Reichenbach and the Prehistory of the Dynamical Approach to Special Relativity

Marco Giovanelli

Università di Torino
Department of Philosophy and Educational Sciences
Via S. Ottavio, 20 10124 - Torino, Italy

`marco.giovanelli@unito.it`

The paper aims to revisit Reichenbach's interpretation of special relativity, making two different but interrelated claims: (I) Reichenbach's interpretation is best characterized not as a variant of the conventionalist interpretation, but rather an early form of the dynamical interpretation; (II) Reichenbach offers a more robust version of the dynamical interpretation than contemporary accounts. On this basis, the paper argues that Reichenbach's approach provides the conceptual resources to (I) strengthen the dynamical approach against common criticisms from defenders of the geometrical approach, (II) expose on its true weak point of both approaches. Unlike the dynamical approach, special relativity does not require a *specific* theory of matter to explain ether drift experiments; rather, it demands that *any* such theory be Lorentz invariant. Unlike the geometrical approach, Minkowski 's formalism helps test this requirement but lacks explanatory power. The paper concludes that, following Lange, special relativity provides an 'explanation by constraint.'

Keywords: Hans Reichenbach • Lenght Contraction • Special Relativity • Dynamical Relativity • explanation

Introduction

Harvey Brown's 2005 book *Physical Relativity* is widely credited with reshaping the debate on the foundations of space-time theories. Brown argues that special relativity as it stands is incomplete: phenomena like length contraction must ultimately receive a *dynamical explanation* in a fundamental theory of the material structure of rods.[1] Defenders of the alternative view, such as Michel Janssen (2009), object that special relativity was already completed by Minkowski, who provided a theory of the mathematical structure of spacetime: length contraction receives a *geometrical explanation* from the fact that the world tube of the rod is intersected differently by the hyperplane of simultaneity. Whatever one's view, following this debate, the problem of the role of rods and clocks in relativity theory has been reframed (see Acuña 2016, for a balanced account): from the logical empiricist concern with *confirmation* (conventional vs. empirical) to a focus on *explanation* (geometrical vs. dynamical).

This paper examines an underappreciated aspect of early discussions surrounding what is now called the dynamical approach. It argues that Hans Reichenbach, already in the 1920s, explicitly raised the problem of 'explanation' within special relativity.

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[1] On Einstein's attitude towards this issue, see Giovanelli 2014.

Reichenbach denied explanatory priority to Minkowski spacetime. In a manner similar to contemporary dynamical approaches, he insisted that special relativity requires the behavior of rods and clocks to be accounted for by a *specific, though as yet unknown, theory of matter*, without advocating any return to Lorentz theory. This paper seeks to draw renewed attention to this aspect of Reichenbach's interpretation of relativity, which, to my knowledge, has not been explicitly discussed in the existing literature. In particular, it advances two distinct but interrelated claims:

(a) *historical claim*: Reichenbach's axiomatization of special relativity should not be regarded as a variant of Moritz Schlick's (1915) conventionalist interpretation, as it is often portrayed, but as an early precursor of the dynamical interpretation;

(a) *systematic claim*: Through an analysis of both the notion of 'contraction' and the notion of 'explanation,' Reichenbach outlined, in many respects, a more robust version of the dynamical interpretation of special relativity than contemporary ones.

Building on these two claims, the paper argues that Reichenbach's work provides the conceptual tools (I) to steel-man the dynamical approach against its most common objections; (II) to expose the cracks in its strongest armor. The advantage of Einstein's special relativity over Lorentz's ether theory is precisely that the former does not need to explain the failure of ether drift experiments by *finding* a *specific* Lorentz-invariant theory of matter; rather, relativity explains such negative results by *requiring* that *any* possible theory of matter *must* be Lorentz-invariant. In Einstein's view, Minkowski's mathematical apparatus facilitates establishing whether available laws comply with this requirement but, contrary to the geometrical approach, does not provide any further explanatory contribution. The paper concludes by arguing that, if one wants to cast the contribution of special relativity relativity in explanatory terms, it is better to speak of an *explanation by constraint*, as suggested by Marc Lange (2016).

1 The Schlick–Reichenbach Correspondence and the Emergence of Reichenbach's Axiomatization

Reichenbach's 1920 habilitation thesis, *Relativitätstheorie und Erkenntnis apriori,* appeared in print during the famous 86th meeting of the *Gesellschaft deutscher Naturforscher und Ärzte* (GDNÄ) in Bad Nauheim (19–25 September), marking the beginning of a politically charged backlash against relativity in Germany (Weyl 1920a). Schlick, who did not attend the meeting, received the booklet around that time (Schlick to Reichenbach, Sep. 25, 1920; HR, 015-63-23). Writing to Einstein, he praised it but complained about Reichenbach's 'neo-Kantian' critique of conventionalism (Schlick to Einstein, Sep. 23, 1920; CPAE, Vol. 10, Doc. 171s). Schlick articulated his stance in correspondence with Reichenbach over the ensuing months (Padovani 2009).

Schlick famously objected that, upon closer inspection, Reichenbach's *a priori* coordinating principles were nothing but arbitrary 'conventions' in the sense of Poincaré (Schlick to Reichenbach, Nov. 26, 1920; HR, 015-63-22). Reichenbach initially offered some resistance. If the coordinating principles were fully arbitrary, he feared, they would be empirically meaningless. In Poincaré's conventionalism, Reichenbach missed a restriction in "the arbitrariness of the principles [...], if the principles are combined"; therefore, he concluded, "I cannot accept the term 'convention'" (Reichenbach to

Schlick, Nov. 26, 1920; 015-63-22). Schlick replied that it would, of course, be unfair to assume he was unaware of this fact (Schlick to Reichenbach, Dec. 11, 1920; 015-63-22). Indeed, in January, Schlick (1921, 110f.), while mentioning Reichenbach's book favorably in an article for the *Kant-Studien*, reiterated in public the objections he had raised in private correspondence.

Reichenbach did not seem to have been fully turned to the conventionalist side at this point. Einstein's (1921, 126) apparent endorsement of Poincaré in his famous January 1921 lecture on 'geometry and experience' may have played a role in tipping the scale in favor of conventionalism. In fact, by September 1921, Reichenbach wrote to Schlick that he considered their difference of opinion resolved (Reichenbach to Schlick, Sep. 10, 1921; SN). He hoped to finally meet Schlick in person in a few days at the Jena *Physikertag*, where he was going to present a report on his project for an axiomatization of special relativity (Reichenbach to Schlick, Sep. 10, 1921; SN). When he sent Schlick the published version of the report, Reichenbach (1921) emphasized that his axiomatization "obviously provides a confirmation of conventionalism"; however, he also qualified this remark by insisting that it "reveals those facts that even conventionalism cannot interpret" (Reichenbach to Schlick, Jan. 18, 1922; SN). Schlick was impressed though he wished to examine the technical details more closely (Schlick to Reichenbach, Jan. 27, 1922; SN)

