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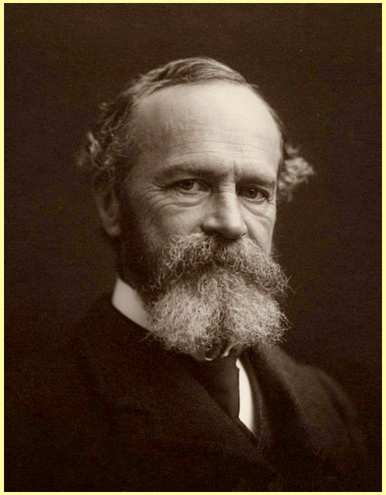

Physical and Experiential Time

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Overview

1. Characteristics of experiential time

2. Time in classical physics and relativity

3. How physical time *corrects* experiential time

4. Time in quantum gravity

5. Conclusion

1. Time in direct experience

- We are all caught in a well-defined NOW
- This NOW is continually ***shifting***: this is the "flow of time" (from the "A theory" of time)
- There are ontological differences between PAST, NOW (PRESENT), and FUTURE: such as that the FUTURE is ´open´, the PAST is ´fixed´, the PRESENT is ´real´. (Past, Present, Future are reflected in the "tenses" of language)

Note:

- Time *asymmetry* is not the same as ´time flow´: asymmetry does not imply motion
- On reflection, there are obvious problems with the notion that time ***flows***: e.g., how fast does it flow? This seems to require a second time, etc. $\longrightarrow$ infinite regress?

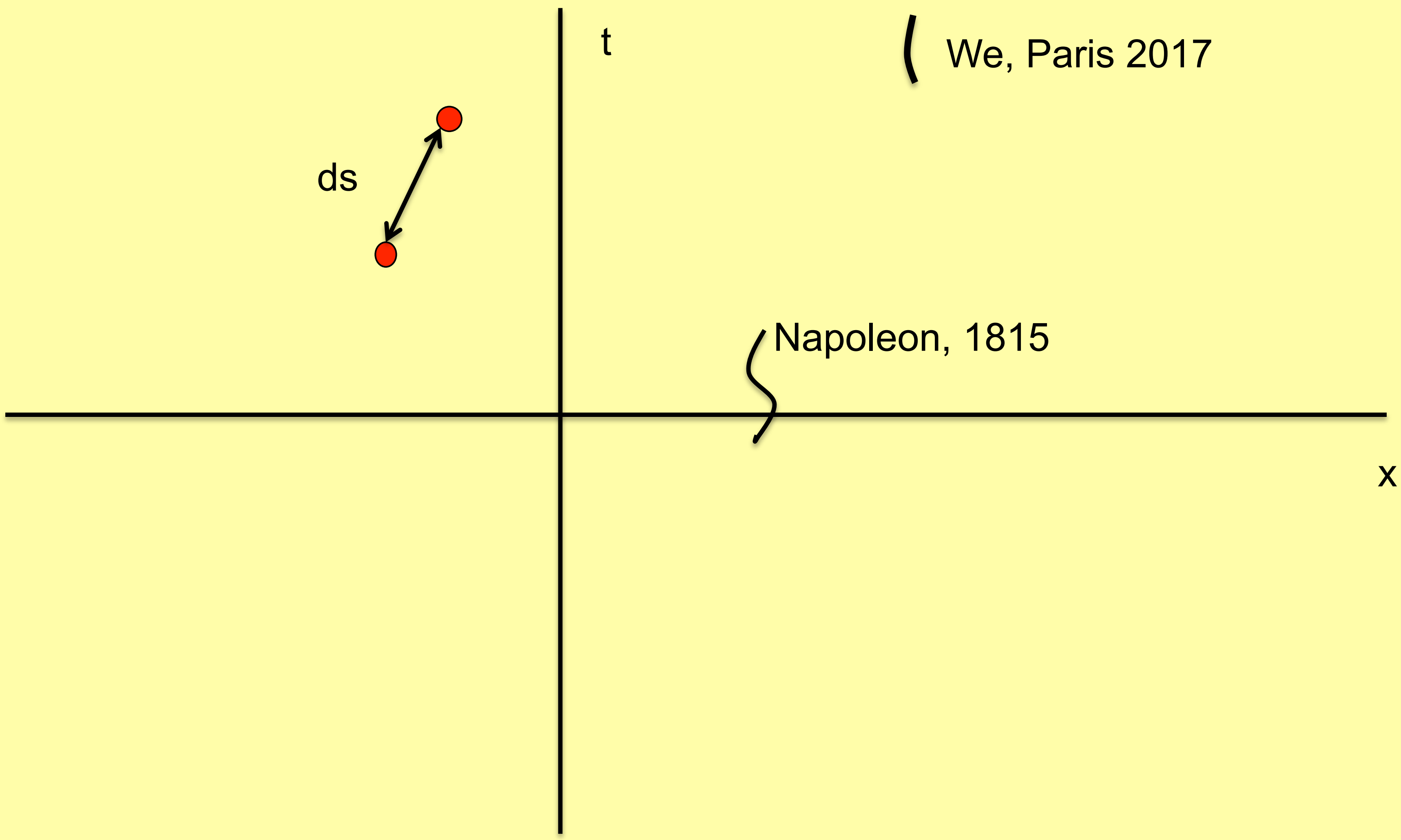
¨Time does not exist¨: McTaggart (1908)

