Paradoxes of time travel
Metaphysical concerns
Does physics permit time travel?

Time travel

Christian Wüthrich

http://philosophy.ucsd.edu/faculty/wuthrich/

14 The Nature of Reality

Paradoxes of time travel
Metaphysical concerns
Does physics permit time travel?
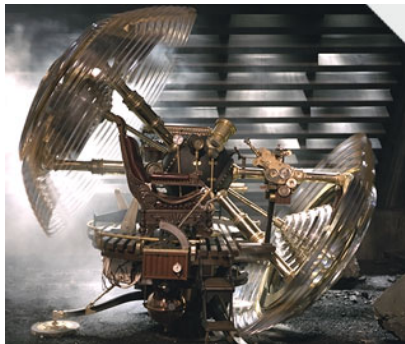
The Time Machine

- H G Wells (1895), picture from 2002 movie *The Time Machine*
- forward and backward travel in time
- forward time travel: twin paradox in special relativity

Paradoxes of time travel
Metaphysical concerns
Does physics permit time travel?

Standard Definition

Definition (Time travel (David Lewis))

"an object time travels iff the difference between its departure and arrival times in the surrounding world does not equal the duration of the journey undergone by the object" (Joel Hunter, 'Time travel', Internet Encyclopedia of Philosophy, *http://www.iep.utm.edu/timetrav/)*

Paradoxes of time travel
Metaphysical concerns
Does physics permit time travel?

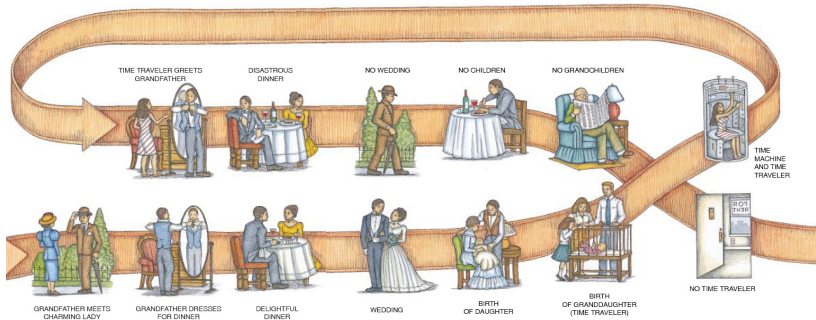# A *prima facie* problem for static theory

Question

If time is like space, how comes we can easily move around in the latter but not the former?

Possible responses: (Dainton, *Time and Space*, p. 110)

1. "Time travel involves insuperable paradoxes of a broadly logical sort, and so is metaphysically impossible.

2. "Time travel is not metaphysically impossible, but is forbidden in our world by contingent physical laws.

3. "Time travel is neither metaphysically impossible nor physically (or nomologically) impossible: it either does or could occur in our universe."

Paradoxes of time travel
Metaphysical concerns
Does physics permit time travel?

The paradoxes
Resolving them

Grandfather paradox

Paradoxes of time travel
Metaphysical concerns
Does physics permit time travel?

The paradoxes
Resolving them

Predestination paradox

- *Star Wars III: Revenge of the Sith*
- Anakin Skywalker has nightmares that his wife will die in giving childbirth
- in attempt to prevent this, he turns to the Dark Side for help
- this corrupts him and makes him assault her so that she 'loses her will to live' and dies shortly after giving childbirth
- Skywalker caused the very event he was trying to prevent exactly by trying to prevent it
- similar paradoxes in Shakespeare's *Macbeth*, *Star Trek*, *Harry Potter*, *The Terminator*...
- doesn't necessarily involve time travel

Paradoxes of time travel
Metaphysical concerns
Does physics permit time travel?

The paradoxes
Resolving them

Ontological paradox: uncaused effects

- Who wrote Shakespeare's plays?

- Time traveller discovers that neither Shakespeare, nor Marlowe, nor Bacon, nor any other of the usual suspects has...

- So he travels back in time to bring his *Complete Works* to Shakespeare together with a timeline.

- Shakespeare then copies and publishes the plays according to the timeline...