Reichenbach clarified his position in more accessible terms in a long review paper on the philosophical interpretations of relativity, completed around March 1922 (Einstein to Reichenbach, Mar. 27, 1922; CPAE, Vol. 13, Doc. 119). By outlining his axiomatization of special relativity, Reichenbach emphasizes once again that he prefers to *avoid* the term 'conventionalism.' The problem, he insists, is "not only to detect the *arbitrary* principles of knowledge, but also to determine the totality of admissible combinations" (Reichenbach 1922a, 362/2:39).[2] Reichenbach presents his axiomatization as the solution to this problem. In particular, he emphasizes that the latter was organized around two pairs of distinctions (362f./2:39f.):

– *axioms* vs. *definitions*. In this context, 'axiom' refers not to a mathematical postulate but to an observable fact, either experimentally confirmed or provisionally assumed. In contrast, 'definitions' are rules coordinating empirical realities with mathematical concepts. Einstein showed that judging whether two distant events are simultaneous involves a convention about the ratio ϵ of one-way light speeds in a round trip. Since we cannot measure one-way speed without presupposing simultaneity, Einstein's convention $\epsilon = 1/2$ is not 'more correct' than others. The distinction between 'conventional' elements (definitions) and empirical ones (axioms) limits the wiggle room for Poincaréan adjustments of theory to data. For example, it is a 'fact' that simultaneity 'conventions' must be 'univocal' (independent of prehistory) (Reichenbach 1922c).

– *light axioms* vs. *matter axioms*. Light axioms state only the properties of electromagnetic signals, and matter axioms those of rigid rods and natural clocks. Reichenbach claimes that a *light geometry* alone could ground space and time measurement. While in Einstein's theory light served only to define simultaneity, in Reichenbach's axiomatization it can be used for all time and distance measurements (via light travel time). The benefit of light geometry is that it avoids

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[2] In the remainder of this paper, page numbers after the slash indicate the corresponding passages in the translation.

defining the 'metric' using material entities like rods and clocks—complex atomic systems whose behavior depends on physical laws. In Reichenbach's system, *matter geometry* based on rods and clocks appears only after light geometry, as a series of 'matter axioms.'

The separation between these two conceptual pairs is central to Reichenbach's axiomatization: light axioms express facts accepted by classical optics and are thus confirmed independently of special relativity. The difference between classical and relativistic light geometry is a *matter of convention*, depending on the definition of simultaneity. Whether matter geometry agrees with classical or relativistic light geometry is a *matter of fact*, which is empirically testable in principle. Thus, only the matter axioms encode the physical content specific to relativity: "Einsteinian kinematics rests on the hypothesis that [relativistic] light geometry is identical with the geometry of rigid rods and natural clocks" (Reichenbach 1922a, 365/2:41).

As Reichenbach (1922b) points out in a popular French article submitted to the *Revue philosophique* in May, his goal was not merely to *endorse* conventionalism but to *constrain* its scope. Whether Lorentz or Galilei transformations apply to light signals depends, it is true, on arbitrary definition; whether Lorentz transformations are *also* the transformations for rods and clocks, however, is an objective empirical issue. Nevertheless, at this point, Schlick, who had moved to Vienna in the winter term of 1922–1923, seems to consider Reichenbach a reliable conventionalist ally, whose interpretation of relativity was "not only factually unassailable, but also brilliantly expressed" (Schlick to Reichenbach, Aug. 15, 1922). In the meantime, Reichenbach was already working on expanding the 1921 report into a book. In October, Weyl informed him of a significant flaw in his attempt to derive the Lorentz transformations for the light axioms alone (Weyl to Reichenbach, Oct. 5, 1922; HR, 015-68-02). Reichenbach managed to somewhat patch the problem in the last draft of the book finished by the of 1923 (Rynasiewicz 2005).

Axiomatik der relativistischen Raum-Zeit-Lehre was published in May–June 1924. In November, Weyl (1924) wrote a scathing review for the *Deutsche Literaturzeitung,* complaining about the cumbersomeness of Reichenbach's presentation. Weyl's attack—one of the leading relativists of his time—dealt a significant blow to Reichenbach, who, even a decade later, would recall the episode with lingering resentment (Reichenbach to Einstein, Apr. 12, 1936; EA, 10-107). Reichenbach's urge to defend his work is therefore hardly surprising. On July 28, 1925, the journal *Zeitschrift für Physik* received a paper in which Reichenbach firmly took a stance. In particular, he complained that Weyl misunderstood his work as a 'mathematical investigation,' whereas his axiomatization was intended as an "epistemological clarification" of the theory of relativity (37/136).

2 The Physical Consequences of Reichenbach's Axiomatization

As Reichenbach explains, his axiomatization differs from the typical 'deductive axiomatization' associated with David Hilbert. In that tradition, one sets an abstract general principle as an axiom, such as a variational principle (see Reichenbach 1924, 2). Reichenbach, in contrast, put forward a 'constructive axiomatization,' in which axioms are empirically grounded statements subject to experimental verification, to be distinguished from purely conventional definitions.[3] His axiomatization "has the

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[3] On the modern constructive axiomatizations of special relativity, see Adlam, Linnemann, and Read 2025.

great advantage for physics that the *implications of each experimental result* can be immediately recognized" (Reichenbach 1925, 32/172). Some statements of the theory are purely definitional and not empirically testable. Among those that are, not all depend on every axiom; thus, one can immediately tell whether an assertion rests on confirmed or uncertain axioms (Reichenbach 1925, 32/172).

As we have seen, light *axioms* (I–V) capture *facts* established by pre-relativistic optics, along with the limiting nature of the speed of light. The difference between classical and relativistic light geometry, Galilei and Lorentz transformations, is conventional, based on an arbitrary *definition* of simultaneity. In Reichenbach's axiomatization, only the matter axioms (VI–X) contain the empirically testable content of relativity: the claim that the Lorentz transformations are also the transformations for rods and clocks. Axioms VI and VII are shared with classical theory; the others are specific to relativity. Axiom VIII encodes the Michelson–Morley experiment, and Axioms IX and X combined the transverse Doppler effect. While the latter still lacked confirmation, the Michelson–Morley experiment was widely accepted as a settled matter. However, shortly before Reichenbach's article appeared, the experimentalists Dayton C. Miller (1925a, 1925b) started to raise doubt by presenting the results of a series of Michelson-type experiments conducted at Mount Wilson, in Southern California. Reichenbach used the controversy to challenge Weyl and show the value of his axiomatization in addressing the question: *what would happen to relativity if Axiom VIII were empirically refuted?*

2.1 Michelson's and Miller's Ether-Drift Experiments

Reichenbach (1924, 53; 1925, 43; 1926; 1928, 226,299) repeatedly present the familiar 'received view' account of the Michelson–Morley experiment. Nevertheless, it deserves brief attention, since Reichenbach's goal is precisely to *challenge* this account. As is well known, the essential aim of the experiment was to determine whether the speed of light varies with direction due to the Earth's motion through the hypothesized ether. In the setup schematically depicted in fig. 1, a beam of light is split at point O by a semi-transparent mirror, sending two coherent beams along two perpendicular arms of equal length, each ending at mirrors S_1 and S_2. The beams reflect back and recombine at O, creating an interference pattern—a series of alternating bright and dark fringes. If they return at the same time, their wave crests and troughs align, and the pattern remains stable. If one beam takes slightly longer, the waves arrive out of step, causing a shift in the fringes (Reichenbach 1926, 325/195f.).