- According to the ¨A series¨ events first are future, then present, then past.
- But in all cases it is *exactly the same event* that is at stake
- This is contradictory, so the ¨A series¨ is inconsistent
- But ¨time¨ without flow is not time
- So time does not exist

2. Space and time in classical physics and relativity: a mismatch with experiential time(?)

- Four-dimensional manifold, consisting of points representing the spatiotemporal locations of all events in the history of the universe.
- There is no ***preferred*** NOW here. All events are *equally* ´now´, because they are all represented at the instant they actually occur. This is a “tenseless” description.

Minkowski spacetime

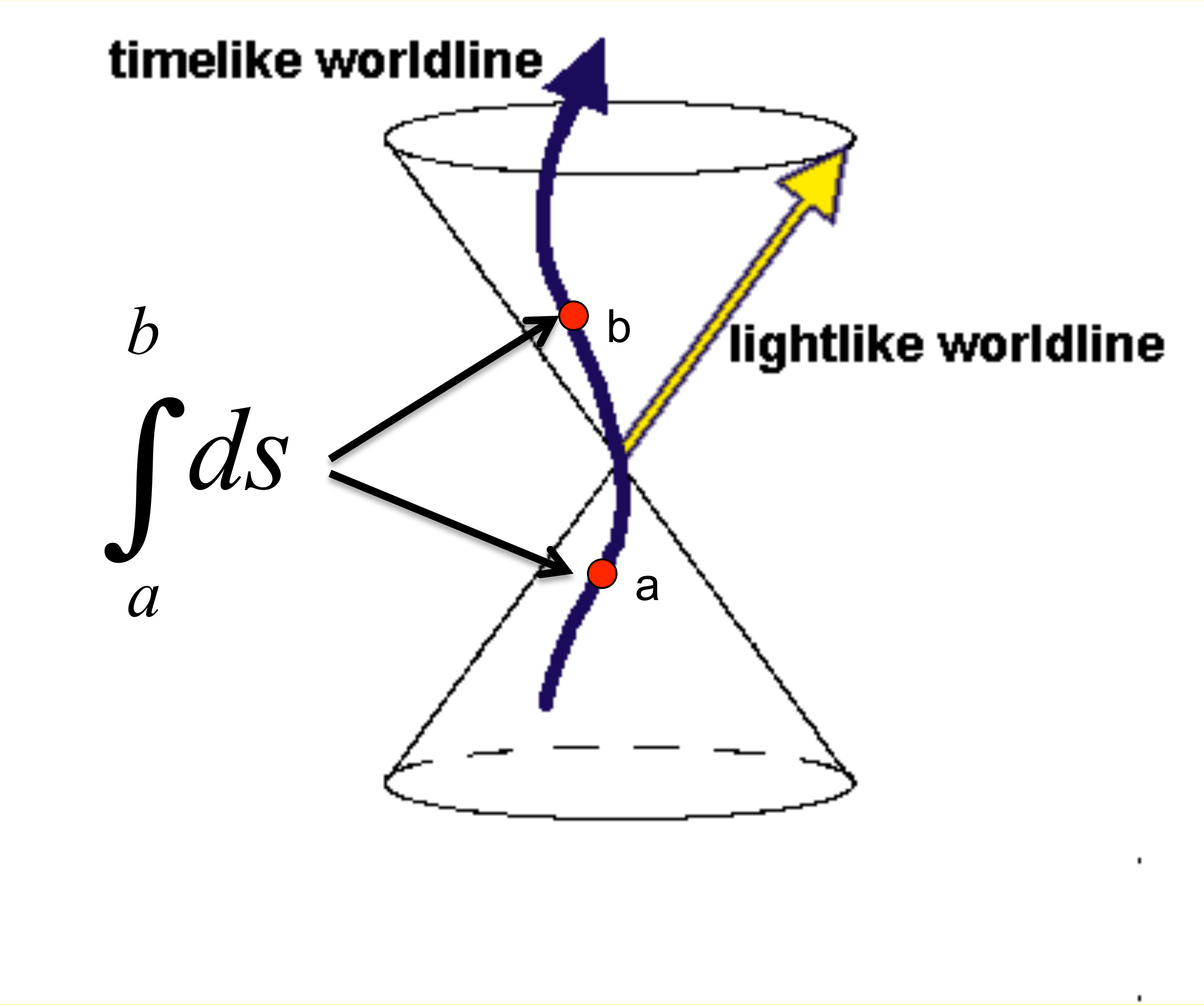


Time

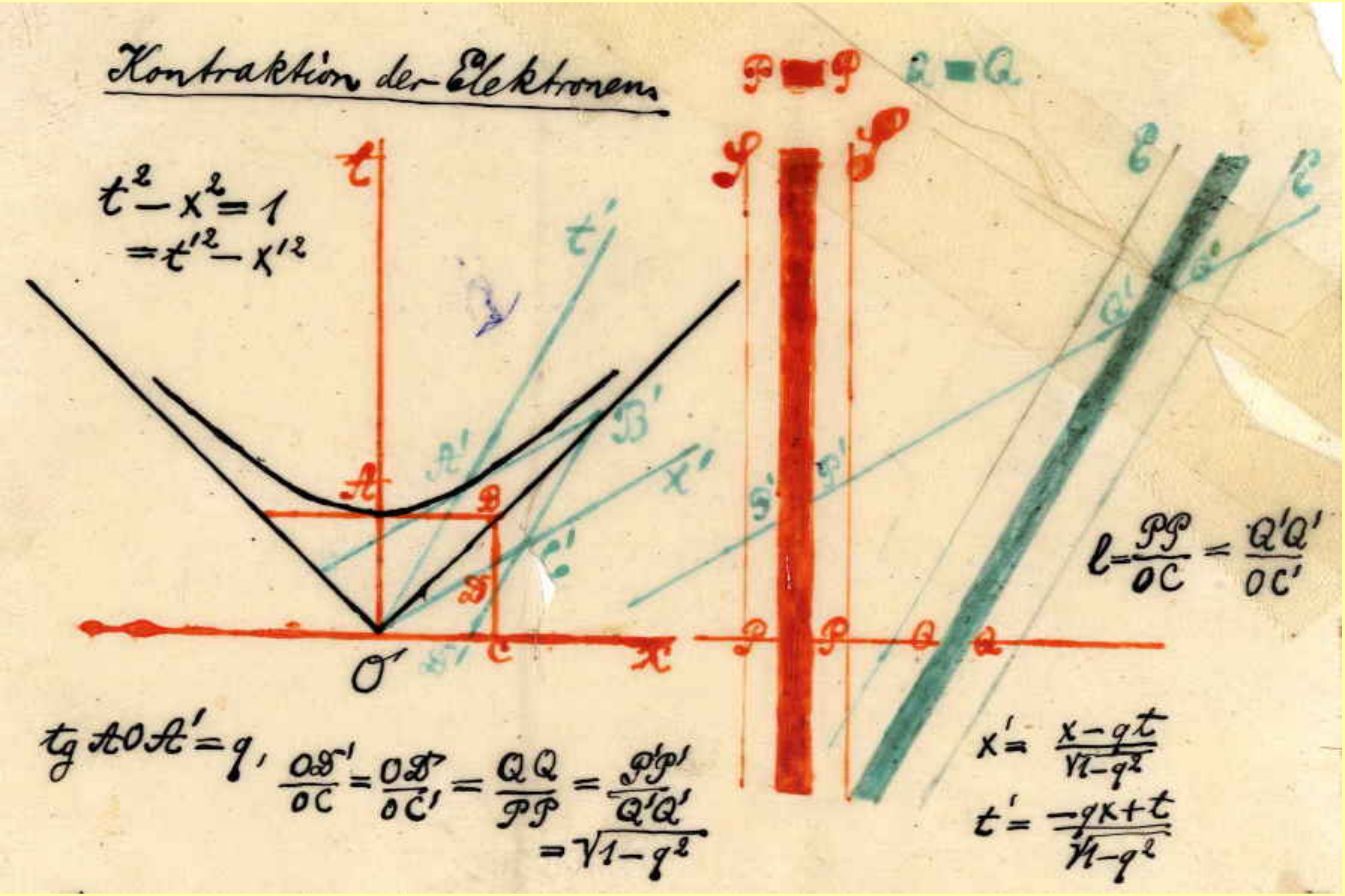
Relativity replaces Newtonian global time and absolute simultaneity with ´many-fingered´ time: *proper time intervals between points on a worldline* determine the evolution of physical processes.

