IPP-SR-10: Dynamical and geometrical approaches to spacetime theories

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HT24

The course

1. Newton's laws
2. Galilean invariance
3. The Michelson-Morley experiment
4. Einstein's 1905 derivation of the Lorentz transformations
5. Spacetime structure
6. General covariance
7. Relativity and conventionality of simultaneity
8. Frame-dependent effects
9. The twin paradox
10. Dynamical and geometrical approaches to relativity
11. Presentism and relativity
12. Acceleration and redshift

Dynamicists...

...versus geometricians

Today

The Lorentzian pedagogy

Constructive and principle theories, reprise

Arrows of explanation

Geometrical sub-views

Norton's challenge

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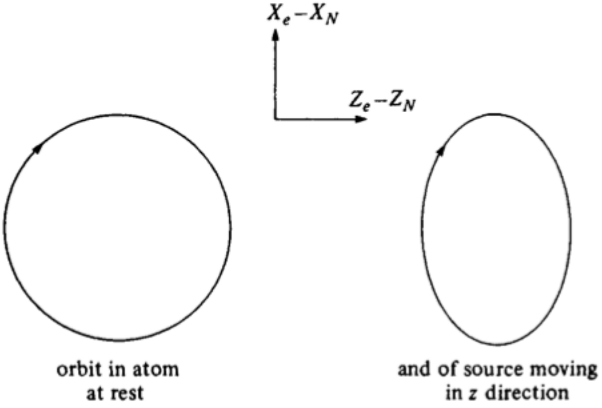
- He shows that, when such an atom is gently accelerated up to some constant velocity, its moving state will be contracted with respect to its stationary state—in accordance with the length contraction of subsystems under active Lorentz boosts.
- The moral—what he calls he *Lorentzian pedagogy*—is that we can *explain* the behaviour of macroscopic systems via appeal to the micro-dynamical underpinnings of those systems.

Bell's electrons

Fig. 6.



Brown on Bell

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- Brown takes inspiration from the Lorentzian pedagogy: he maintains that appeal to the fundamental physical laws governing the systems under consideration can explain their behaviour.
- As Bell stresses, though, there are some limitations to his electron model as a means of illustrating the Lorentzian pedagogy...

Bell's provisos

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Can we conclude then that an arbitrary system, set in motion, will show precisely the Fitzgerald and Larmor effects? Not quite. There are two provisos to be made.

The first is this: the Maxwell-Lorentz theory provides a very inadequate model of actual matter, in particular solid matter. It is not possible in a classical model to reproduce the empirical stability of such matter. ...

The second proviso is this. Lorentz invariance alone shows that for any state of a system at rest there is a corresponding 'primed' state of that system in motion. But it does not tell us that if the system is set anyhow in motion, it will actually go into the 'prime' of the original state, rather than into the 'prime' of some other state of the system at rest. In fact, it will generally do the latter. A system set brutally in motion may be bruised, or broken, or heated, or burned. (Bell 1976, pp. 74-75)

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1. appeal to the fundamental laws governing the physical systems under consideration.
2. hope that we can actually build stable bodies (such as rods and clocks) from matter governed by such laws. (Cf. the clock hypothesis.)

Pauli’s endorsement

Should one, then, completely abandon any attempt to explain the Lorentz contraction atomistically? We think that the answer to this question should be No.The contraction of a measuring rod is not an elementary but a very complicated process. It would not take place except for the covariance with respect to the Lorentz group of the basic equations of electron theory, as well as of those laws, as yet unknown to us, which determine the cohesion of the electron itself. (Pauli 1921, p. 15)

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- For this reason, Brown and Pooley (2006) advance what they call a *truncated Lorentzian pedagogy*.

The truncated Lorentzian pedagogy

In order to predict, on dynamical grounds, length contraction for moving rods and time dilation for moving clocks, Bell recognised that one need not know exactly how many distinct forces are at work, nor have access to the detailed dynamics of all of these interactions or the detailed micro-structure of individual rods and clocks. It is enough, said Bell, to assume Lorentz covariance of the complete dynamics—known or otherwise—involved in the cohesion of matter. We might call this the truncated Lorentzian pedagogy. (Brown and Pooley 2006, p. 7)

Essence of the truncated approach

- We can offer a *partial* explanation of special relativistic effects via appeal to the Poincaré invariance of the dynamical laws.

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- A full (untruncated) explanation is deferred to a later date.

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The Lorentzian pedagogy suggests (straightforwardly) that the detailed microdynamics associated with special relativistic systems would provide the constructive account of the behaviour of those systems.

Bell's 1992 remarks

If you are, for example, quite convinced of the second law of thermodynamics, of the increase of entropy, there are many things that you can get directly from the second law which are very difficult to get directly from a detailed study of the kinetic theory of gases, but you have no excuse for not looking at the kinetic theory of gases to see how the increase of entropy actually comes about. In the same way, although Einstein's theory of special relativity would lead you to expect the FitzGerald contraction, you are not excused from seeing how the detailed dynamics of the system also leads to the FitzGerald contraction. (Bell 1992, p. 34)

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- Brown is fully onboard with this lesson...
- ...but others (the geometricians) have a very different story to tell.

“Enter me.” (He says in parentheses.)

Janssen on geometry as constructive

Minkowski (1909) did for special relativity, understood strictly as a principle theory, what Boltzmann had done for the second law of thermodynamics. It turned special relativity into a constructive theory by providing the concrete model for the reality behind the phenomena covered by the principle theory. (Janssen 2009, p. 40)

Summary so far

Spacetime structure

Dynamical laws

Constructive explanation?