According to ether theory, the two beams return to point O simultaneously only if the apparatus is at rest relative to the ether. Since the Earth was assumed to move through the ether, classical optics predicted a 'deviation': the beam traveling along the arm S_2, aligned with the Earth's motion, would take slightly longer to return, resulting in a shift in the interference fringes. Thus, the experiment was supposed to reveal the Earth's absolute motion through the ether by detecting such a shift. In the 1880s, Albert A. Michelson (1881), later with the assistance of Edward W. Morley (1887), showed that "in spite of the extreme precision of the measurement, there is no difference in the time to traverse either arm of the apparatus" (Reichenbach 1926, 326/195). At the turn of the century, "Morley and Miller [1905a, 1905b] replicated this negative result in spite of the renewed increase in precision" (Reichenbach 1926, 326/195; translation modified). How can this negative result be explained? The subsequent unfolding, Reichenbach argues, was usually considered uncontroversial:

- At the turn of the century, “Lorentz [1895] in Leyden presented his explanation” of this equality “that assumed that all rigid bodies moving in opposition to the ether undergo a contraction” (Reichenbach 1926, 325/197). The arm of the apparatus aligned with the direction of motion is *contracted* by the amount $\sqrt{1-\frac{v^2}{c^2}}$ when it moves relative to the ether. The theoretical asymmetry between the ether frame and frames moving with respect to it is hidden from observation by introducing a sort of universal conspiracy of nature.
- In 1905, “a more basic explanation was proposed by A. Einstein in which these contractions occur as a result of a universal principle, the principle of relativity” (Reichenbach 1926, 326/197), and in particular of the relativity of simultaneity. Einstein, on the contrary, declared both arms *equally long* when measured in their own rest frame, but one arm would appear contracted by the factor $\sqrt{1-\frac{v^2}{c^2}}$ when observed from a relatively moving system. In this way, the theoretical symmetry between rest and moving systems is reestablished, and the ether could be expunged from the theory.

Lorentz’s and Einstein’s theories *agree* on the same empirical fact, stated in axiom VIII: ‘Two space intervals which are equal when measured by rigid rods, are also light-geometrically equal,’ meaning they are equal when measured by the round-trip time of a light signal. The null result of the Michelson–Morley experiment confirmed this equality.

Further support came recently from Rudolf Tomaschek (1924), a critic of relativity, who repeated the interferometer experiment using starlight instead of terrestrial light sources (Reichenbach 1925, 39/180). However, Reichenbach noted that “[r]ecently, doubts have been raised by Dayton C. Miller, who obtained a positive result on Mount Wilson” (39/180). If confirmed, Miller’s experiment would imply unequal round-trip times along the two arms ($\overline{OS_1O} \neq \overline{OS_2O}$). The material-rod-based equality of distances would then conflict with the electromagnetic-signal-based one, disproving Axiom VIII. Though Miller’s results were still debated, Reichenbach quickly used the controversy to highlight the value of his axiomatization: “In this context, the axiomatization is proved to be extremely useful because it shows what particular role the Michelson experiment plays in the theory, what follows from it, and what is independent of it” (39/180).

2.2 Two Kinds of Contraction: Einstein Contraction vs. Lorentz Contraction

The question, then, is this: what would become of special relativity if the null result of the Michelson–Morley experiment were refuted—that is, if Axiom VIII turned out to be incorrect? Before addressing this question, Reichenbach cautions his readers against uncritically accepting the standard interpretation of the Michelson experiment that we have just presented. Lorentz’s dynamical contraction of one arm of the apparatus is usually considered an *ad hoc* hypothesis.[4] On the contrary, Einstein’s hypothesis of the contraction resulting from the relativity of simultaneity appeared to be less contrived since it is a consequence of a universal principle (Schlick 1915). According to Reichenbach, both of these claims are incorrect.

Einstein’s theory, like Lorentz’s, agrees that the behavior of rigid rods deviates from classical predictions and conforms instead to relativistic light geometry; therefore, the contraction hypothesis is not *ad hoc*. However, contrary to common belief, the relativity

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[4] On this issue, see see also Janssen 2002.

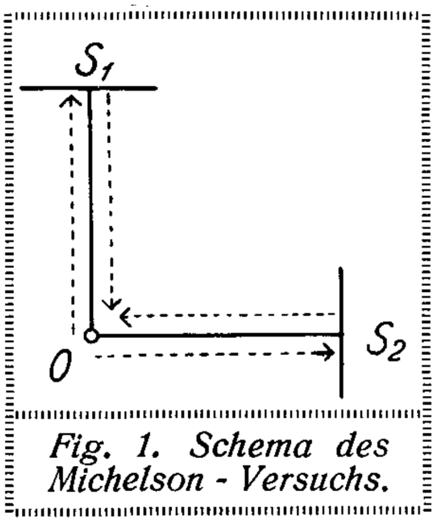

Figure 1: Reichenbach's diagram of the Michelson-Morley apparatus (from Reichenbach 1926, 325)

of simultaneity is unrelated to the contraction involved in the Michelson–Morley experiment. The contraction of the apparatus's arm occurs in the frame relative to which the apparatus is at rest (the Earth), not in the frame relative to which the apparatus is moving (the Sun):

> [W]e should examine a particular error that has crept into the understanding of the theory of relativity. It concerns the problem of Lorentz contraction and thereby leads us to the Michelson experiment. One frequently hears the opinion expressed that in the Lorentzian explanation of the Michelson experiment the contraction of the arms of the apparatus is an '*ad hoc* hypothesis,' whereas Einstein explains it in a most natural way, namely, as a result of the relativization of the concept of simultaneity. But this is false. *The relativity of simultaneity has nothing to do with length contraction in the Michelson experiment.* That this opinion is false already follows from the fact that the contraction of one of the arms of the apparatus occurs precisely in the system in which the apparatus is at rest. (Reichenbach 1925, 43/187; my emphasis)

Einstein contraction has often been called 'apparent,' for it is not the arm of the interferometer that contracts, but its 'projection' onto a system at rest.[5] In contrast, Lorentz contraction is usually regarded as 'real' —a true dynamical phenomenon caused by the action of the ether on molecular forces, similar to the contraction of a metal due to a drop in temperature. Reichenbach, however, explicitly *rejects* this widespread interpretation. In particular, Reichenbach denies that Einstein contraction has anything to do with the null result of the Michelson–Morley experiment:

> That this opinion is false already follows from the fact that the contraction of one of the arms of the apparatus occurs precisely in the system in which the apparatus is at rest. The 'Einstein contraction' only explains that the arm is *shortened if it is measured from a different system.* But that does not explain the Michelson experiment. [The latter] proves that the rod lying in the direction of motion *is shorter when measured in the rest system than it should be according to the classical theory.* [. . .][T]he Einsteinian theory, as well as Lorentz's, differs from the classical theory in asserting a measurably

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[5] The *projection* of a moving bar AB in K is the segment $A'B'$ marked on the x-axis at the simultaneous positions of A and B in the frame K; for Einstein's stance on the distinction between *real* and 'apparent,' see Giovanelli (2023).

