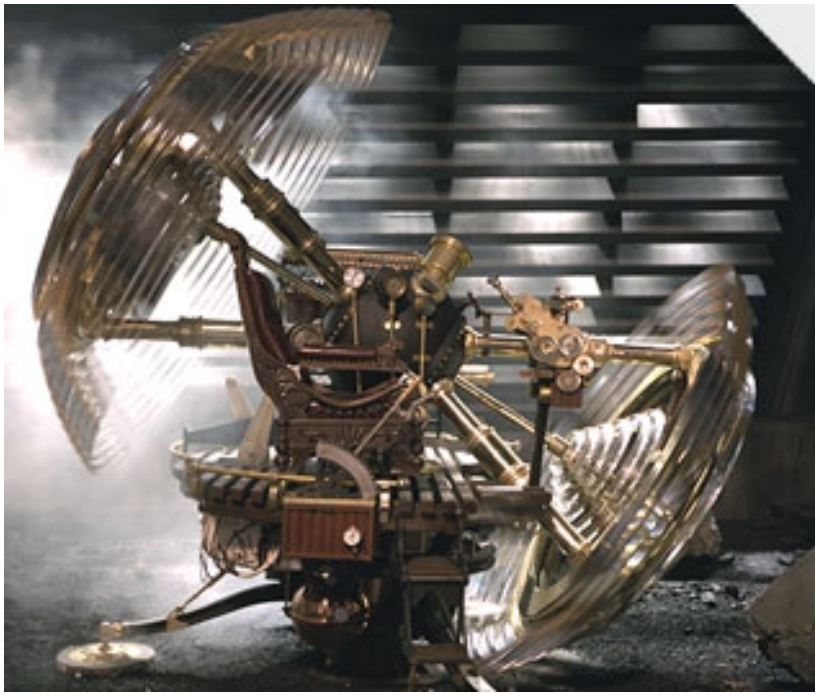
Time travel

Christian Wüthrich

http://www.wuthrich.net/

Introduction to Philosophy of Physics

The Time Machine



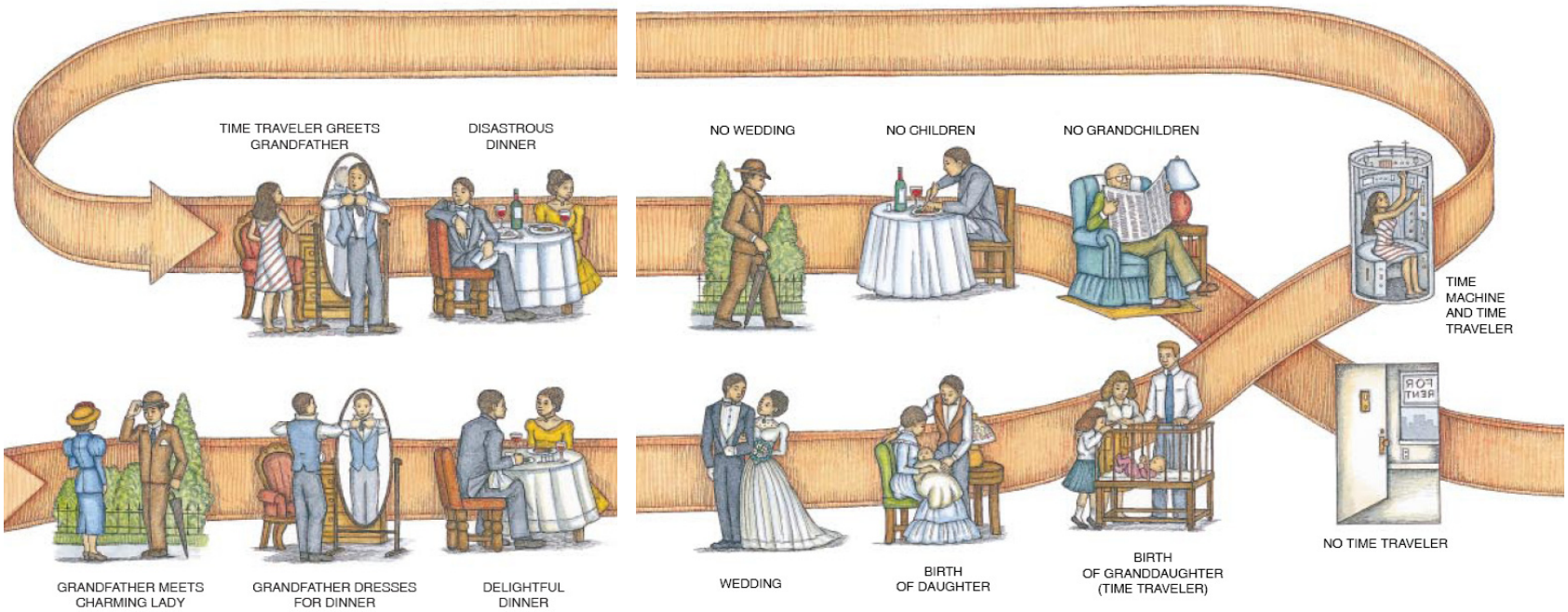
- H G Wells (1895), picture from 2002 movie *The Time Machine*
- forward and backward travel in time
- forward time travel: twin paradox in special relativity

Time travel: the standard definition

Definition (Time travel (according to 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*)*

Grandfather paradox



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

Ontological paradox: uncaused effects

Question: does the following constitute a violation of the principle of causality?

- 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.

Resolving the ontological (and predestination) paradox

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
- moreover: is the principle of causality really violated?
- Should there be a distinction between 'local' and 'global' causation?
- similarly with predestination paradoxes: undoubtedly irony in these stories, but they don't threaten consistency

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*)
- Jack Meiland's two-dimensional model of time travel
- multiverses and similar modal constructs
- consistency constrains such as Ivan Novikov's self-consistency principle

Meiland's two-dimensional model

Jack W Meiland, 'A two-dimensional passage model of time for time travel', *Philosophical Studies* 26 (1974): 153-173.