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Behaviour of physical bodies

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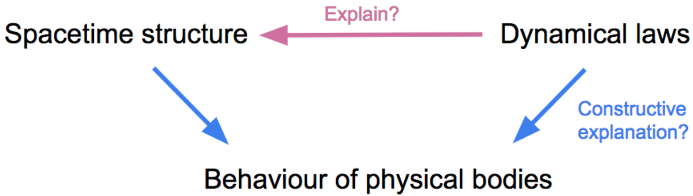
A shift of focus

In order make progress in this debate on the correct constructive underpinnings of relativistic phenomena, authors change focus: to whether spacetime structure *explains* the form of the dynamical laws governing the matter out of which our physical systems are constructed, or vice versa.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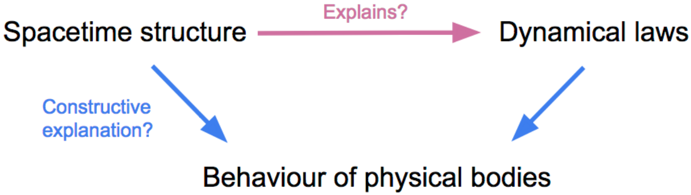
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Arrows of explanation

Our central disagreement ... is a dispute about the direction of the arrow of explanation connecting the symmetries of Minkowski spacetime and the Lorentz-invariance of the dynamical laws governing systems in Minkowski spacetime. I argue that the spacetime symmetries are the explananans *and that the Lorentz invariance of the various laws is the* explanandum. *Brown argues that it is the other way around.* (Janssen 2009, p. 29)

Spacetime as an explanation of dynamical symmetries?

> *In the neo-Lorentzian interpretation it is, in the final analysis, an unexplained coincidence that the laws effectively governing different sorts of matter all share the property of Lorentz invariance, which originally appeared to be nothing but a peculiarity of the laws governing electromagnetic fields. In the space-time interpretation this coincidence is explained by tracing the Lorentz covariance of all these different laws to a common origin: the space-time structure posited in this interpretation.* (Balashov and Janssen 2003, p. 314)

Brown's reply

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As a matter of logic alone, if one postulates spacetime structure as a self-standing, autonomous element in one's theory, it need have no constraining role on the form of the laws governing the rest of the theory's models. So how is its influence supposed to work? Unless this question is answered, spacetime cannot be taken to explain the Lorentz covariance of the dynamical laws. (Brown and Pooley 2006, p. 84)

Philosophers of physics proofs-that-*P*

with *a priori* metaphysical warrant. Therefore P.

Brown

How is the explanation based on the postulation of not-P supposed to work? Therefore P.

Butterfield

In fascinating recent debates, the Greats have defended not-P. Agreed: Not-P is an interesting

(From Erik Curiel, `strangebeautiful.com`.)

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3. If the view can be made to hold together, spacetime symmetries (and structure) would be *explained* by dynamical facts.

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1. A 'meta-law', in the sense of e.g. (Lange 2007)?
2. A pragmatic restriction?

Unqualified and qualified geometrical views

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- But in what sense can a qualified geometrical approach offer a *constructive* explanation of the behaviour of the physical bodies under consideration?
  - Only when spacetime is hypostatised? (Acuña 2016, Read 2020b)

Maudlin's qualified geometrical approach?

> *Complete physical understanding of an equilibrium state would require a complete account of the internal structure of the rigid system, both its composition and the forces among its parts. But even absent such a detailed account, we can make some general assertions about rigid bodies in any Special Relativistic theory. The fundamental requirement of a relativistic theory is that the physical laws should be specifiable using only the relativistic space-time geometry. For Special Relativity, this means in particular Minkowski space-time. It is the symmetry of Minkowski spacetime that allows us to prove our general result.* (Maudlin 2012, p. 117)

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- The remaining issues are (a) whether this spacetime structure is ontologically autonomous, and (b) whether it can offer a constructive explanation of the above effects.
- Advocates of the dynamical approach will assent to neither (a) nor (b)—but note that Maudlin doesn't *explicitly* do this either (at least in the above quote).

Moral

There are different versions of the geometrical view, and one has to be very careful to distinguish them from one another.

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Constructivists, such as Harvey Brown, urge that the geometries of Newtonian and special relativistic spacetimes result from the properties of matter. Whatever this may mean, it commits constructivists to the claim that these spacetime geometries can be inferred from the properties of matter without recourse to spatiotemporal presumptions or with few of them. I argue that the construction project only succeeds if constructivists antecedently presume the essential commitments of a realist conception of spacetime. (Norton 2008, p. 821)

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- So Brown's approach fails, according to Norton, for it implicitly makes certain spatiotemporal presuppositions.
- Is this fair? Let's consider two responses to Norton.

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(For more on this, see (Stevens 2017).)

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Menon (2018) uses the machinery of 'algebraic fields' to *show* that manifold points can be understood as 'structural properties of matter', in line with the above quote.

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  - For this, one would surely need to argue that the formulation in (ii) is *metaphysically prior* to the formulation in (i)—but how would such an argument proceed?

In sum

In light of the recent writings of Pooley, Stevens, and Menon, it's not clear whether Norton's charges against the dynamical approach find their mark.

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Next time: the *metaphysics of time* in special relativity.

References I

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