> different effect on rigid rods that *has nothing to do with the definition of simultaneity.* (43–44/187–188; translation modified; my emphasis)

Einstein contraction depends on the relativity of simultaneity and “is related to the comparison of *different magnitudes* within the *same theory*” (Reichenbach 1925, 44/188). A comparable case is annual parallax, the apparent displacement of a star observed from opposite sides of Earth’s orbit. Lorentz contraction is related to “the behavior of the *same magnitudes* according to *different theories*” (45/188) using the round-trip time of light as *tertium comparationis*.[6] An analogous case is the difference in gravitational light deflection, where in general relativity the deflection is twice as large as it would be according to Newtonian theory.

According to Reichenbach, only Lorentz contraction is at stake in the Michelson experiment, not Einstein contraction: “It just happens that both contractions depend upon the same factor [$\sqrt{1-\frac{v^2}{c^2}}$], and this is probably the reason why they are always confused with one another” (46/189). The fact that Lorentz contraction and Einstein contraction amount to the same factor is, in Reichenbach’s assessment, a mathematical fortuity that follows from the linearity of the Lorentz transformations. In order to provide a proof of this claim, Reichenbach resorts to the somewhat idiosyncratic notation introduced in his 1924 monograph.

Reichenbach labels l the length of a rod with Lorentz–Einstein behavior, and L the length of a rod with classical behavior. K and K' denote, respectively, the stationary and moving frames. He then uses index notation where the upper index ^{K} marks the frame in which the rod is measured, and the lower index $_K$ marks the frame in which the rod is at rest. In both the classical and Lorentz–Einstein theories, the lengths of unit rods in the rest frame K are equal, i.e., $l_K^K = L_K^K = 1$. The difference emerges when one considers the length of the rod in the moving system:

- *classical theory*: the rod has a unique length regardless of motion:

$$\frac{L_K^K}{L_{K'}^{K'}} = \frac{1}{1} \quad \text{no contraction;} \tag{i}$$

- *Lorentz theory*: the length of the moving rod measured in K' is contracted relative to the classical length in the same frame K':

$$\frac{l_{K'}^{K'}}{L_{K'}^{K'}} = \frac{\sqrt{1-\frac{v^2}{c^2}}}{1} \quad \text{Lorentz contraction;} \tag{ii}$$

- *Einstein theory*: the length of the moving rod measured in K is contracted relative to the length measured in K':

$$\frac{l_{K'}^{K}}{l_{K'}^{K'}} = \frac{\sqrt{1-\frac{v^2}{c^2}}}{1} \quad \text{Einstein contraction.} \tag{iii}$$

Reichenbach aims to prove that the numerical equality of the Lorentz and Einstein contraction factors $\sqrt{1-\frac{v^2}{c^2}}$ follows solely from the linearity of the Lorentz transformations. His proof runs as follows (Reichenbach 1928, 230f./199). According to classical

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[6] See also Reichenbach 1928, 228/196f. This distinction is also used by Grünbaum (1955; 1963, sec. 12F) without citing Reichenbach. See also Giannoni (1971).

theory, $L^K_{K'} = L^K_K$; since $l^K_K = L^K_K$, then $L^K_{K'} = l^K_K$. Substituting in eq. (iii), it follows that:

$$\frac{l^K_{K'}}{L^K_{K'}} = \frac{\sqrt{1-\frac{v^2}{c^2}}}{1} \tag{iv}$$

Because of the transformation's linearity, this ratio depends only on the relative velocity v between frames, not on which frame the length is measured. Thus, eq. (iv) is the same ratio as eq. (ii). Since eq. (iv) is also the same as eq. (iii), it follows that eq. (ii) and eq. (iii) express the same ratio, QED. However, Reichenbach insists, there is a deep *conceptual difference* between the two contractions despite their accidental *numerical equality* (Reichenbach 1925, 45f./189f.).

2.3 Two Kinds of Explanation: Deviation vs. Adjustment

As we have seen, according to Reichenbach, both Lorentz's and Einstein's theories assert an agreement between relativistic electromagnetic signal-based geometry and rod-based geometry (Reichenbach 1924, 36; tr. 1969, 176). The difference between Lorentz's and Einstein's theories must be sought in the way they account for this set of physical facts. According to Reichenbach (1), Lorentz *explains* this empirical fact by claiming that the moving rods, because of their motion through the ether, *must have* a *shorter length* than the rest 'ether' rod by a factor $\sqrt{1-\frac{v^2}{c^2}}$. Einstein *stipulates* that the moving and rest rods have the *same length*, despite the fact that the moving rod *as measured in the rest system* is shorter by a factor $\sqrt{1-\frac{v^2}{c^2}}$ than the rest rod.

Both theories, although empirically equivalent, are, according to Reichenbach, ultimately explanatorily unsatisfying: (1) Lorentz's theory is unsatisfying since it provides a *bad explanation*, as there is no reason to assume that the behavior of rigid rods must be classical. (2) Einstein's theory is unsatisfying because he provided *no explanation* at all and simply declared by convention that relativistic rods are rigid. The superiority of Einstein's approach is that it frees us from the prejudice that classical light geometry is more 'natural,' so rods and clocks that departing from the latter must mean 'distortion.' Einstein shows that we could just as well redefine rigid rods as those rods that conform to relativistic light geometry. However, once this prejudice is overcome, the task is far from complete.

The realization that what counts as a rigid rod is a matter of *convention* should not lead us to sidestep the problem of *explanation*, but rather help reframe it. Unlike Lorentz, one need not explain why rods *disagree* with classical light geometry. But unlike Einstein, one must still explain why they *agree* precisely with relativistic light geometry. Reichenbach suggests that the term *adjustment* (*Einstellung*), introduced by his nemesis Weyl, aptly captures this peculiar form of 'explanation,' distinct from the traditional notion of *deflection* (*Abweichung*) used implicitly by Lorentz. Reichenbach already made this proposal in his 1924 book, though it played a minor role (Reichenbach 1924, 70–71/90-91); in the 1925 paper, the argument took center stage.

As Reichenbach explains, Weyl (1920b) introduced the term to account for the surprising Riemannian behavior of all physical ideal rods of whatever material: they always have the same length when compared side by side after traveling different paths (Reichenbach 1922c, 366). This regularity suggests that rods 'adjust' each time to an equilibrium value, rather than 'preserve' it.[7] The length of a macroscopic rod,

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[7] Following Weyl (1920b, 650), Reichenbach used this analogy: (1) a spinning top maintains

for example, may be proportional to some fundamental constant of nature. Thus, in Reichenbach's reading, the *axiom* of Riemannian geometry—the path independence of rod length—is *explained* by a theory of matter implying, say, the fixity of that constant. This explanation does not account for the *deviation* from a standard behavior, but rather for the *convergence* of rods of all kinds to a non-trivial one (see Ryckman 2005, sec. 424).