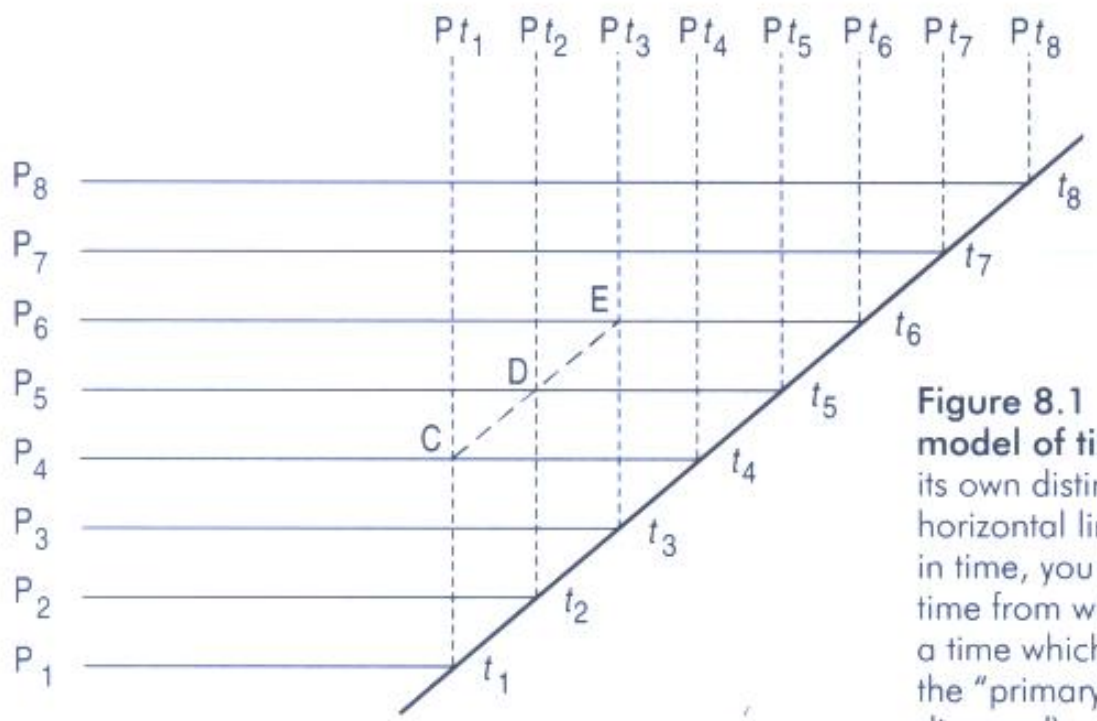
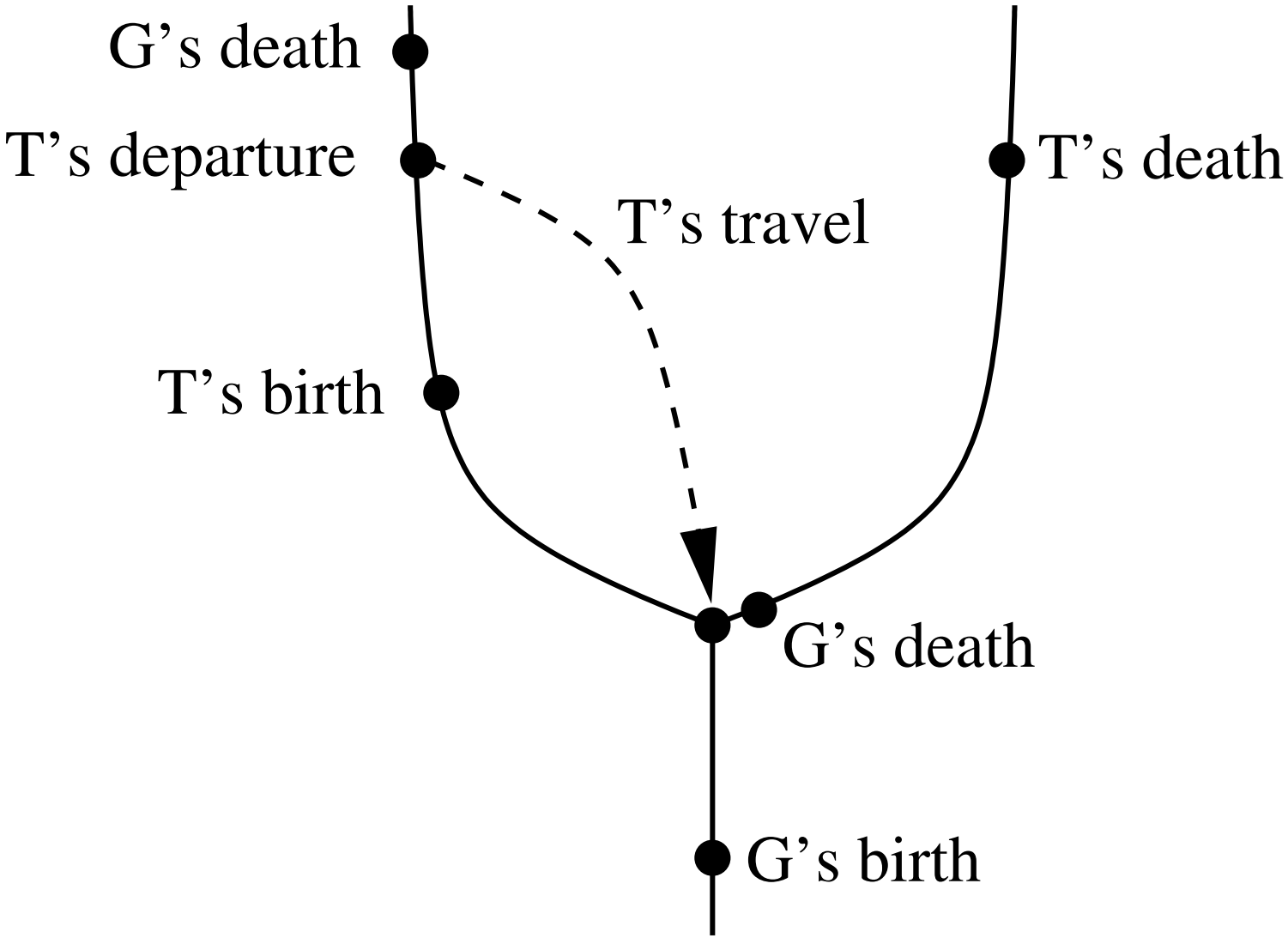


