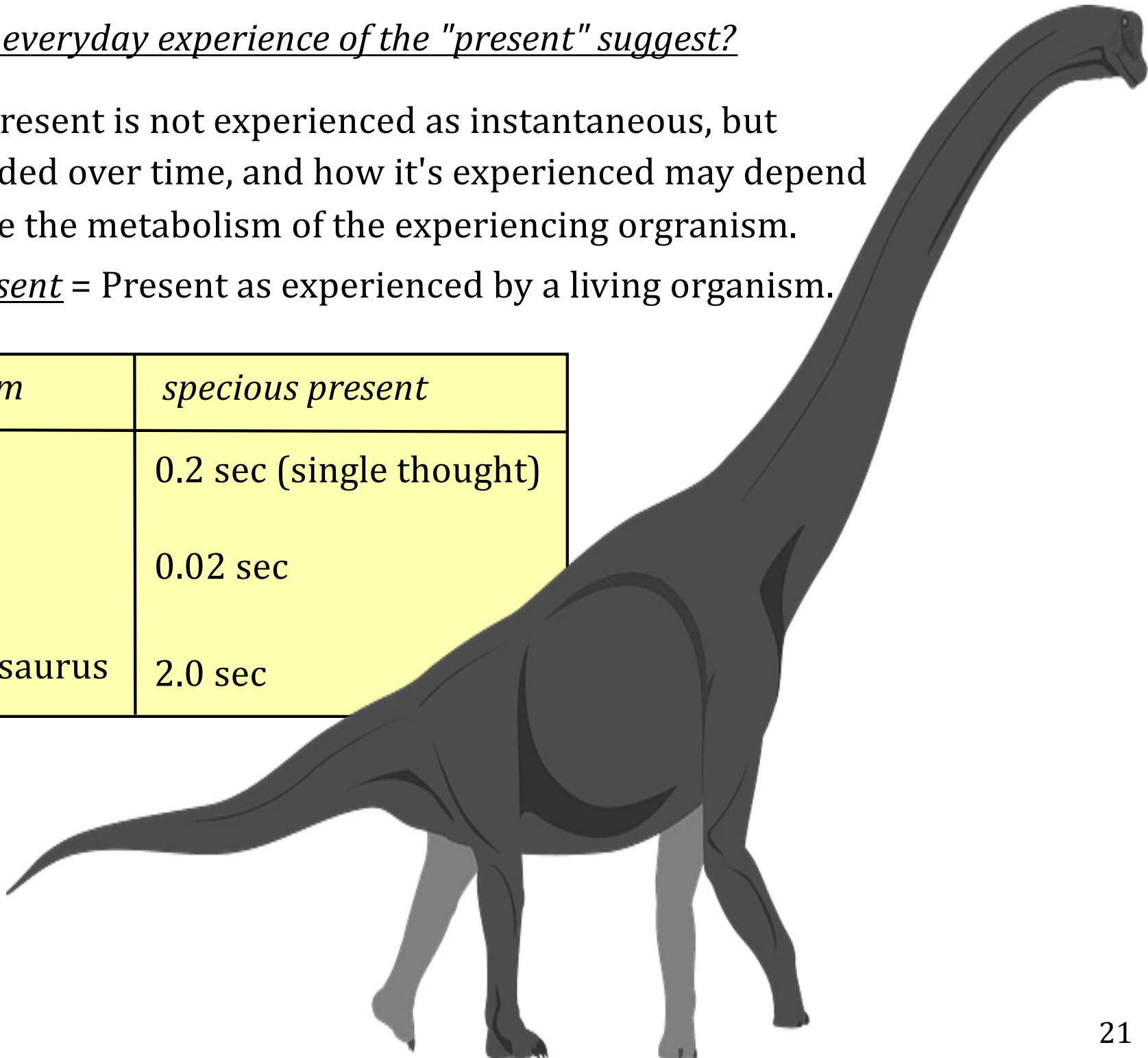
BUT!

- What *exactly* are our intuitions about the present?
- Is the "manifest image" of our everyday experience of the present really incompatible with the "scientific image" given by Special Relativity?
- Is the manifest image of our everyday experience of the present really the same as the Newtonian global present? Do we really experience the present as an *instant*?

What does our everyday experience of the "present" suggest?