The analogy with special relativity appears to be this. As we have seen, the empirical content of Lorentz–Einstein theory "can be formulated as meaning that *light geometry and matter geometry are identical*" (Reichenbach 1924, 11; tr. 1969, 14). It is a striking *coincidence* that any physical ideal rod—whether made of steel, wood, etc. —always yields measurements equal in light-geometric terms. As Reichenbach notes, "[l]ight is a much simpler physical object than a material rod, and, when searching for a relation between the two, it should be initially supposed that it would not correspond to so ideal a scheme as the posited matter axioms" (Reichenbach 1925, 47-48/95). This coincidence begs for an *explanation.* Yet it is not about explaining the *divergence* from the obvious classical behavior, but rather the *convergence* toward a non-trivial relativistic behavior:

> The word adjustment, first used in this way by Weyl, is a very good characterization of the problem. [...][A]ll metrical relations between material objects, including the observed fact of the Michelson experiment, must therefore be explained in terms of the particular way in which rigid rods adjust to the movement of light. Of course, the answer can only arise from a detailed theory of matter about which we have not the least idea [...][.] The word 'adjustment' here thus only means a problem without providing an answer; the relevant fact is strictly formulated in the matter axioms without using the word 'adjustment.' Once we have this theory of matter, we can explain the metrical behavior of material objects; but at present the explanation from Einstein's theory is as poor as Lorentz's or the classical terminology. (46–47/191)

According to Reichenbach, the difference between Lorentz's and Einstein's theories lies not in their differing empirical content, but in their different *explanatory strategies.*

Lorentz's theory assumes the classical behavior of rods as 'natural,' so that any deviation from that standard *requires* an explanation. Einstein's theory *dispenses* with any explanation by defining the behavior of rods as 'natural' if it agrees with the Michelson–Morley experiment: "The superiority of Einstein's theory lies in the recognition of the epistemological legitimacy of this procedure" (Reichenbach 1928, 233/202). Certainly, Einstein's conventionalism removes the prejudice that the classical behavior of rods and clocks is *a priori* correct. However, Einstein's agnosticism is unsatisfying, since it does not explain why rods and clocks happen to behave relativistically. Without a suitable *theory of matter* describing those physical systems we happen to use as rods and clocks, "Einstein's theory provides just as little an explanation [*Erklärung*]" of the metrical behavior of material objects "as Lorentz's" (Reichenbach 1925, 43/87).

Once he has clarified the meaning of explanation in the relativistic context, Reichenbach is in a position to explore the implications of a possible positive result from a Michelson-type experiment. As previously noted, this was far from a purely theoretical concern at the time. Miller's (1925a) new findings quickly ignited significant

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its vertical orientation by perseverance (*Beharrung*) due to angular momentum conservation, but easily loses it if *disturbed*; (2) a magnetic needle maintains its northward orientation by adjustment (*Einstellung*) to the Earth's magnetic field, and thus always *returns* to the it unless *hindered* externally.

discussion within the physics community (Lalli 2012), and Reichenbach became the first 'philosopher' to attempt to engage in the debate:

> Now we can also address the question what would change in the theory of relativity if Miller's experiment were held to prove that the hitherto negative result of the Michelson experiment is in principle wrong. *Nothing would change* in Einstein's theory of time as it has nothing to do with the Michelson experiment. Also nothing would change with the light geometry; it remains in any case a possible definition for the space-time metric and probably a much better and more accurate one than the geometry of rigid rods and natural clocks. *But what would change is our knowledge about the adjustments of material things to the light geometry.* With respect to the matter axioms, as far as they differ from the classical theory, the Michelson experiment is the only one that has been confirmed. If this should be refuted, one has to develop a more complex view of the relationship between material objects and the light geometry. (Reichenbach 1925, 47/192; my emphasis)

As we have seen, if Miller's results were not spurious, only this axiom VIII would need revision. The principle of the *constancy* of the speed of light could still hold; by changing the conventional definition of simultaneity, one could still claim that light propagates as a spherical wave in any uniformly moving frame. The assertion of light as a *limiting* velocity also remains valid, as confirmed by measurements on fast electrons (β rays), whose kinetic energy approaches infinity as their speed nears that of light (Reichenbach 1924, 72/92). What would be refuted is the claim that light always has a *numerical value* c when measured by rods and clocks. A refutation of Michelson–Morley experiment would mean that rods do not adjust to the relativistic light geometry as Einstein expected. This would simply show that "rigid rods do not after all possess the preferred properties that Einstein still attributes to them" (Reichenbach 1925, 328/203).

3 Schlick–Einstein Correspondence on Reichenbach's Axiomatization

It is worth noting that Einstein drew very different conclusions from Miller's experiment. Einstein's view at the time is clearly conveyed in a letter sent to Robert A. Millikan, the *de facto* head of Caltech: if Miller's result were to be confirmed, Einstein wrote, then "the whole theory of relativity would *collapse like a house of cards*" (Einstein to Millikan, Jul. 13, 1925; CPAE, Vol. 15, Doc. 20; my emphasis). The analogy seems to allude to the 'theoretical rigidity' that Einstein demanded from a good theory: if any one of its conclusions proves to be false, the theory must be completely abandoned, since it is constructed in such a way that any modification would lead to its complete breakdown (see Einstein 1919). A few days later, an equally resolute statement by Einstein was published on August in *Science News-Letter* (Science Service 1925).

Reichenbach's markedly different attitude toward Miller's results appeared puzzling. By the end of the year, Schlick wrote to Einstein, expressing his bewilderment about Reichenbach's 1925 paper, which "quite clearly shows the limit of the axiomatic method" (Schlick to Einstein, Dec. 27, 1925; CPAE, Vol. 15, Doc. 140). In particular, Schlick was disconcerted by Reichenbach's claim that the Lorentz contraction is not *ad hoc*. After all, this had been Schlick's 'conventionalist' reading of special relativity for at least a decade (Schlick 1915; 1923, 60f.). He likely saw Reichenbach's remark as a barely concealed jab. In Schlick's conventionalist reading, Lorentz and Einstein theories are empirically equivalent. The choice between them is thus one of simplicity, not truth (Schlick 1915). Einstein's theory is preferable precisely because it avoids *ad hoc* assumptions.