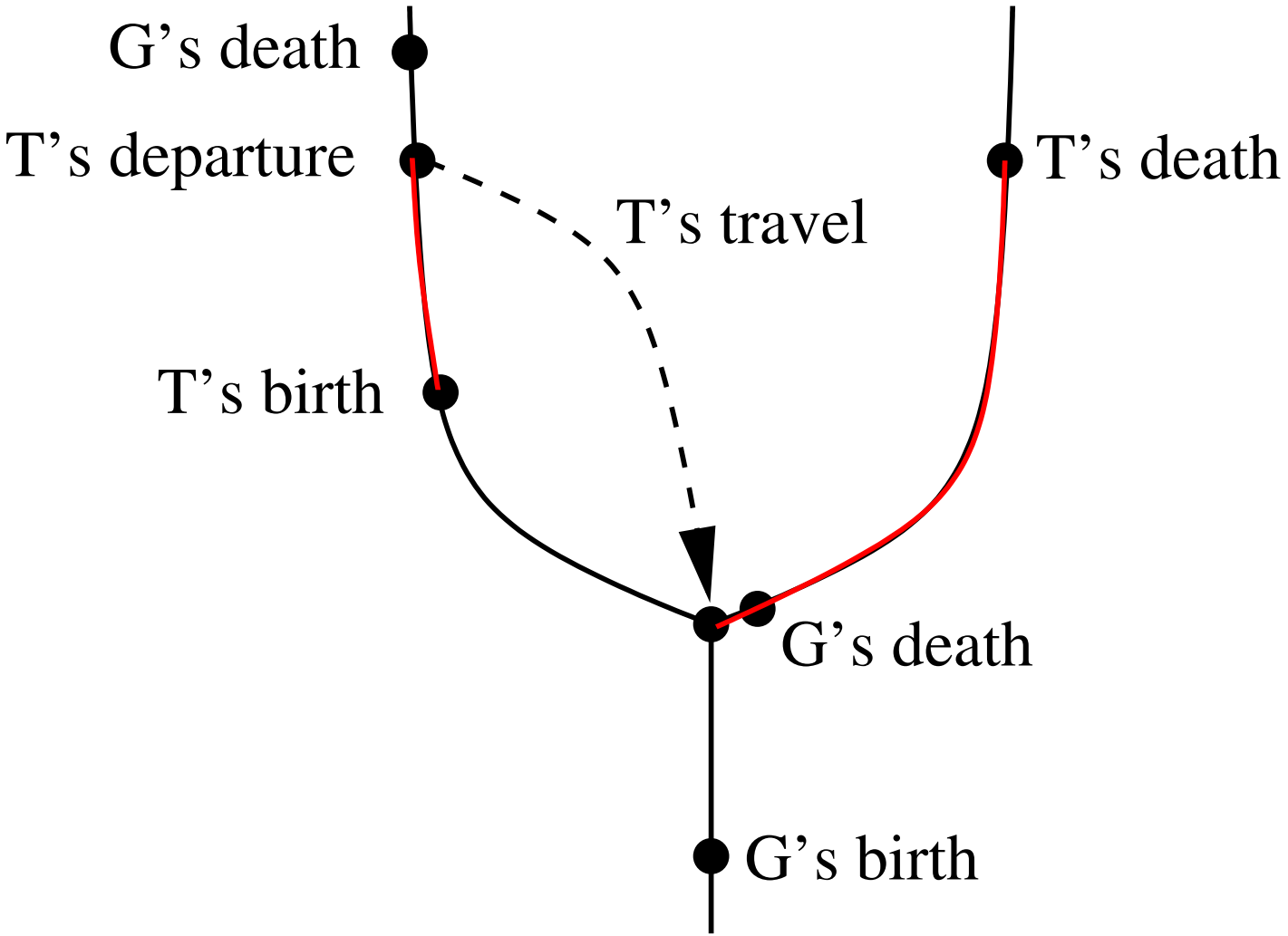
Figure 8.1 Meiland's two-dimensional model of time travel. Each moment has its own distinct past, indicated by the horizontal lines. If you were to travel back in time, you would arrive in the past of the time from which you departed, rather than a time which preceded your departure on the "primary" timeline (indicated by the diagonal).

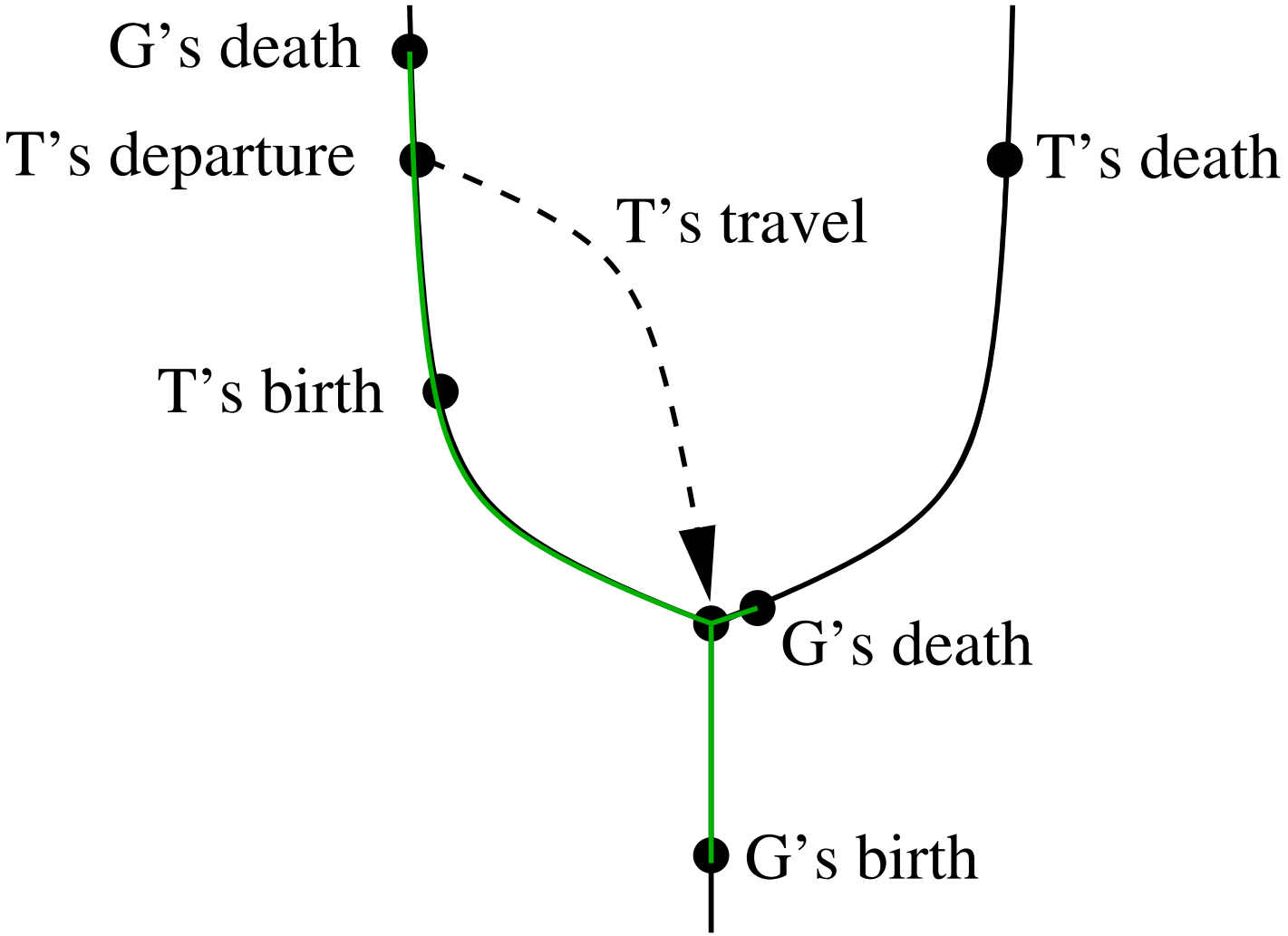
- The past changes in the sense that it is not cumulative.

The multiverse proposal



Important: if everybody's worldlines have beginning and end points in all branches, the grandfather paradox cannot arise (and similar paradoxes mutatis mutandis).




