Title: On the 'Dynamical Approach' to spacetime structure

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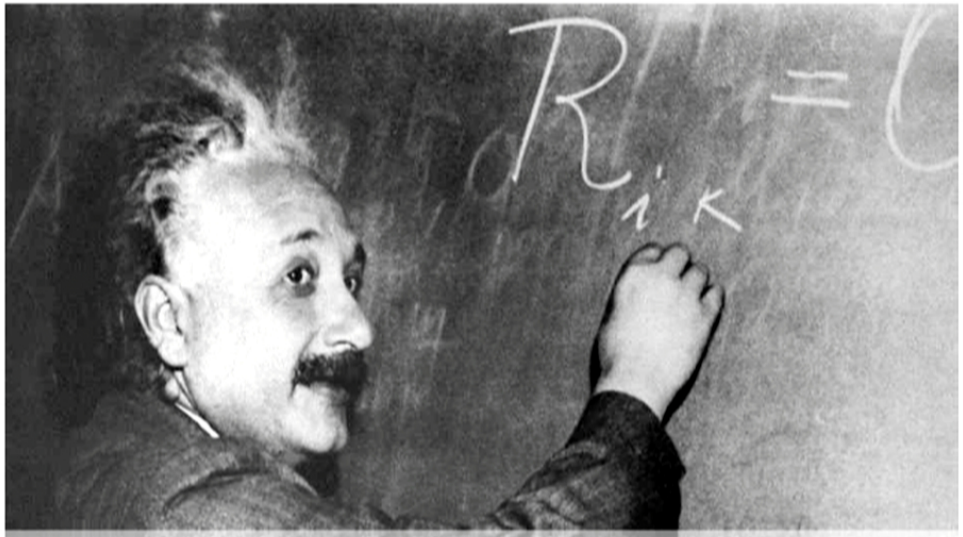
Abstract: In (relatively) recent years some philosophers of physics have developed and advocated a new view about how to understand spatiotemporal structures posited in theories such as classical mechanics, relativistic theories and GR; it is called the 'dynamical approach' to spacetime (H. Brown 2005, Physical Relativity). The dynamical approach (DA) holds that spacetime structure should not be thought of as conceptually prior to the laws of nature, or as constraining the forms that the laws may have. Instead, the DA approach says that the laws of nature are prior, and spacetime structures are no more than a reflection, or codification, of facts (especially symmetry facts) about the dynamical laws in our world. In my talk I will explore the motivations and arguments given in support of the dynamical approach, and raise doubts about whether they are coherent and compelling. Although no-one should come away from my talk with a perfect understanding of the nature of spacetime (or even just: spacetime as it appears in classical relativistic theories), I hope that all will come to appreciate the difficulty of deciding what even clear and mathematically well-understood physical theories really tell us about basic aspects of physical reality.



On the 'Dynamical Approach' to Spacetime Structure

3 December, 2014

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- Discuss the latest twist in the traditional debate between 'relationist' and 'absolutist' or 'substantivalist' views about spacetime: the 'Dynamical Approach' (DA)

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- Show how, despite some appeal, the DA can be seriously questioned
- Suggest that other ways of pursuing a relationist agenda may be more promising

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- Recent history of debate:
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  - 1980s/90s: "Hole Argument" and *points* dominate
  - 2000s: Brown & Pooley, & the 'Dynamical Approach' (also Nick Huggett, Robert Disalle)

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  - spacetime in SR "has Minkowski structure" because the dynamical laws are Lorentz-covariant (and not *vice versa*)
- Absolute space structure is not independently existing, prior to the laws; nor does it "act on" bodies in any way.

Pre-relativity debates
Brown's mystery of inertia

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- Imagine a Newtonian world with only a few, widely scattered and non-interacting particles. Each one is effectively 'free'. The law of inertia tells us that there is a (family of) coordinate system(s) which we can lay down on space and time, such that the spacetime paths of each particle is a straight line of constant velocity. How is that not a miraculous, pre-established harmony? How do the particles "know" how to move in just the right way so as to make this law come true?

Brown contra Nerlich & co.

- "The idea that the space-time connection plays this explanatory role in the special theory, that affine geodesics form ruts or grooves in space-time which somehow guide the free particles along their way, has become very popular, at least in the late 20th century philosophical literature. It was expressed succinctly by Nerlich in 1976:

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  - "... without the affine structure there is nothing to determine how the [free] particle trajectory should lie. It has no antennae to tell it where other objects are, even if there were other objects ... It is because space-time has a certain shape that world lines lie as they do."

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  - "... without the affine structure there is nothing to determine how the [free] particle trajectory should lie. It has no antennae to tell it where other objects are, even if there were other objects ... It is because space-time has a certain shape that world lines lie as they do."
- "It is one of the aims of this book to rebut this and related ideas about the role of absolute geometry. Of course, Nerlich is half right: there is a prima facie mystery as to why objects with no antennae should move in an orchestrated fashion. That is precisely the pre-established harmony, or miracle, that was highlighted above. But it is a spurious notion of explanation that is being offered here. If free particles have no antennae, then they have no space-time feelers either." (Brown, *Physical Relativity* (2005, p. 24))

Dynamical approach and Special Relativity

- "The dynamical approach seeks to offer a reductive account of the Minkowski spacetime interval in terms of the dynamical symmetries of the laws governing matter. It therefore qualifies as a type of relationalism, although this is not something that Brown himself emphasises." (Pooley 2012)

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- "Consider, for example, the relativistic phenomenon of length contraction. Do rods behave as they do in virtue of the spatiotemporal environment in which they are immersed or are facts about the geometrical structure of spacetime reducible to (inter alia) the behaviour of rods?" (ibid)

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- continues: "And if one opts for the latter point of view, what explanation is to be given of why measuring rods in motion are contracted relative to similarly constituted rods at rest? Brown reads Bell (1976) as seeking to demonstrate that "a moving rod contracts, and a moving clock dilates, because of how it is made up and not because of the nature of its spatio-temporal environment"."