$$\int_a^b ds$$

Relativity



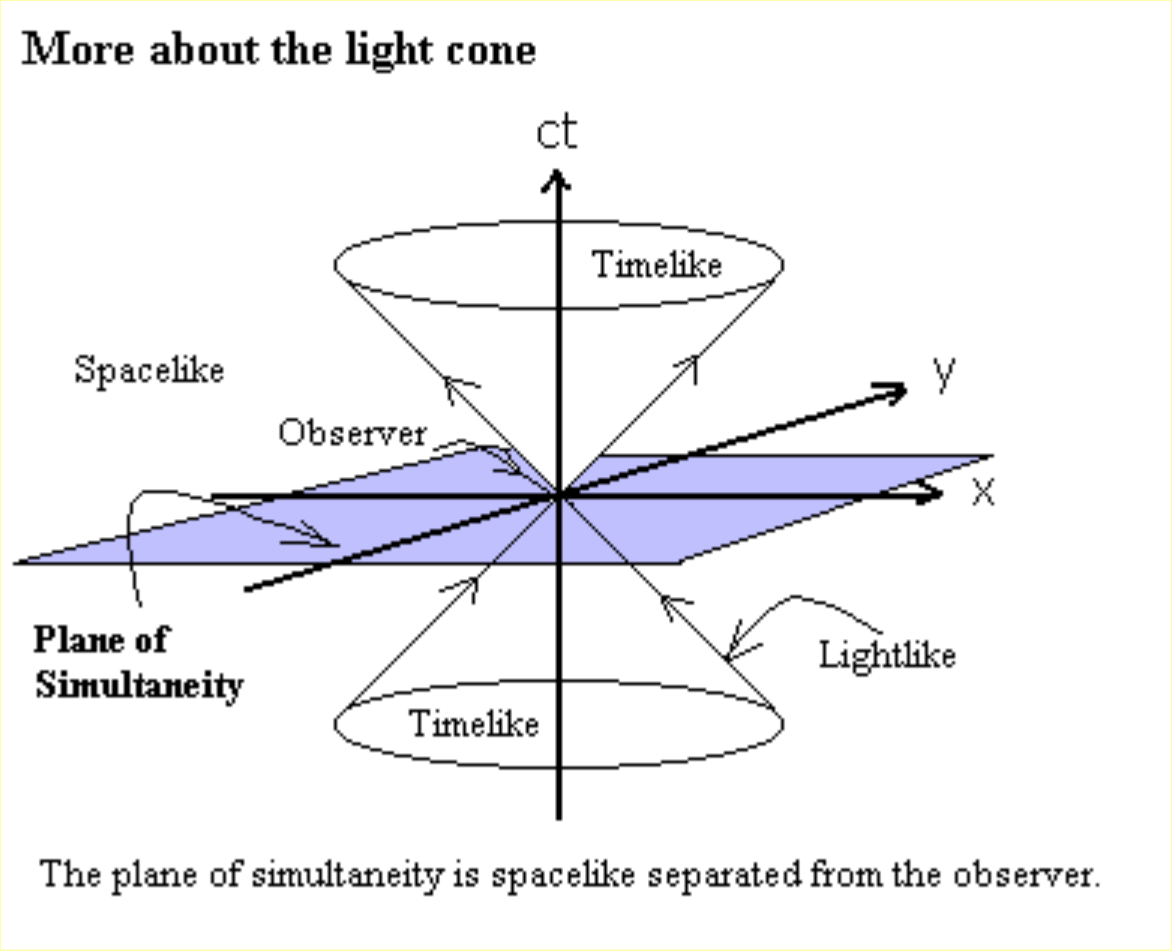
Geometry of Minkowski Spacetime



General Relativity

- In SRT spacetime exists independently. In GRT spacetime becomes dynamical and ¨physical¨, but still space and time *exist*.
- *Globally* the spacetime structure of GRT may be curved and may possess a different topology. GRT spacetime stands to SRT as a dynamically curved spatial surface to a fixed and flat Euclidean plane.
- However, *locally* SRT applies, so that in small spacetime regions the causal structure of GRT is the same as in SRT.

Distant simultaneity



Simultaneity in SRT

- The status of special relativistic simultaneity is controversial: Is it conventional or not?
- What is not controversial: whatever one takes for simultaneity in SRT, events that are simultaneous with event X are spacelike separated from X and *cannot influence* X.

- So even if simultaneity is non-conventional, it cannot play a role in a physical explanation of what goes on in X.

Simultaneity in GRT

- The situation is basically the same as in SRT: if there is any viable global notion of simultaneity at all (depending on the global properties of the spacetime), simultaneous events are at spacelike separation wrt each other
- Therefore, events simultaneous with a given event cannot causally affect this event

3. How physical time improves on and *corrects* experiential time

- The deceptiveness of the common NOW
- The lack of definition of the experiential Now: the specious present
- The explanatory superfluity of the NOW

The common NOW

Our intuition that we are in contact with others in one shared, spatially extended NOW is patently false: simultaneity is causally ineffective.

But physics can *explain* this intuition: it is due to the huge value of the speed of light. We perceive things at great distances without clear signs that the information we receive is about *earlier* events.

Clearly: the physical description is more accurate than the intuitive one!

More generally:

If an observer is modeled by a timelike worldline:

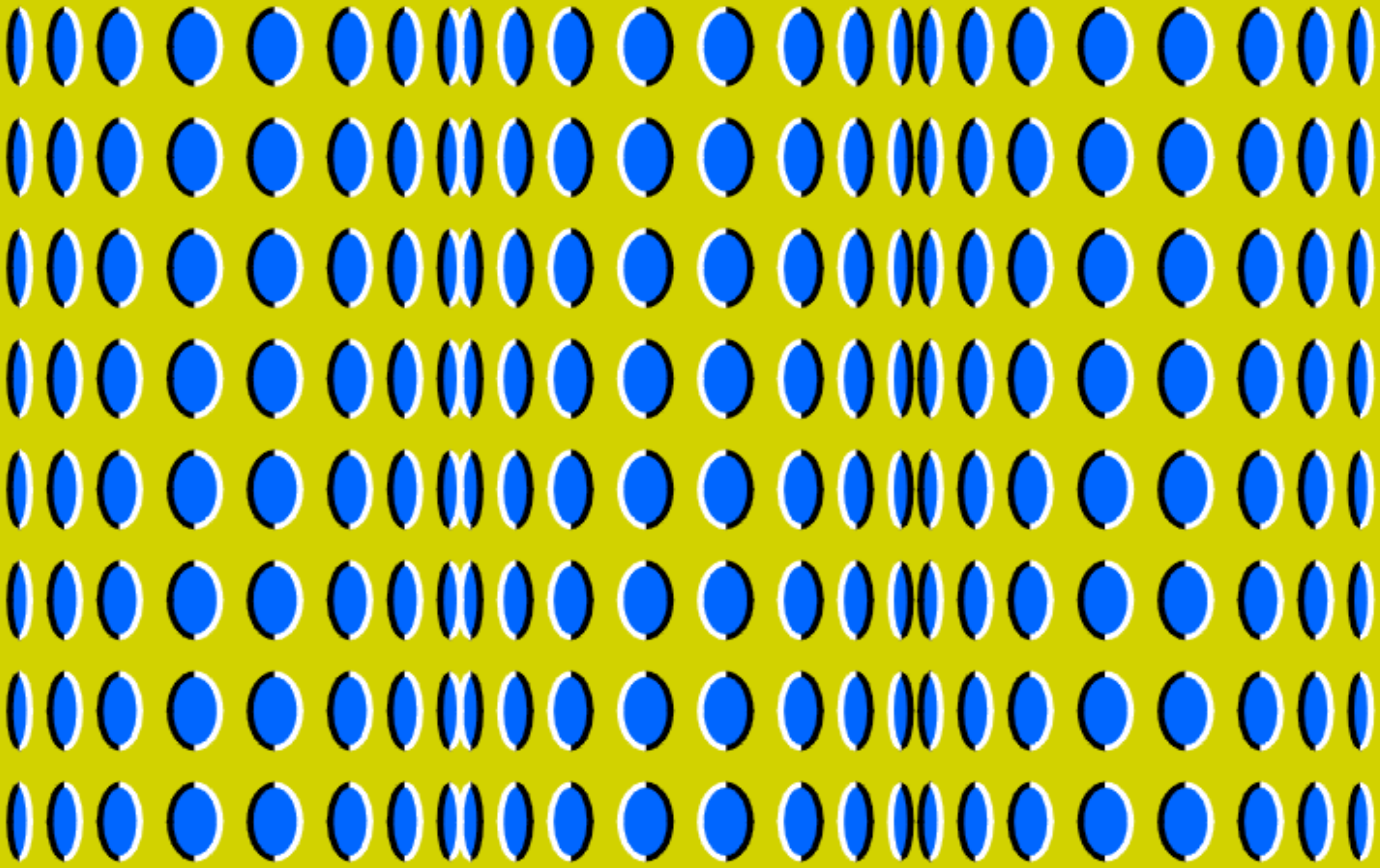
- Perception at any point on this worldline is independent of what happens simultaneously
- Therefore, *a global now is irrelevant for our time perception*
- A fortiori, the question of whether or not spacetime can be foliated as a stack of spaces-at-a-time is irrelevant for experiential time