G's death
T's departure
T's travel
T's death
T's birth
G's death
G's birth

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 (Novikov's self-consistency principle)

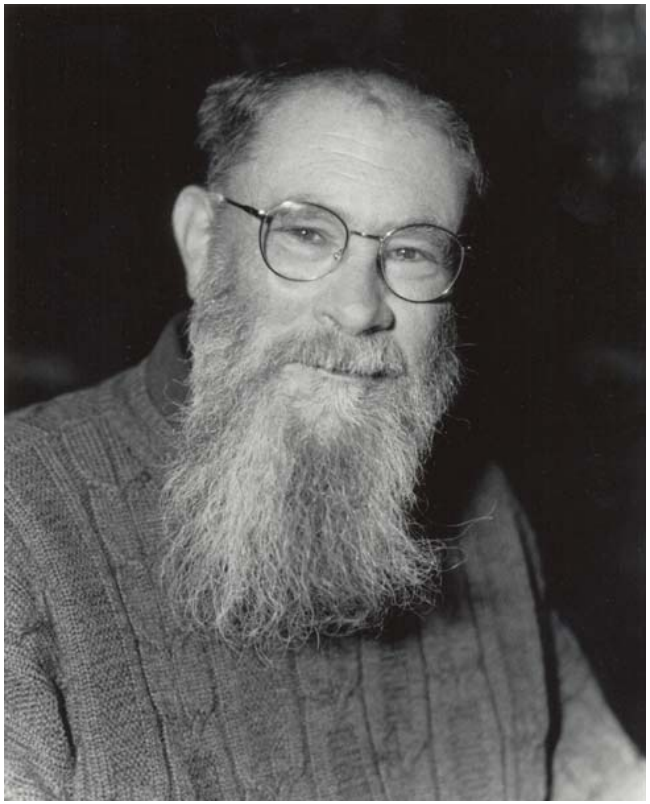
If an event's existence would engender an inconsistency, such as a change of the past, then the probability that this events occurs is zero.

Problems:

- better formulated in terms of inconsistent sets of events
- probabilistic formulation means that event can still occur...

We will come back to what the source of the CCs is.

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

Conclusions so far

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

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.

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 (metaphysically) impossible.

$\therefore$ Time travel is (metaphysically) impossible.

Note: it may be that the first premise needs to be qualified or even rejected, but metaphysicians are usually interested in the second, so let's look at that.

The bilking argument against backward causation

Max Black. Why cannot an effect precede its cause?. *Analysis* 16 (1956): 49-58.

Michael Dummett. Bringing about the past. *Philosophical Review* 73 (1964): 338-359.

- General idea of bilking argument: set up an experiment such that whenever we observe the absence (presence) of an earlier potential effect e, we try to produce (prevent) the subsequent occurrence of the potential cause c
- Repeat the experiment many times, get statistics and find that either
  - (i) e often occurs despite the absence of c and that e was often absent when we produced c; or
  - (ii) our attempts to produce c consistently fail if e didn't occur, and whenever e occurs, we cannot prevent the occurrence of c.

- Example: dancing chief (Dummett 1964)
- in case (ii) (bilking fails) our ability to produce c depends on the previous presence or absence of $e \Rightarrow$ thus it seems as if e is a necessary causal antecedent condition for c and should thus be considered its cause rather than its effect
- in case (i) (bilking successful) our hypothesis of backward causation is simply false, as there seems to be no causal relation between c and e
- Many have concluded that this argument shows that in cases where experimental design can be implemented, there cannot exist backward causation.

Problem with bilking argument

1. If conditions for experimental design are not satisfied: you cannot discover whether an alleged earlier effect has in fact occurred
   - because it is nomologically impossible to do so
   - or it is possible to discover this, but only at the price of disrupting the system in a way that is itself causally relevant for occurrence of e (e.g. in quantum mechanics)
2. Even if the experimental design can be implemented, the argument may not be successful: we may fail to bilk not because there's a (reversed) causal relation between e and c, but simply because of "strangely convenient coincidences" (Dainton, 122)
   - these coincidences may be due to global consistency constraints

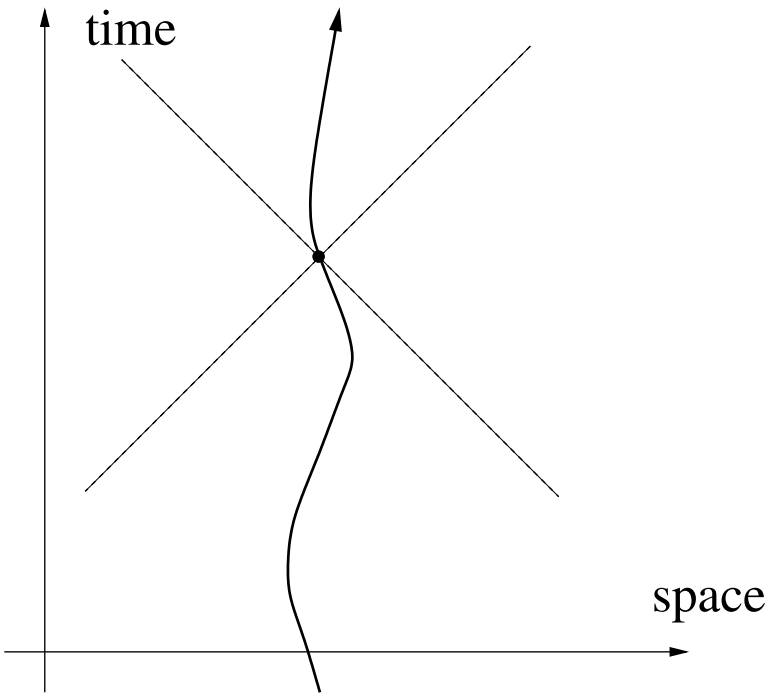
- In conclusion, not clear how successful bilking argument really is against the possibility of backward causation.

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...

Does physics permit time travel?

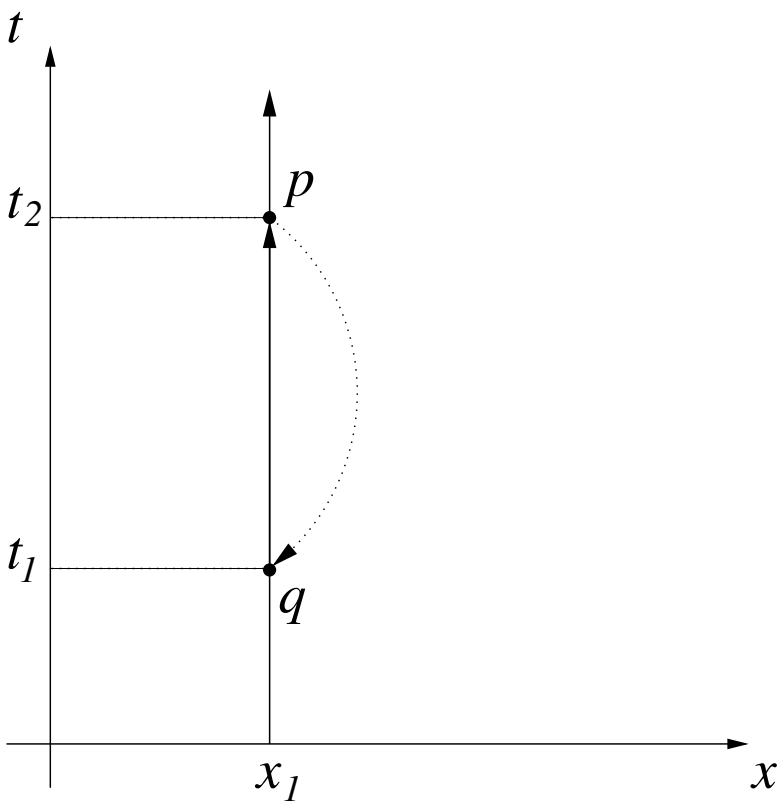
Cast problem in spacetime language:



- simplification to one spatial and one temporal dimension
- convention: propagation of light drawn as bisecting line
- Recall the Light postulate in SR (Module 3)

$\Rightarrow$ Nothing ever travels faster than light.