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- Brown endorses what Bell called "Lorentzian pedagogy" (LP): "... we need not accept Lorentz's philosophy to accept a Lorentzian pedagogy. Its special merit is to drive home the lesson that *the laws of physics in any one reference frame account for all physical phenomena, including the observations of moving observers."*

DA and explanatory priority

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- "According to [DA], every relativistic phenomenon has an explanation with no direct appeal to geometry: dynamics suffice. Why do the twins age differently? Not because they literally measure the interval along their respective worldlines, but because *the laws governing the relevant biological processes in each dictate that on meeting they will be asynchronous*." (Huggett 2009)

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  - [Is a mixed-bag of different symmetries for different laws conceptually possible?]

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Challenging DA in SR

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- Compare with 10^{23} -particle quantum model of a square peg not fitting into a round hole of the same maximum diameter.

Objection 2: laws *require* spacetime structure to be meaningful

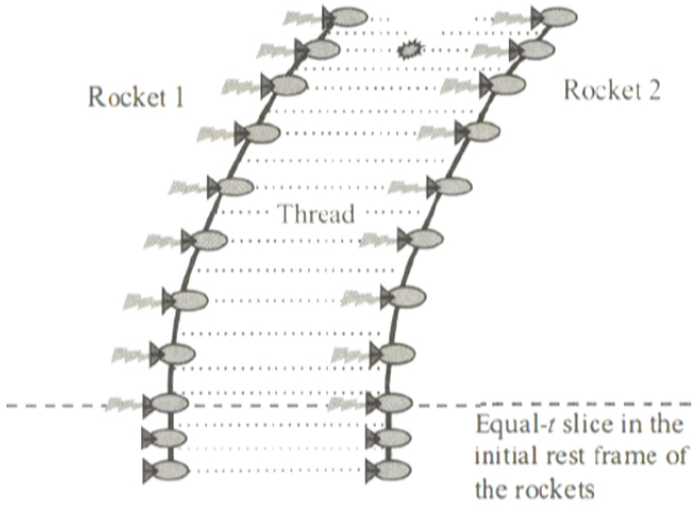
- Contrast Newton's gravity law - couched only in terms of *relative* distances *vs* the 1st or 2nd law: $\mathbf{F} = m(d\mathbf{v}/dt)$

Sidelight: Lorentz Pedagogy, rockets and strings

- Bell (1976) uses the example of two rockets connected by a string to argue that LC is *really real.*

The string breaks

- Rockets begin accelerating ‘at same time’.
- Maintain distance (in *L*).
- String breaks *because of* (?) LC



Sidelight: Lorentz Pedagogy, rockets and strings

- Even T. Maudlin has drunk the Kool-aid:
  - The physicists at CERN must have been thinking along the same lines as Rindler: if the Lorentz-FitzGerald contraction is merely a matter of *looking at the same events from a different angle*, or merely a matter of *describing the same events in a different coordinate system*, then of course it can't cause a thread to break! If it really has nothing to do with electrical or interatomic forces, then it can't have any observable physical effect. And indeed, what we have called the *coordinate-based Lorentz-FitzGerald contraction* is nothing more than an observation about the relations between different Lorentz coordinate systems. But, as Bell rightly insists, there is also a *physical* Lorentz-FitzGerald contraction that *does* depend on interatomic forces and can have physical effects.

Why does the string break?

- Not:
  - because a special *physical LC effect* springs up in the string *because it is in motion;*
- Rather:
  - because the accelerations of the rockets cause their separation to become greater than what the string's elasticity permits it to bridge.
  - This can be narrated in different ways in different frames, but in *none* of these stories do the details of interatomic forces matter in the way DA proponents suggest.

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- Raises question: what is a *law of nature (physics)*?

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- "For the first time since Aristotle introduced the fundamental distinction between natural and forced motions, inertial motion is part of the dynamics. It is no longer a miracle." (Brown 2006)

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  - TeVeS has *two* "metric fields", g_{ab} and $\tilde{g}_{ab}$, with the first playing the normal g_{ab} role in mathematics, while the second is the "physical" metric as displayed in the behaviors of rods, clocks, etc.

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- TeVeS theory, even if conceptually coherent, is nonetheless a *different theory from GR*. What one can say about the status of the metric in TeVeS does not automatically imply anything about what one can (should) say for GR.

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- is not obviously more credible or interesting than the substantivalist contrary
- DA *qua* relationalism needs to be fleshed out w.r.t.
  - What is the nature of *the laws of nature*?

My alternative approach to defending a relationalist line

- Take nature's laws as *primitive necessities* - ones we have not yet fully uncovered
- Don't try to answer the ontology/ideology question yet. (In light of QM weirdness, how can we pretend to do so??)
- Notice that current physics (and astrophysics) give us hints and clues that unreducible, substantial spacetime geometry may *not* appear in the "final theory" (QG/TOE)
  - relativity of rotation/Mach's Principle seems satisfied in FRW cosmologies
  - Several approaches to QG are relationally inspired, background-independent.