The ´specious present´

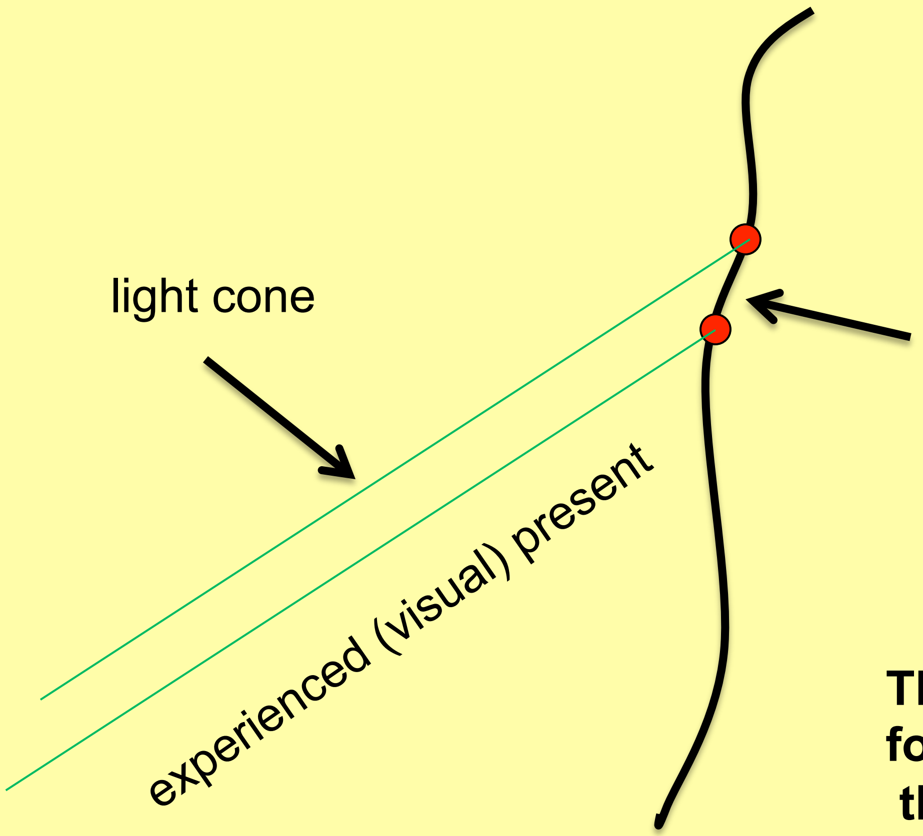
- Research in sensory physiology shows that our perception of the present combines data from finite intervals (a,b) along our worldlines.
- It is an empirical fact that differences in perceptual content during such intervals may give rise to the experience of continuous ***motion, change, flow***, even if there is no objective physical continuous motion at all.

Analogy: experience of motion produced by static pictures

Motion?



The resulting picture



This picture applies ´tenselessly´, for *all* specious presents along the observer's worldline

Scientific analysis of time perception

Ingredients:

- Physical temporal structure, including physical asymmetries
- The subject as a causal agent, making use of his environment
- Evolutionary processes
- And more…

Physical time and experiental time

- Our intuited “common now” is an illusion
- Our feeling of “flow” is the way our brain represents differences in perceptual content during the specious present. It is our way of responding to the (objective) temporal order of events.

- ***This can all be stated, and made the subject of explanation, within the physical “block universe”. We do not need a shifting physical NOW.***

The resources of the “A theory”

- First problem: what meaning can be given to flow (passage) that is not already there in the block picture (where it is the occurrence of different events at different moments, in their temporal order)?
- Second problem: In what way do the concepts introduced by the A theory improve our explanatory possibilities? Can they figure in scientific explanations?

Trying to give content to a notion of "flow" that is beyond the physical notion requires by definition non-physical concepts

- E.g., a "supertime" *T* may be introduced: the NOW is at time t_1 at Supertime T_1. The NOW is *flowing* at the speed dt/dT.
- Or ¨primitive tense operators¨ may be introduced that mimic these supertime results (Bradford Skow). E.g.: "*It will be the case* that the NOW is located at t" means: "Relative to a point of Supertime Later than the Current one, the Now is located at t."

Problems with these proposals

- Such concepts do not figure in physical theories, so cannot function in physical explanation
- Additional “wheels” are introduced, without added empirical content
- The function of these explanations is to tell a story that is close to intuition; but the intuitions involved are unreliable, from a scientific point of view

This rebuts statements like the following:

- “Now one very serious challenge to the tenseless theorist is to explain why, if time does not pass in reality, it appears to do so. What, in tenseless terms, is the basis for our experience as-of the passage of time?”
- “Even if the tenseless theorist can discharge his obligation, the doubt remains that the tensed theorist can produce a simpler explanation of our experience.”