Initially, Schlick and his circle saw Reichenbach's axiomatization as a refined version of this view (Zilsel 1925). However, Schlick now admitted to Einstein—clearly with some disappointment—that Reichenbach was pursuing a fundamentally different line of thought:

> The remarks on p. 43[/187] [. . .] seem to me to show only that his axiomatic system cannot find any difference between special relativity and Lorentz's theory (with the contraction hypothesis), which seems self-evident to me, since the equations are the same in both. The real difference between the two theories—which is a philosophical one and thus not accessible through the purely logical method of axiomatization—is, I believe, well captured by the mode of speech that Reichenbach rejects, namely, that Lorentz's hypothesis was an *ad hoc* invention. For even if, logically speaking, special relativity must make just as many basic assumptions as Lorentz's theory, in the former they naturally fit into the framework of the relativity principle, and the contraction hypothesis is not, psychologically speaking, an *ad hoc* invention—whereas in Lorentz–Fitzgerald's version, it appears as an *ad hoc* addition. (Schlick to Einstein, Dec. 27, 1925; CPAE, Vol. 15, Doc. 140)

Schlick's criticism misconstrues the issue at stake. Reichenbach's axiomatization does not fail to capture the epistemological difference between the two theories; rather, it situates it at a different juncture. For Schlick, the choice between Lorentz and Einstein theory is ultimately arbitrary—an appeal to the *simplest convention*; for Reichenbach, it is guided by an inference to the *best explanation.* While Lorentz's theory offers a *bad* explanation, Einstein's theory clears the way for a *good* one.

Still, Schlick was right in noting that the contrast between their interpretations becomes especially clear in Reichenbach's response to Miller's experiment. If Miller's findings had been confirmed, Schlick contended, the presumed natural 'conspiracy' concealing the ether would have been exposed, and we would have had to revert to the ether theory—essentially Lorentz's framework without the contraction hypothesis. Reichenbach, however, denied the necessity of such a reversal. In this sense, Schlick concluded, Reichenbach's axiomatic approach also lacks any 'physical consequences' —in direct contradiction with the title of his paper:

> The final remarks of the essay—on the possible interpretation of Miller's experiments—also seem to me to miss *the philosophical core of the issue.* If those experiments had indeed proven (which is certainly not the case) that a particular direction (that of the 'aether wind') were privileged, then relativistic physics would surely be abandoned. And even if it were possible to preserve relativity by assuming certain 'matter axioms,' this path would not be taken. Yet the axiomatic approach remains indifferent to this. It seems to me, therefore, that in a strict sense, one cannot really speak of physical consequences arising from axiomatization. These questions still strike me as philosophically important, and I would be most grateful if you could let me know with a line whether I am right. (Schlick to Einstein, Dec. 27, 1925; Vol. 15, Doc. 140; my emphasis)

Einstein, as far as we know, did not reply. In earlier correspondence, he had acknowledged that labeling Lorentz contraction as *ad hoc* was misleading, in a way that resonates with Reichenbach's stance (Einstein to Lorentz, Jan. 23, 1915; Vol. 8, Doc. 47). Still, with respect to Miller's experiment, Einstein's stance aligned more closely with Schlick's than with Reichenbach's. On January 19, 1926, a concise yet unambiguous statement by Einstein appeared in what was then Germany's most influential newspaper, the *Vossische Zeitung:* “If the results of Miller’s experiments should indeed be confirmed, the relativity theory *could not be upheld*” (emphasis mine).

Reichenbach (1926) submitted a popular article on Miller’s experiment, which was published in the weekly magazine *Die Umschau* on April. By then, he has become aware of what “Einstein himself has recently said in the newspapers,”; nevertheless, he saw no reason to revise his “less radical opinion” (Reichenbach 1926, 327/202), namely that “*Miller’s result in no way affects the philosophical consequences of the theory of relativity*” (328/203; my emphasis). For Reichenbach, the outcome would merely require a change in our understanding of the physical processes that govern rods and clocks. Special relativity would turn out to be “a first-order approximation in the same way that the ideal gas law cannot be maintained if the accuracy is increased” (Reichenbach 1925, 48/192).

Reichenbach expresses some doubts about the correctness of Miller’s experiment (Reichenbach 1926, 326f.). However, the philosophical point lay elsewhere: “*What then does the theory of relativity have to infer from Miller’s experiment?*” (327/202). On this matter, Reichenbach does not hesitate to voice a view that sharply diverged from that of Einstein. Reichenbach concurs that “[t]he Michelson experiment, of course, played a crucial role in the *historical development* of the theory” (327/202; my emphasis); however, according to Reichenbach, “it does not occupy this same significant place in the relativistic theory’s *logical structure*” (327/202; my emphasis). The logical structure of the theory was, of course, captured by his own axiomatic formulation:

> Under the ten axioms of the theory of relativity as I have laid them out, *i.e.*, its ten most basic empirical propositions, there is only one that entails the Michelson result; it is only this axiom then that is thereby threatened. The principle of the constancy of the speed of light could be maintained in a more limited form even if the Michelson experiment’s negative result were overturned. One could construct a ‘light geometry’ using light signals but employing no rigid rods to maintain a metrical understanding of the world and allow the previous formulation of all physical laws. From this perspective, the Michelson experiment serves only as a bridge between the light geometry and the geometry of rigid rods. Should this connection be lost, this would only mean that rigid rods do not after all possess the preferred properties that Einstein still attributes to them. This would not mean a return to the old aether theory, but rather a step towards the renunciation of a preferred system of measurement in nature. (327/203)

Of course, Reichenbach did not dispute that Miller’s result would impact the ‘physical theory of relativity’—the empirical assertion that ideal rods and clocks follow relativistic light geometry could no longer be upheld. His claim, rather, is that it would not undermine the ‘philosophical theory of relativity,’ that is, Einstein’s insight that simultaneity is not an empirical fact but a matter of definition. For Reichenbach, Einstein’s realization that time is not absolute “is independent of specific, physical observations” (203/328). While this insight arose “from a particular physical theory”, namely special relativity, it has “given rise to philosophical insights which no longer belong to the realm of physics but rather to the philosophy of nature” (204/328).

4 Dynamical vs. Geometrical Explanation in the *Philosophie der Raum-Zeit-Lehre*

Whether Reichenbach was aware of Schlick’s criticism is unclear. If he did, he was not swayed. Indeed, Reichenbach’s line of reasoning reappears in Reichenbach’s monograph