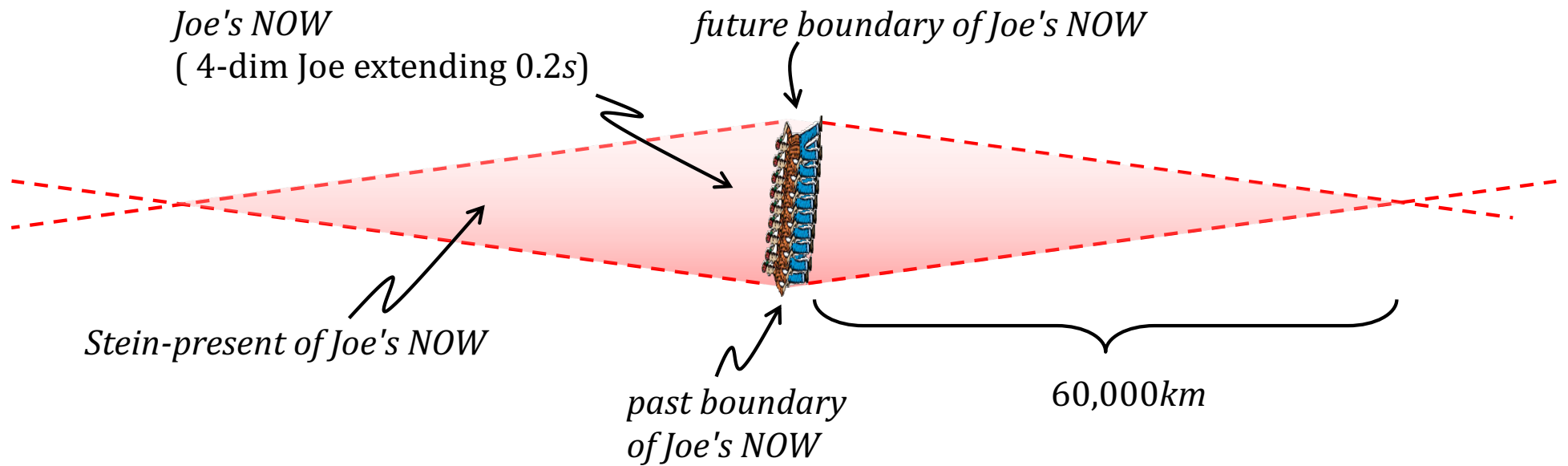
- Claim: The present is not experienced as instantaneous, but rather extended over time, and how it's experienced may depend on things like the metabolism of the experiencing organism.
- Specious present = Present as experienced by a living organism.

<i>organism</i>	<i>specious present</i>
human	0.2 sec (single thought)
gnat	0.02 sec
brachiosaurus	2.0 sec



Def. 1. *NOW* = temporally extended spacetime region occupied by an object during its specious present.

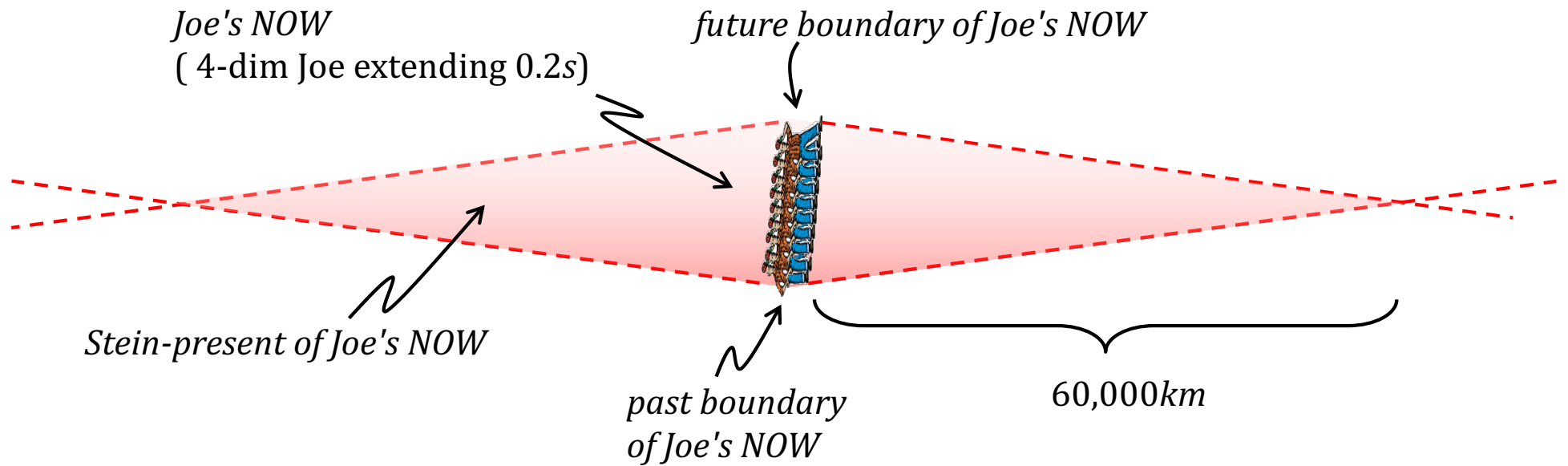
Def. 2. *Stein-present of NOW* = Region bounded by past lightcone of future boundary of *NOW*, and future lightcone of past boundary of *NOW*.