After Jasper Fforde, *The Eyre Affair*, 2001.

[Paradoxes of time travel]
Metaphysical concerns
Does physics permit time travel?

The paradoxes
Resolving them

Resolving the ontological and predestination paradoxes

David Lewis, 'The paradoxes of time travel', *American Philosophical Quarterly* **13** (1976): 145-152.)

- problem with ontological paradox: unexplained and uncaused effects
- Lewis (1976): there are many unexplained, uncaused events: existence of God, big bang, decay of tritium atom
- fact that ontological paradoxes contravene our causal intuitions not in itself an argument against possibility of these stories
- similarly with predestination paradoxes: undoubtedly irony in these stories, but they don't threaten consistency

Paradoxes of time travel
Metaphysical concerns
Does physics permit time travel?
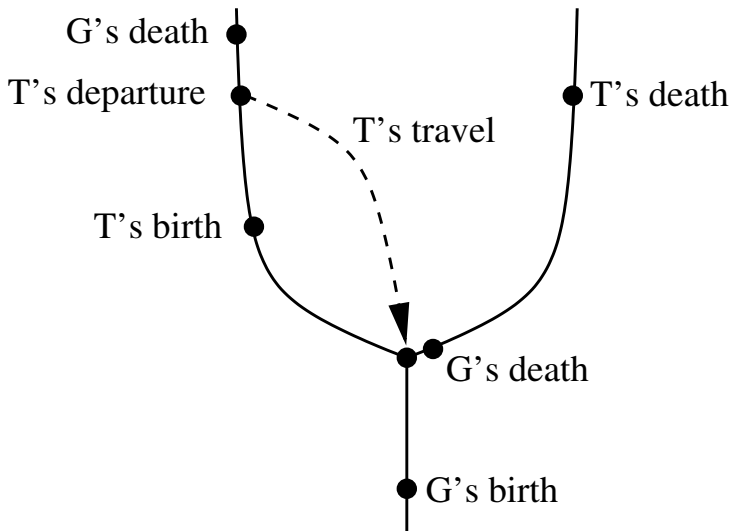
The paradoxes
Resolving them

Resolving the grandfather

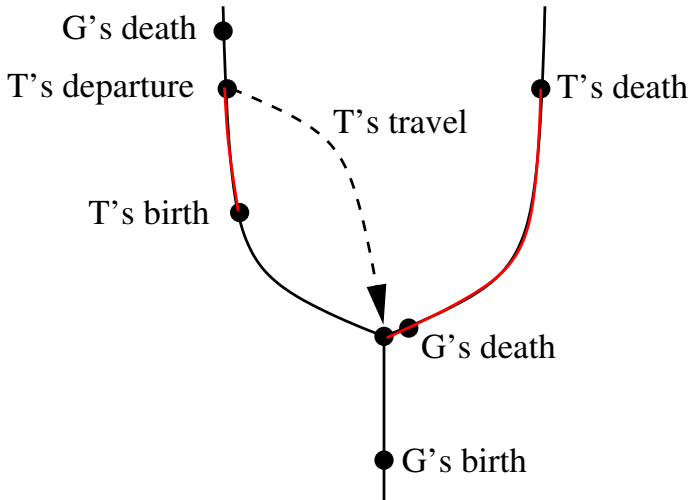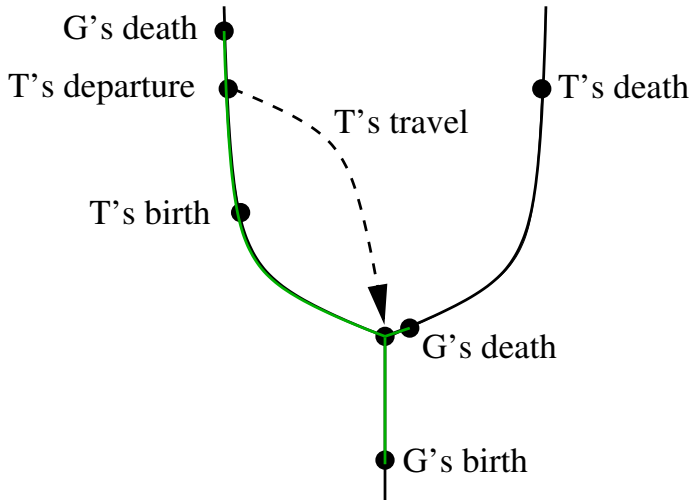There's an obvious inconsistency here, so more work will be required...