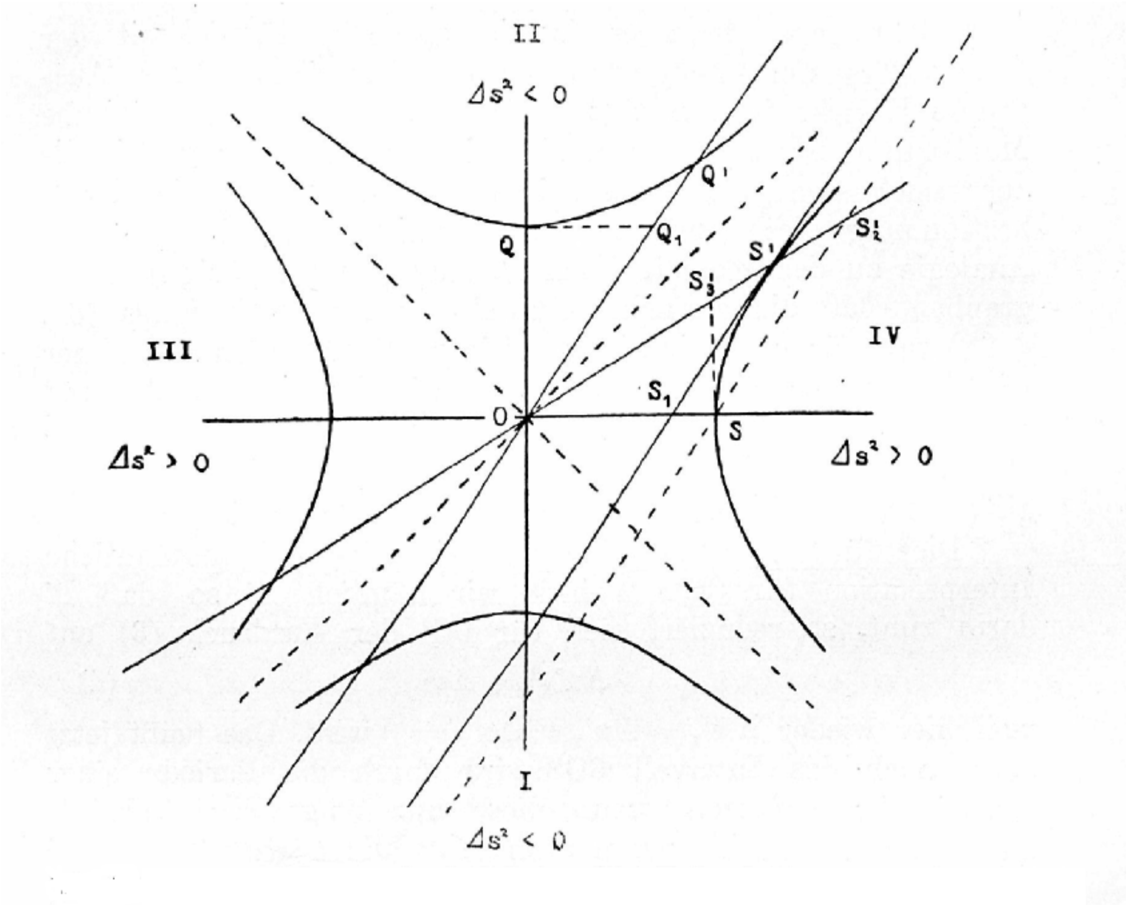

Figure 2: Minkowski diagram from Reichenbach 1928, 215

Philosophie der Raum-Zeit-Lehre (Reichenbach 1928), which had already been completed by the end of 1926 (Reichenbach to Schlick, Dec. 6, 1926; SN). By the time the book's galley proofs were finalized in late 1927, the relevance of Miller's experiment was already waning, particularly in Germany. Reichenbach could now state that the "Michelson experiment has been confirmed to a very high degree" and regarded "this matter closed" (Reichenbach 1928, 225/195). Nonetheless, Reichenbach still found it necessary to address the "erroneous interpretations in the usual discussions on relativity" that had surfaced in the discussion over Miller's result (Reichenbach 1928, 225/195).

In §31, Reichenbach restates the position he had advanced in his 1925 paper, with little or no revision. However, he introduces a novel element presenting the difference between Lorentz and Einstein contraction in geometrical terms—that is, by resorting to the Minkowski diagram in fig. 2. The name of Minkowski is, surprisingly, never mentioned in his 1924 axiomatization. This is ultimately not simply an oversight. One might perhaps expect that Reichenbach saw in Minkowski's work a 'geometrical explanation' replacing the 'dynamical explanation' that Einstein had failed to provide. However, this is not the case. Reichenbach seems to believe that Minkowski's geometrical presentation of Einstein's kinematics does not provide any explanatory contribution. In Reichenbach's view, Minkowski's "geometrical interpretation of the Lorentz transformation" (Reichenbach 1928, 206/177) was nothing but a '*graphical representation*' of the agreement between light and matter geometry: the Lorentz transformation, which differs from the Galilean transformation in terms of light geometry only by definition, is also the transformation for rods and clocks (175/205).

Reichenbach borrows the expression '*graphical representation*' (*graphische Darstellung*) from Arthur Stanley Eddington (1925, 295). However, in section §15 of the book, he takes care to provide a more precise definition. Reichenbach characterizes 'graphical representations' as structural analogies between different physical systems: The same *mathematical system* A can be *physically realized* by different systems $a, b, c, \ldots$; thus, one can use, say, the system b to *graphically represent* the system a (Reichenbach 1928, 125f./103). In other terms, while the physical realization is a *vertical coordination* of the same mathematical system with different physical systems, the *graphical representation* is a horizontal coordination among different physical systems that realize the same mathematical structure.[8]

Reichenbach gives several examples (126/103), but for the sake of brevity, let's apply this definition to our case. Minkowski's achievement was to have presented analytically the dependence of the measurement of space upon simultaneity, in the combining of space and time into a unique mathematical structure A, a four-dimensional manifold x_1, x_2, x_3, x_4 endowed with an indefinite metric: $ds^2 = dx_1^2 + dx_2^2 + dx_3^2 - dx_4^2$. The Lorentz transformations can be derived from the invariance of this expression. This *mathematical structure* A can be *physically realized* in different ways: (a) rods and clocks, where $ds > 0$ is realized by rods, $ds < 0$ by clocks, and $ds = 0$ by light rays; (b) by lines on a Minkowski diagram as depicted in fig. 2, where $ds > 0$ is realized by the horizontal axis OS, $ds < 0$ by the vertical axis OQ, and $ds = 0$ by a dotted line tilted at 45°. Since (a) and (b) are both realizations of A, (a) can be *graphically represented* by (b).

Of course, the mathematical content of special relativity is not altered simply because we have visualized the relativistic behavior of rods and clocks using a Minkowski diagram: "we only give a graphical representation, which means that the logical structure [*Beziehungsgefüge*]" (220/190) exhibited by rods, clocks, and light rays is also presented through the relations among the lines in the Minkowski diagram. Reichenbach concludes with a passing, yet significant remark: if, after Minkowski's work, we "speak of a *geometrization* of physical events, this phrase should not be understood in some mysterious sense; it refers to the identity of types of *structure* and not to the *identity of the coordinated physical elements*" (220/190; my emphasis). Minkowski's approach serves as a *geometrical illustration* of the relativistic behavior of rods and clocks, not as a *geometrical explanation*.

An example of such 'geometrical rapresentation' relevant for this paper is, of course, Reichenbach's use of a Minkowski diagram (fig. 2) to expound the difference between Lorentz and Einstein contraction:

- *Lorentz contraction*: the rest-length $OS' = l_{K'}^{K'}$ of the moving rod as measured in the moving frame K' is shorter than the rest-length $OS'_2 = L_{K'}^{K'}$ of the classical theory measured in the same frame K'. This is an *objective difference* on which both Einstein and Lorentz agree. It is represented graphically by the fact that, in the relativistic theory, the world strip of a moving rod is bounded on the right by the solid line parallel to OQ', tangent to the hyperbola at S'; in the classical theory, by the dotted line passing through S. That is, the classical strip is wider than the relativistic strip.

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[8] This might recall Dorato and Felline's (2010) idea of a 'structural explanation'; however, Reichenbach seems to consider the structural analogy non-explanatory.