- The *Stein-present of Joe's NOW* extends very far in space (60,000km = distance light travels in 0.2s), but it's not global.
- It encompasses most humans Joe comes into contact with, all of whom can agree on its status as the "present".

Def. 1. *NOW* = temporally extended spacetime region occupied by an object during its specious present.

Def. 2. *Stein-present of NOW* = Region bounded by past lightcone of future boundary of *NOW*, and future lightcone of past boundary of *NOW*.



- Claim: The *Stein-present* of a human's *NOW* is sufficient to ground the intuitions of the presentist, while at the same time being compatible with Special Relativity.

Conclusion: *By itself*, Special Relativity says nothing about the ontological status of time.

- *In order to say it does, we have to provide it with an interpretation, and we may have to engage in speculative metaphysics with respect to the notion of the present.*

C. Ontological Status of Change

Basic Question: Is change (becoming) real?

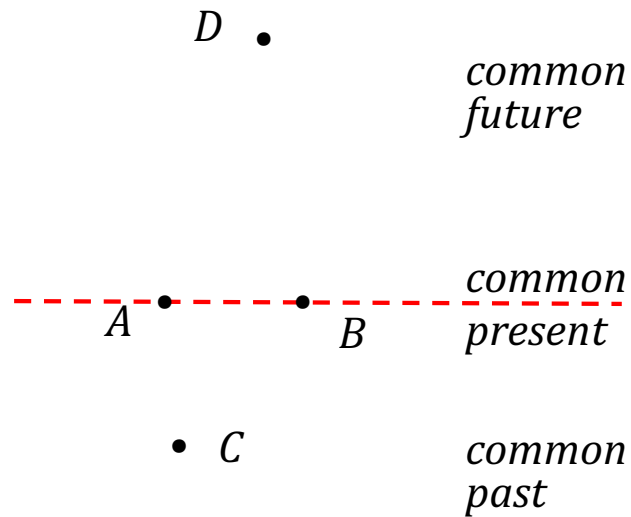
- (a) *Heracliteanism*: Becoming (change) is fundamentally real.
- (b) *Parminedeanism*: Being is fundamentally real; change is an illusion.

Typical Claim: Special Relativity supports Parminedeanism.

Why?

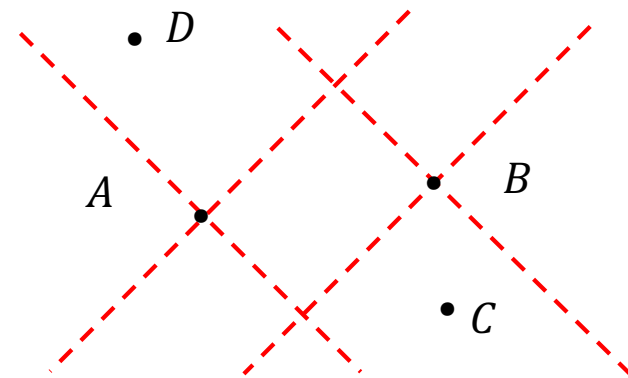
- Our manifest image of Becoming indicates that there should be an absolute distinction between:
 - (i) *Events that have become*
 - (ii) *Events that coexist and are in the process of becoming*
 - (iii) *Events that have yet to become*
- And: If this distinction is made in terms of (i) events in the *past*, (ii) events in the *present*, and (iii) events in the *future*, then in Special Relativity there is no such absolute distinction!

Manifest Image of Becoming (?)



- A and B coexist (co-present events).
- C has become (past event).
- D has yet to become (future event).