Resolutions:

- reject classical logic in favour of logic which permits contradictions (*dialethic logic*)

- two-dimensional model of time travel

- multiverses and similar modal constructs

- consistency constrains such as Ivan Novikov's self-consistency principle

Paradoxes of time travel
Metaphysical concerns
Does physics permit time travel?

The paradoxes
Resolving them

The multiverse proposal

Paradoxes of time travel
Metaphysical concerns
Does physics permit time travel?

The paradoxes
Resolving them

Important: if everybody's worldlines have beginning and end points in all branches, the grandfather paradox cannot arise

Paradoxes of time travel
Metaphysical concerns
Does physics permit time travel?

The paradoxes
Resolving them

Paradoxes of time travel
Metaphysical concerns
Does physics permit time travel?

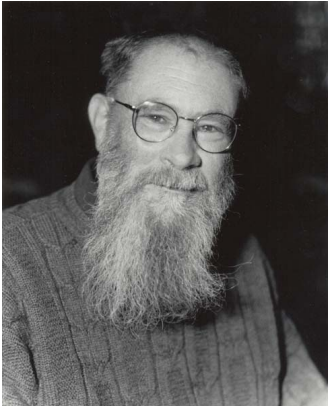The paradoxes
Resolving them

Consistency constraints

John Earman, *Bangs, Crunches, Whimpers, and Shrieks*, Oxford University Press, 1995.

- Earman (1995): grandfather paradox nothing but crude way of saying that there are consistency constraints (CCs) in order to ensure absence of contradictions

- CCs thus imply that a time-travelling murderer must fail to kill Grandpa in the intended way

Principle (Self-consistency principle)

No inconsistent set of events transpires.

Paradoxes of time travel
Metaphysical concerns
Does physics permit time travel?

The paradoxes
Resolving them

Lewis's modal inconsistency

- CCs entail that past cannot be changed; so if John Connor's mother survives 1984, she does so tenselessly
- Modal paradox: Terminator can and cannot kill Sarah Connor before she gives birth to John
- Lewis (1976): invalid equivocation of 'can'
- 'can' is always relative to a set of facts (compossibility): assuming that this and that is the case, this or that can or cannot be done
- paradox resolved

Paradoxes of time travel
Metaphysical concerns
Does physics permit time travel?

The paradoxes
Resolving them

Conclusions so far

1. Logic itself does not prohibit time travel, it just constrains the sort of scenarios that can occur.

Paradoxes of time travel
Metaphysical concerns
Does physics permit time travel?

Metaphysical concerns

- now common view among philosophers: so a time traveller cannot change the past, but she must still affect it
- Causal relation between antecedent conditions prior to departure and consequent conditions upon (the earlier) arrival ascertain personal persistence of time traveller and thus necessary identity conditions.
- But if this relation is causal, it seems as if there must be backward causation, i.e. causal relations where the effect precedes the cause.
- second major worry: CCs make time travel arbitrarily improbable

Paradoxes of time travel
Metaphysical concerns
Does physics permit time travel?

The metaphysical master argument

The metaphysical master argument against the possibility of time travel:

1. Time travel necessarily involves backward causation.
2. Backward causation is (conceptually) impossible.

∴ Time travel is (conceptually) impossible.

I will discuss and qualify the first premise later, but metaphysicians are usually interested in the second.

Paradoxes of time travel
Metaphysical concerns
Does physics permit time travel?