Wellsian time travel four-dimensionally



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

Discontinuities? Not necessarily.
Backward causation? You bet!

Backward causation is unphysical!

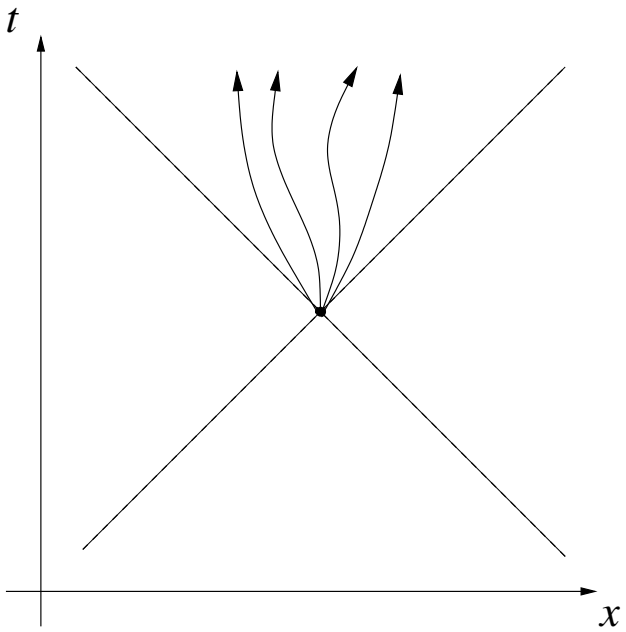


Abbildung: Forward causation

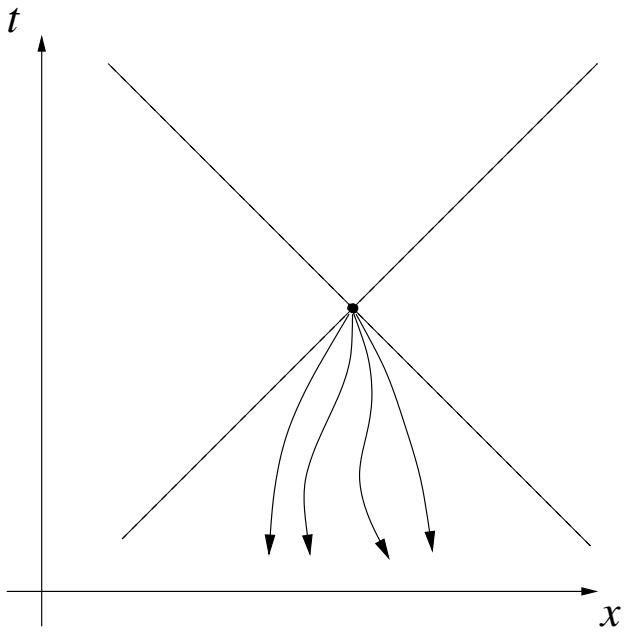


Abbildung: Backward causation

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

Time travel in Einstein's general relativity (GR)

Core of GR: Einstein field equation

$$G_{ab}[g_{ab}] = 8\pi T_{ab}$$

$G_{ab}[g_{ab}]$: functional of the metric g_{ab} and its first and second partial derivatives; contains complete information about the geometrical structure of spacetime.

T_{ab}: energy-mass-density; describes the distribution of (energy and) masses in the spacetime.

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

Spacetime geometry $\Longleftrightarrow$ distribution of matter and energy

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

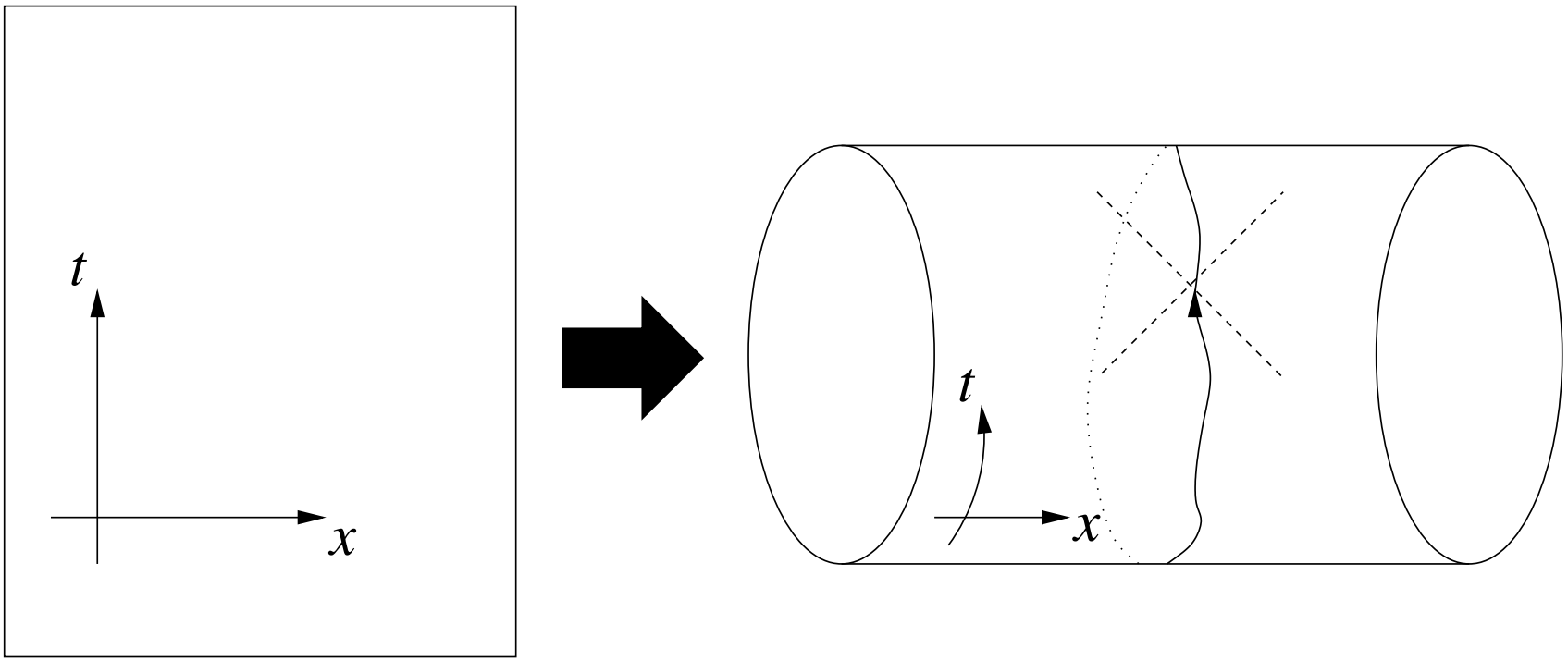
Kurt Gödel 1949: solution of Einstein's equation with closed causal curves (CCCs), the so-called Gödel spacetime