4.Does Quantum Gravity change the situation? (a)

- Causal set theory:
  On the most fundamental level we have *events* with *asymmetric causal relations* between them. These asymmetric relations define an order of "coming into being".

  However, this commits the mistake of equating *asymmetry* with *motion*; it does not help solving the traditional conceptual problems connected with time flow.

Does Quantum Gravity change the situation? (b)

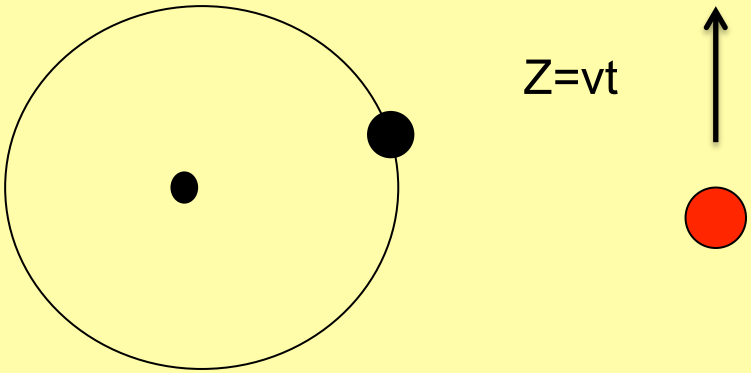
- Canonical quantum gravity and its variations: The “problem of time”. The quantum condition on spatial geometry does not have the form of an evolution *in time.*
  (e.g., the Wheeler–DeWitt equation $H\Psi=0$)

  Still, one expects that a “internal time” should be constructible in some way…

Internal time

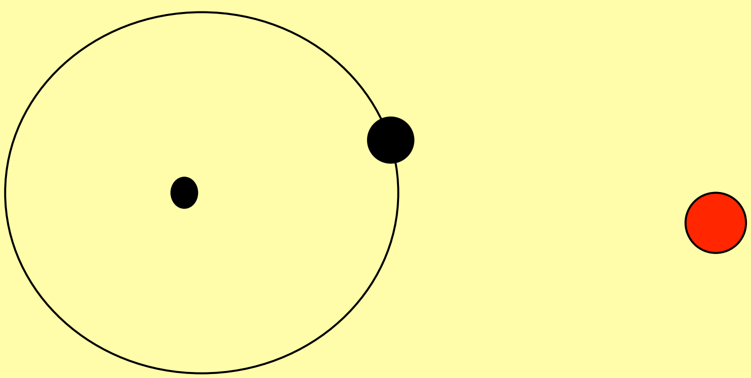
One possible cue (Banks, Kiefer, …):

There is an (approximate) equivalence between the *time-dependent* Schrödinger equation for an electron in an atom, in the external potential field of a moving charge, and the *time-independent* Schrödinger equation for the quantum system of electron *plus* charge (Mott, 1931).



$$\frac{\hbar}{i}\frac{\partial \psi}{\partial t} = H_a \psi + V\psi$$

$$H_{tot}\psi = E\psi$$



IF the mass of the charge is very large, and the charge can be described by a momentum eigenstate

$$\frac{\hbar v}{i}\frac{\partial \psi}{\partial Z} = H_a \psi + V\psi$$

Emergent time

In the ¨Mott approach¨ time "emerges" as Z/v if and when the object properties position and momentum of the ¨clock system¨ are sufficiently well-defined.

Emergence: appearance of new behavior and new quantities in a *limiting situation*, *via approximations*.

Emergent time

Time as an *emergent quantity* originates from a background of object properties in which the notion of flow makes even less sense than in the original dilemmas:

What could it mean that MZ/p=Z/v is dynamical and flows?

5. Conclusion

- Already in classical physics, the notion of time flow is conceptually problematic
- Moreover, intuitions about time are in some respects obviously deceptive---which casts doubt on the value of intuition in this context
- What intuitive time adds to physical time does not help to explain our time experience
- If anything, results of quantum gravity research reinforce this conclusion: if time is truly emergent, time does not even exist at the fundamental level.