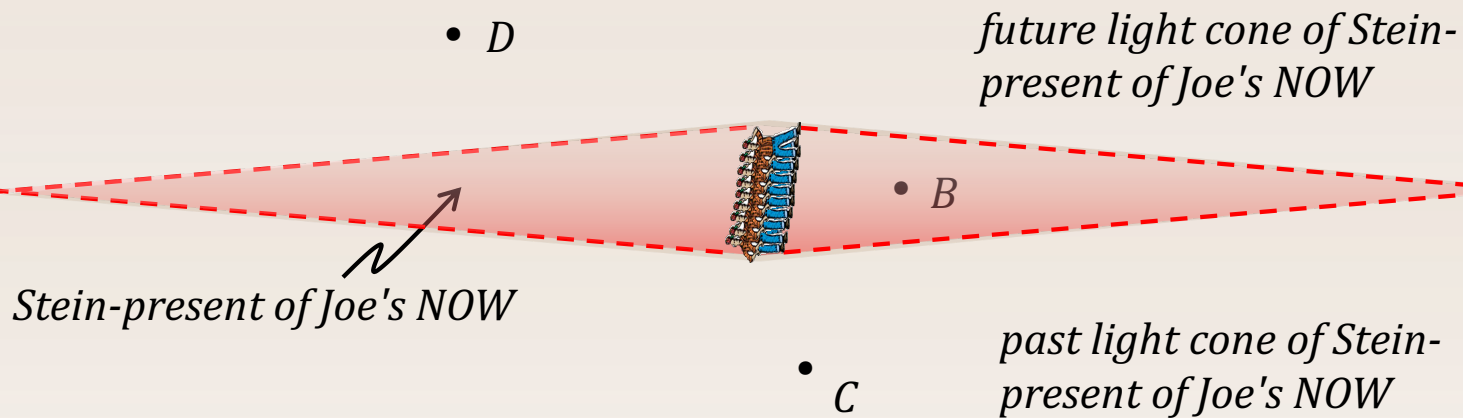
Imcompatible with Minkowski spacetime structure



- A and B do not coexist.
- C has become for B but not for A.
- D has yet to become for A but not for B.

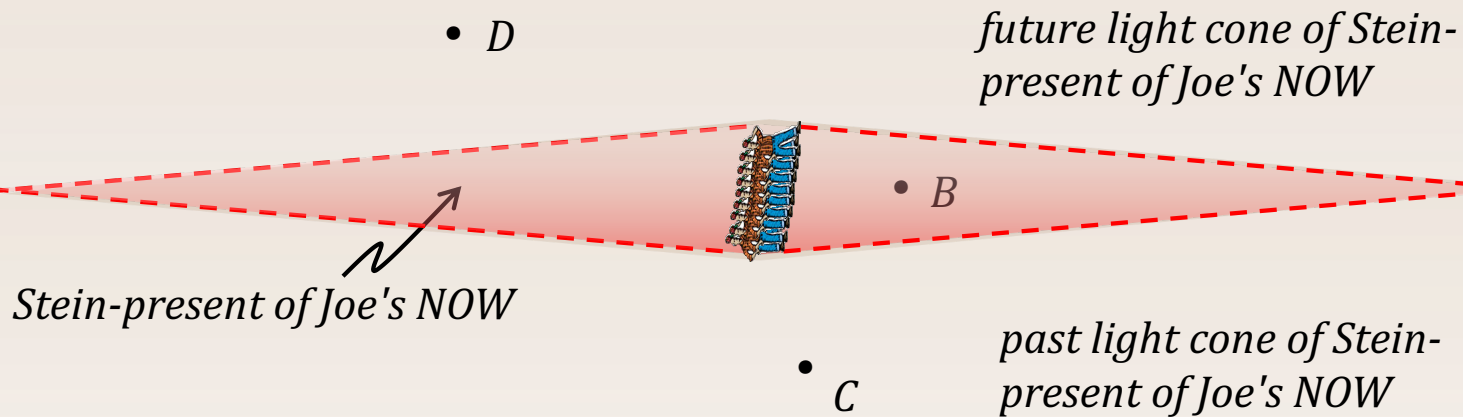
Can the manifest image of Becoming be made compatible with Minkowski spacetime?

Let's replace the absolute present with the Stein-Present of NOW...



- Object X has become with respect to object Y just if X is in the past lightcone of the *Stein Present of Y 's NOW*.
- Objects X and Y coexist just if X falls within the *Stein Present of Y 's NOW* and Y falls within the *Stein Present of X 's NOW*.
- Object X has yet to become with respect to object Y just if X is in the future lightcone of the *Stein present of Y 's NOW*.

- Because most (all?) humans will agree on the *Stein-present* of any given human's *NOW*, they will also agree on the future with respect to this *Stein present*, and on the past with respect to this *Stein-present*.
- So: Most (all?) humans will agree on which events have become, which coexist, and which are yet to become.



- Object X has become with respect to object Y just if X is in the past lightcone of the *Stein Present of Y 's NOW*.
- Objects X and Y coexist just if X falls within the *Stein Present of Y 's NOW* and Y falls within the *Stein Present of X 's NOW*.
- Object X has yet to become with respect to object Y just if X is in the future lightcone of the *Stein present of Y 's NOW*.

Conclusion: *By itself*, Special Relativity says nothing about the ontological status of change.

- *In order to say it does, we have to provide it with an interpretation, and we may have to engage in speculative metaphysics with respect to the concept of becoming.*