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 its curvature or topology

Examples of spacetimes with closed causal curves

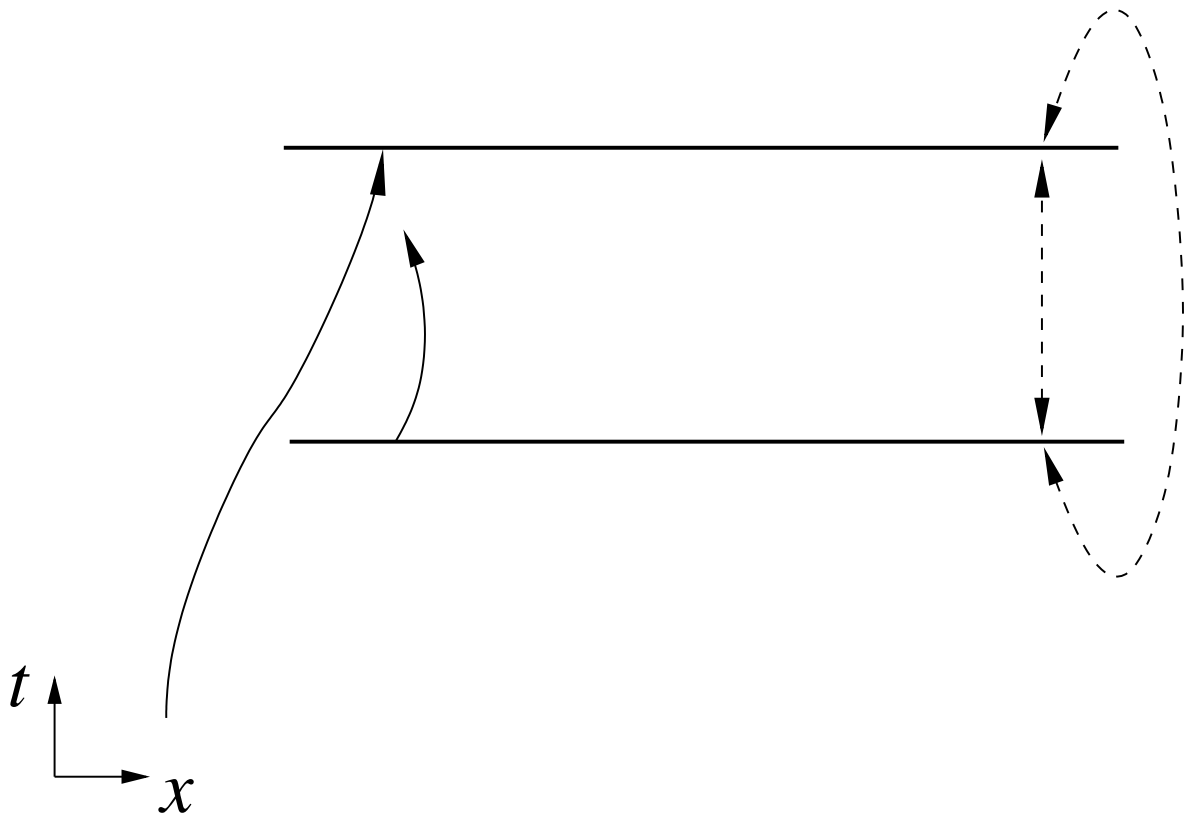
Basic idea:

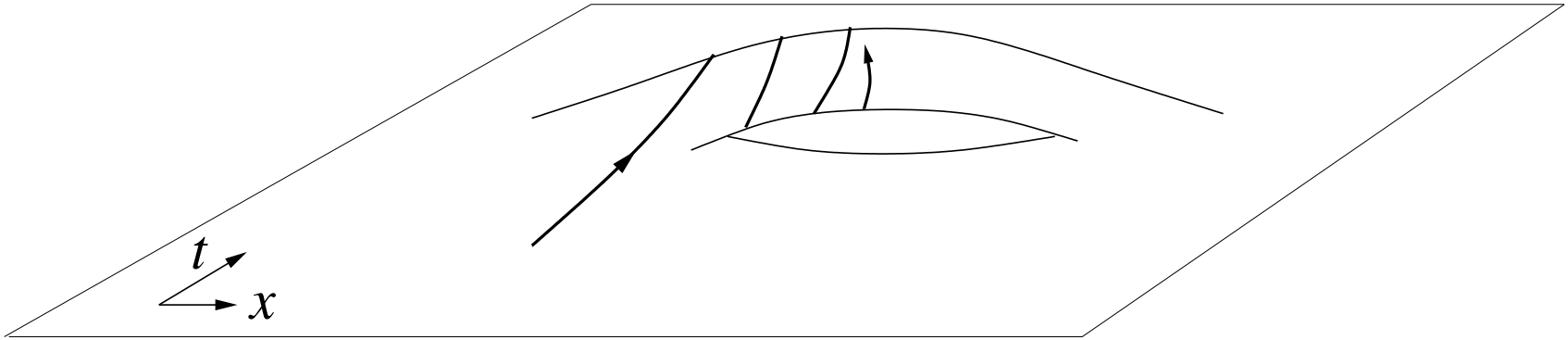


Deutsch-Politzer-spacetime: 'regional' acausalities

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

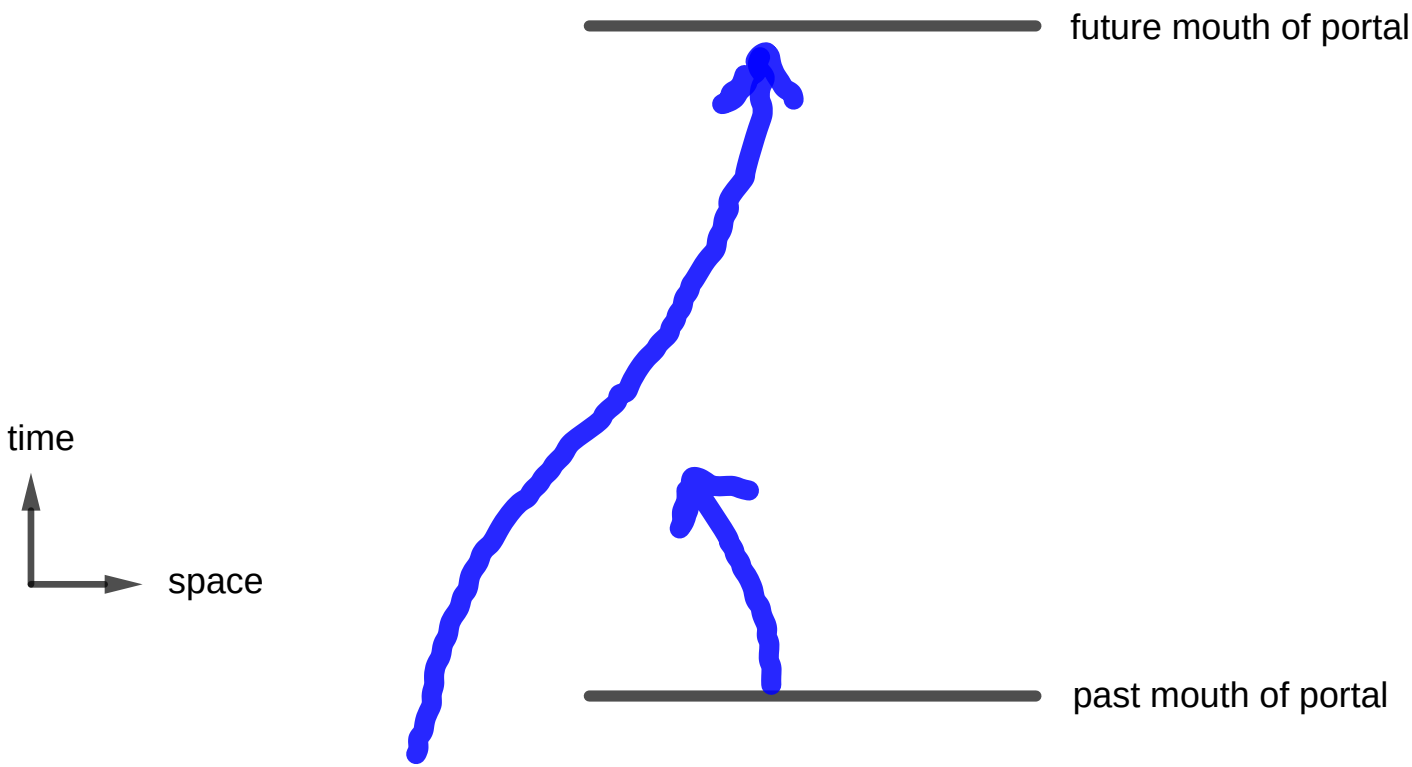
It is also possible that CCCs are confined to region:





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

General relativity permits 'time portals'



More realistic spacetimes with CCCs

- Example: spacetime with black holes (Kerr-Newman-spacetime) or wormholes (Einstein-Rosen-bridges)

$\Rightarrow$ GR explicitly permits time travel.

- Does it lend it self 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.

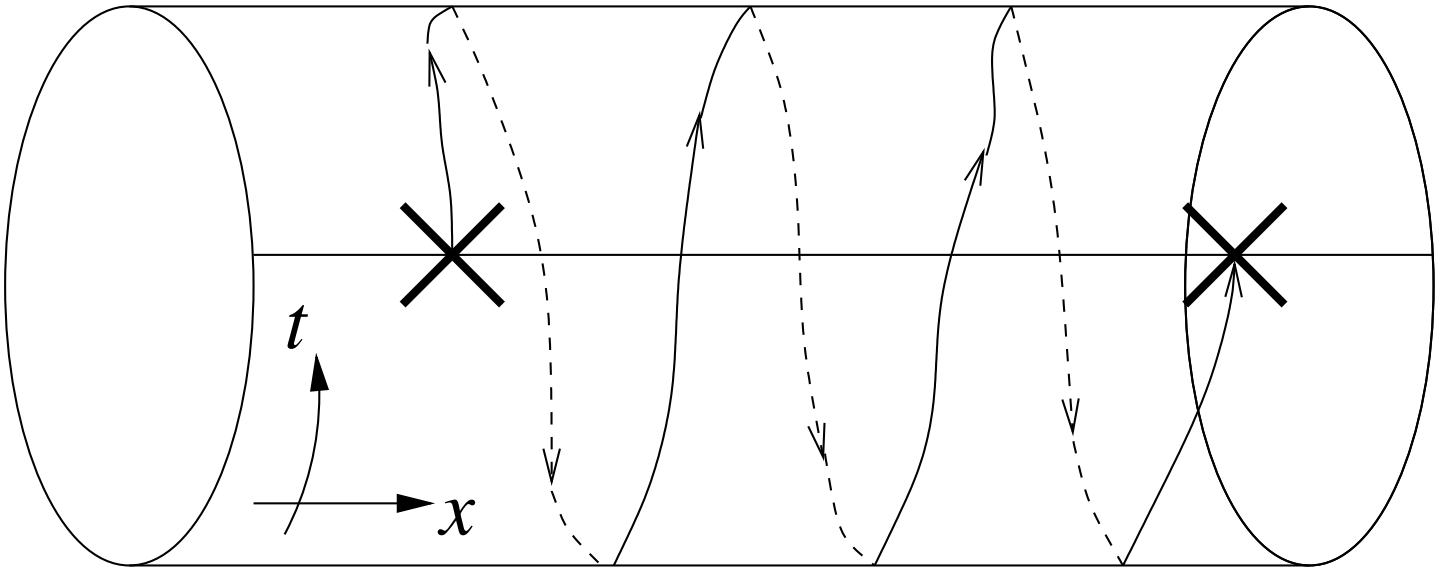
Christian Wüthrich, *On time machines in Kerr-Newman spacetimes*, Master thesis, University of Bern, 1999.

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.

Consistency constraints in GR

Illustration:



$\Rightarrow$ only simple scenarios are possible

But what enforces consistency?

- You should still ask how enforces the CCs.
- Laws of nature? Yes, but... (situation may differ for Humean and non-Humean approaches)
- There is *a priori* nothing surprising about the future imposing constraints on what transpires at earlier times.
- Example: boat trip (Huggett 2010, 140)
- For simplicity's sake, let us assume that the world is deterministic.

The precise physical state as enforcer

Scenario 1

"Consider first a story in which I travel through the portal but somehow don't stop myself: I don't even try, or I give up after failing to persuade my very determined younger self, or, failing to persuade myself, I attempt and fail to restrain myself physically (see figure 13.1). You can imagine other scenarios. As we've seen, either physics or logic mean that any story in which I do travel through the portal must be like this, on pain of contradiction." (Huggett, 141)

The precise physical state as enforcer

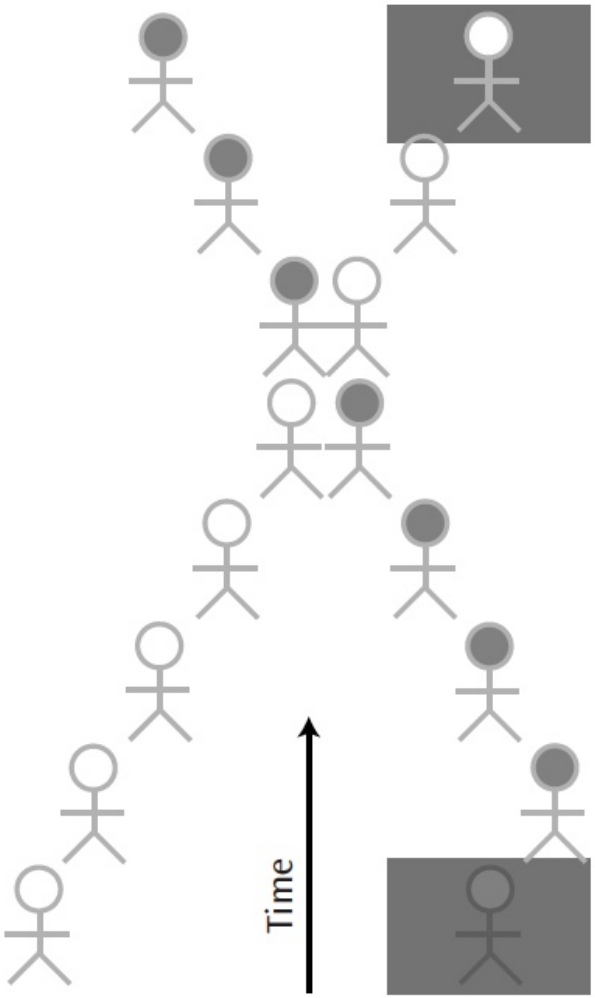


Figure 13.1 I come from the left and enter the later opening (meeting my later post-time-travel self on the way). I emerge from the earlier opening feeling sick (my head is shaded to keep track of my later self). I meet my earlier self headed toward the portal but somehow don't stop myself from traveling through the portal.