Conclusions so far

1. Logic itself does not prohibit time travel, it just constrains the sort of scenarios that can occur.

2. Metaphysical (and other philosophical) arguments against time travel are far from conclusive, particularly because time travel need not involve backward causation...
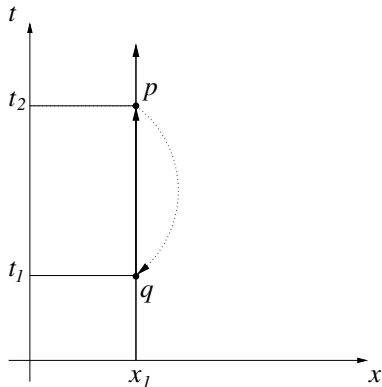
Paradoxes of time travel
Metaphysical concerns
Does physics permit time travel?

Time travel in general relativity (GR)
Spacetime with CCCs

Does physics permit time travel?

Cast problem in spacetime language:
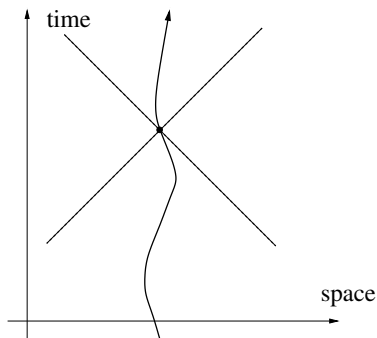
- simplification for one spatial and one temporal dimension
- convention: propagation of light drawn as bisecting line
- Light postulate in special relativity (SR): nothing ever travels faster than light
- Does casting issue in 4d prejudge debate between dynamist and staticist? Yes, but remember that all of this is in defence of staticist.

Paradoxes of time travel
Metaphysical concerns
Does physics permit time travel?

Time travel in general relativity (GR)
Spacetime with CCCs

Wellsian time travel four-dimensionally

- event *p*: switch lever, press button
- event *q*: arrival in our past

Discontinuities? Not necessarily.
Backward causation? You bet!

Paradoxes of time travel
Metaphysical concerns
Does physics permit time travel?

Time travel in general relativity (GR)
Spacetime with CCCs

Backward causation is unphysical!
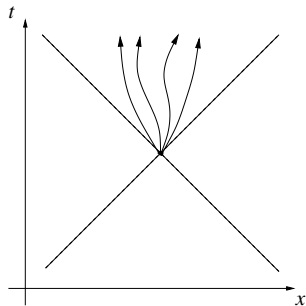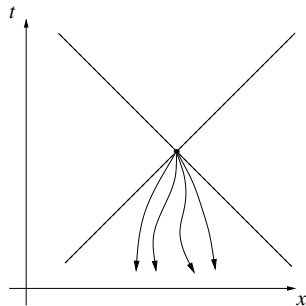

Figure: Forward causation

Figure: Backward causation

P.S. According to SR, signals which leave the point of origin 'sideways' are also prohibited.

Paradoxes of time travel
Metaphysical concerns
Does physics permit time travel?

Time travel in general relativity (GR)
Spacetime with CCCs

Time travel in Einstein's general relativity (GR)

In Einstein's GR, gravity is interpreted as curvature of spacetime:

Spacetime geometry ⇔ distribution of matter and energy

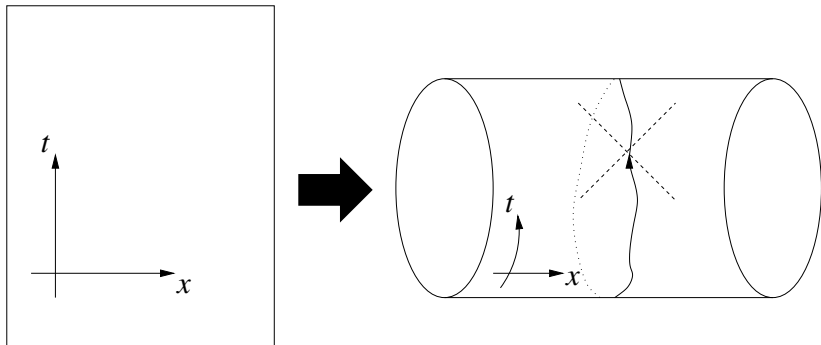Consequence: one can go 'straight' in a curved spacetime and yet return to the same point. (Analogy: globe)

Kurt Gödel 1949: solution of Einstein equations with closed causal curves (CCCs), the so-called Gödel-spacetime

Paradoxes of time travel
Metaphysical concerns
Does physics permit time travel?