The precise physical state as enforcer

Scenario 2

"In the first story involving a duplicate, initially I am exactly as in (i) and my doppelganger—Mick—is a perfect copy of me. I proceed again to the portal, travel back one day, get sick, and decide to try to stop myself from ever time-traveling.
However, before I meet up with my younger self I run into Mick on his way to the portal, and the result of our meeting is a conversation in which I realize that I will not be able to stop my younger self, and in which Mick decides not to time-travel so that he can avoid time travel sickness; I don't interfere with my younger self, and Mick doesn't try to enter the portal, so this story is manifestly consistent. All this is shown in figure 13.2." (Huggett, 142)

The precise physical state as enforcer

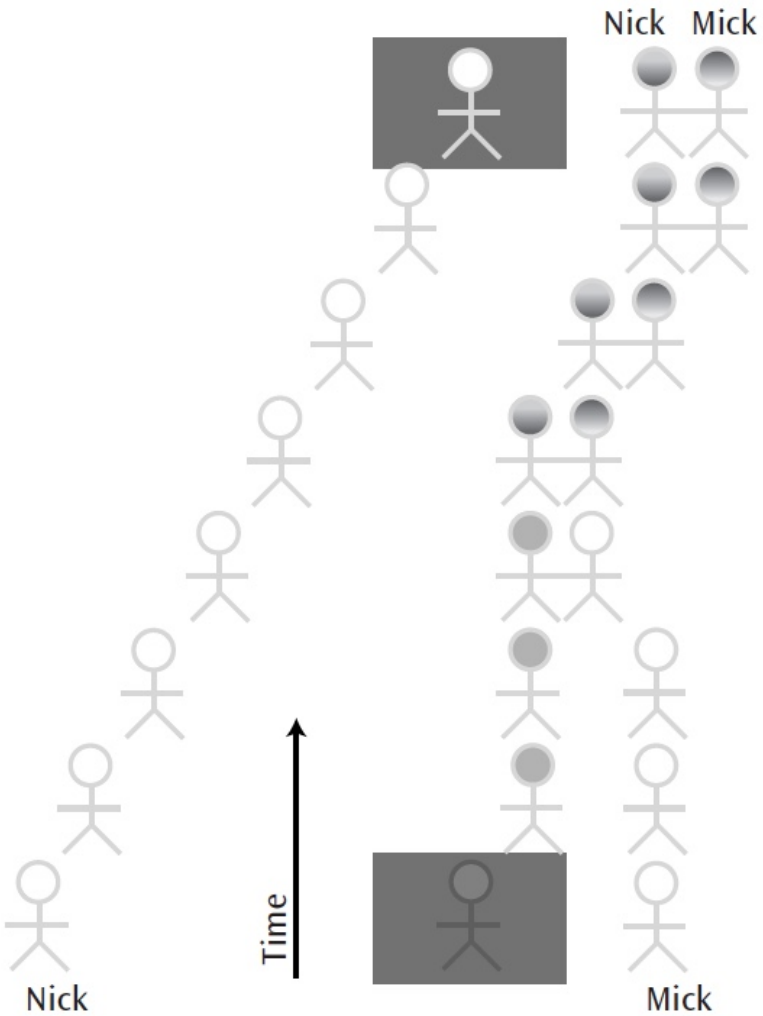


Figure 13.2 The story starts with me (just as before), an exact physical duplicate, Mick, and my later self emerging from the portal. This time my post-time-travel self meets Mick and persuades him not to time travel.

The precise physical state as enforcer

- difference can't lie in younger person (Nick or Mick on their way to the portal)—they are perfectly alike in story
- Thus, it must be the person emerging from the earlier mouth of the time portal—the older Nick.
- This is reasonable: in (i) Nick emerges after his older self tried to prevent him from entering the time portal, but in (ii) he enters without interaction.

The precise physical state as enforcer

Scenario 3

"In the second story with a duplicate, initially I am slightly different from before in some way: perhaps one or two of my neurons are in different states, so that I'm not quite so determined to enter the portal. My doppelganger, Dick, is a perfect copy of me as I would emerge from the portal in story (i): nauseated and determined to stop me from entering the portal. See figure 13.3.
If I were initially exactly as in (i), then the ensuing conversation between Dick and me would start just as the conversation in (i) and (assuming still that determinism rules the interaction) it would have to finish as before, with my going on to enter the portal. But since I am slightly different, then it is compatible with determinism that Dick successfully dissuades me, and I don't travel through the portal. That is, in this final story Dick meets me on my way to the portal and persuades me not to time-travel; in fact no one time-travels, and so no contradictions occur.' (Huggett, 144)

The precise physical state as enforcer

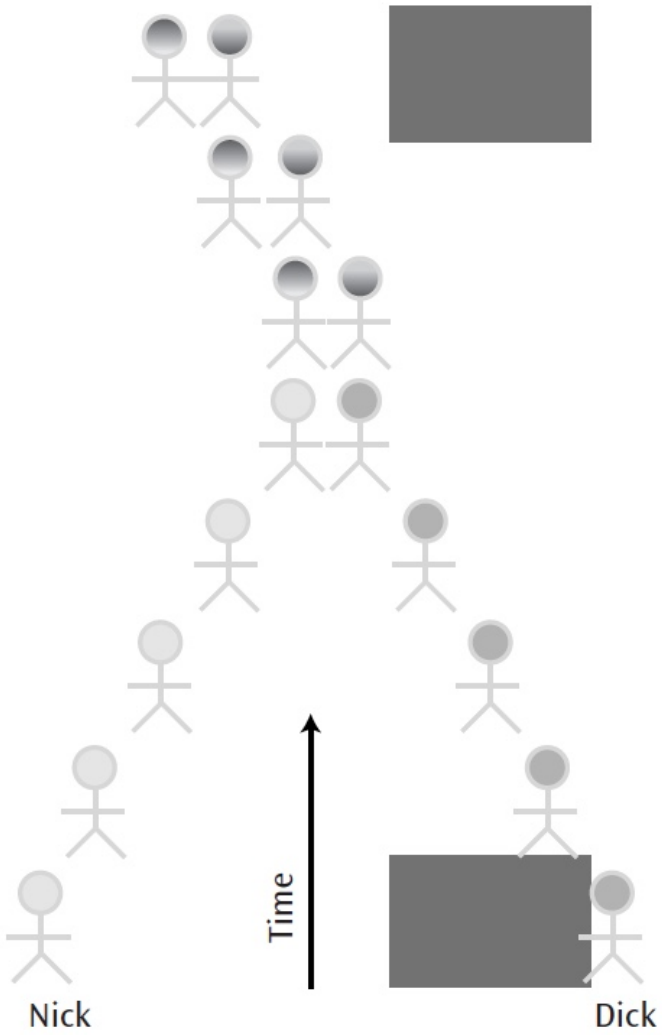


Figure 13.3 In this story I start off a little differently from the first story, and therefore a duplicate of my nauseous post-time-travel self, Dick, can and does stop me from entering the portal.

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.
4. The scenarios considered show how it is the precise physical states of younger or older Nick (which we don't know exactly) that determine whether or not time travel occurs—at least in a deterministic world.