Time travel in general relativity (GR)
Spacetime with CCCs

Closed causal curves

- closed: curve intersects itself
- causal: without backward causation, just 'forward causation' of signals, not faster than speed of light
- But how can curve be closed and causal at the same time??
- Answer: by taking advantage of geometrical structure of spacetime, i.e. of curvature

Paradoxes of time travel
Metaphysical concerns
Does physics permit time travel?

Time travel in general relativity (GR)
Spacetime with CCCs

Examples of spacetimes with closed causal curves

Basic idea:

Paradoxes of time travel
Metaphysical concerns
Does physics permit time travel?

Time travel in general relativity (GR)
Spacetime with CCCs
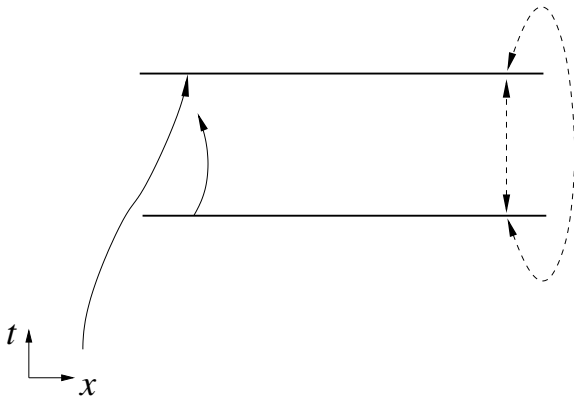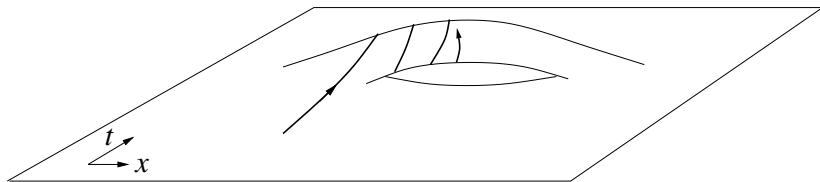
Deutsch-Politzer-spacetime: 'regional' acausalities

'Global' acausalities, i.e. occurrence of CCCs;

It is also possible that CCCs are confined to region:

Paradoxes of time travel
Metaphysical concerns
Does physics permit time travel?

Time travel in general relativity (GR)
Spacetime with CCCs

Deutsch-Politzer spacetime has a local 'handle'; CCCs are confined to this region.

Paradoxes of time travel
Metaphysical concerns
Does physics permit time travel?

Time travel in general relativity (GR)
Spacetime with CCCs

More realistic spacetimes with CCCs

- Example: spacetime with black holes
  (Kerr-Newman-spacetime) or wormholes
  (Einstein-Rosen-bridges)
- ⇒ GR explicitly permits time travel.
- Does it lend itself to great business plan?
- Unfortunately no: astronomical energy consumption to
  follow CCCs in physically realistic spacetimes
- at least: theoretically possible

David Malament, 'Minimal acceleration requirements for 'time travel' in Gödel spacetime', *The Journal of Mathematical Physics* **26** (1985): 774-777.

Christian Wüthrich, *On time machines in Kerr-Newman spacetimes*, Master thesis, University of Bern, 1999.
http://philosophyfaculty.ucsd.edu/faculty/wuthrich/pub/
WuthrichChristian1999MScThesis.pdf

Paradoxes of time travel
Metaphysical concerns
Does physics permit time travel?

Time travel in general relativity (GR)
Spacetime with CCCs

Conclusions

1. Logic itself does not prohibit time travel, it just constrains the sort of scenarios that can occur.

2. Metaphysical (and other philosophical) arguments against time travel are far from conclusive, particularly because time travel need not involve backward causation...

3. So to the best of our knowledge, time travel is neither metaphysically nor physically (or nomologically) impossible; it does or could occur in our world $\Rightarrow$ *prima facie* problem for static theory on p. 4 resolved