- *Einstein contraction*: the length of the moving rod OS', as measured in the rest frame ($OS_1 = l^{K}_{K'}$), is shorter than its rest length in the co-moving frame ($OS' = l^{K'}_{K'}$). The length of the rest rod OS, as measured in the moving frame ($OS'_3 = l^{K'}_{K}$), is shorter than its rest length in the rest frame ($OS = l^{K}_{K}$). This *perspectival difference* depends on the chosen frame. Graphically, it is represented by the fact that the projection OS_1 is shorter than OS', and the projection OS'_3 shorter than OS. Indeed, in K', the points O, S', and S'_3 are simultaneous; O, S_1, and S are simultaneous in K.

Lorentz's philosophical ingenuousness lay in considering the classical behavior 'natural,' namely $OS'_2 = OS$. Thus, from the fact that $OS' < OS'_2$ (Lorentz contraction) when measured by the round-trip time of light in K', he concluded that $OS' < OS$ *must* hold in K.[9] Einstein's philosophical insight was to assert that one *may* stipulate $OS' = OS$ to be the 'natural' behavior, provided one concedes that $OS_1 < OS$ in K and $OS'_3 < OS'$ in K' (Einstein contraction). However, Reichenbach insists, it is often forgotten that the Lorentz contraction also holds in Einstein's theory since $OS' < OS'_2$ in K' (Reichenbach 1928, 229/199).

The two contractions are, nevertheless, independent (229f./199f.). Reichenbach shows that one can alos construct hypothetical cases in which there is no Lorentz contraction ($OS'_2 = OS$), but Einstein contraction occurs by a suitable definition of simultaneity: (a) $\epsilon = 1/2$ in K': OS appears contracted with respect to OS'_2, if simultaneously measured in K', whose line of simultaneity is tilted: $OS'_3 < OS'_2$;[10] (b) $\epsilon > 1/2$ in K: OS is contracted, if simultaneously measured in K, $OS_\epsilon < OS$, since the line of simultaneity would be tilted in K:

> The example [...] makes particularly clear that the *Einstein contraction* is a *metrogenic* phenomenon. In the geometrical representation this means that we may choose as the length of the rod differently directed sections through the world-strip of the rod. On the other hand, the geometrical representation of [fig. 2] shows very clearly that through the difference in the width of the strip, the *Lorentz contraction* indicates a difference in the *actual behavior* of the rod. These considerations also explain how it is possible to compare rods l and L, although only one of them is physically realized. OS is the same in both theories; the classical theory claims that the right-hand boundary of the strip parallel to OQ' must be drawn through S, whereas the new theory places the boundary along the tangent to the hyperbola which passes through S'. (232/200; my emphasis)

The term 'contraction' is, in both cases, somewhat misleading: Einstein's 'contraction' does not imply any physical change, whereas Lorentz's 'contraction' is only a counterfactual change (227/196f.).

It is precisely this unfortunate terminological choice that has led to "a mistaken application of the principle of causality" (232/201). According to Reichenbach, the search for a causal explanation within special relativity is not only legitimate, but necessary; only it has "to be posed in a different form" (232/201). Reichenbach once more invokes Weyl's expression *adjustment* to describe the nature of the sought-for explanation (see above, section 2.3). However, in this way, the task (*Aufgabe*) is merely stated, without offering a solution: "The answer can of course be given only by a *detailed [ausgeführte] theory of matter*" (233/201; my emphasis). If this theory of matter were "*exactly formulated*, we would be able to *explain* the metrical behavior

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[9] Giannoni (1971) calls it the Lorentz-Fitzgerald contraction.

[10] By the square of the standard contraction factor, $L_K^{K'} = 1 - \frac{v^2}{c^2} L_{K'}^{K'}$, since the contraction is applied twice in the same direction and at the same speed: $OS'_3 < OS' < OS'_2$.

of physical structures"; because no such theory of matter is presently at hand, "an explanation by Einstein's theory is as little possible as we can speak of an explanation by Lorentz's theory or by the classical theory" (233/201; my emphasis).

Conclusion

As the preceding sections have shown, Reichenbach consistently argued that special relativity is explanatorily inadequate without a *detailed theory of matter* describing the behavior of rods and clocks. On this basis, the paper concludes that, from a *historical* point of view, Reichenbach's interpretation of special relativity should be seen as the first attempt at a dynamical interpretation of special relativity[11] that does not advocate a return to the ether theory. More importantly, one can venture to claim that, from a *systematic* point of view, Reichenbach's reading of special relativity offers a more compelling version of the dynamical approach than the one advocated today. In particular, Reichenbach provides a clearer articulation of the key features of what counts as a 'good' dynamical explanation in this context:

- *explanandum*: what must be explained is not *Einstein contraction* but *Lorentz contraction*. The former is frame-dependent and needs no explanation; the latter reflects the coincidental agreement between rod- and light-based distance measurements, which calls for explanation.
- *explanatio*: the sought-for explanation should not aim to account for the *deviation* from a classical standard—since classical rods and clocks behavior is not inherently natural—but for the *adjustment* of the behavior of material rods and clocks to that of electromagnetic signals.
- *explanans*: Minkowski's geometrical interpretation of special relativity merely provides a *coordination* of the relativistic behavior of rods and clocks with the configuration of lines in a spacetime diagram, due to the shared mathematical structure. An *explanation* of the relativistic behavior of rods and clocks requires a theory of their material structure.

On the one hand, Reichenbach rules out the geometrical approach, questioning the explanatory role of geometry in physics. On the other hand, he presents a version of the dynamical approach that addresses some common objections—particularly the claim that it misunderstands length contraction's perspectival nature. In this sense, Reichenbach's interpretation helps to *strengthen* the dynamical approach's framework. However, for this very reason, it more clearly exposes what I take to be the framework's *fault line*.

In Reichenbach's reading, special relativity claims that the Lorentz transformations, which are derived light-geometrically, also apply to rods and clocks. This coincidence calls for an explanation. Special relativity would need to *find* a *specific* Lorentz-invariant theory of matter accounting for the serendipitous behavior of rods and clocks. Here, in my opinion, lies Reichenbach's 'dynamist' misconception. Special relativity needs only to *require* that *any* possible theory of matter be Lorentz-invariant. Minkowski's formalism offers the advantage of directly verifying whether available theories satisfy this constraint.[12] In this sense, Einstein (1919) famously described special relativity as

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[11] Reichenbach (1928, §40) also pursued a dynamical interpretation of general relativity, but this lies beyond the scope of this paper.

[12] See, *e.g.*, Einstein (1914, 340; 1949, 59).

a ‘principle theory’ rather than a ‘constructive one.’ Of course, Einstein did not deny that a detailed constructive theory of matter must be found; its equations might have solutions corresponding to the material systems used as rods and clocks. But such a theory would be an *instantiation* of special-relativistic requirement, not an *explanation* of the relativistic behavior of rods and clocks.

As Schlick sensed, Einstein’s and Reichenbach’s different reactions to Miller’s unexpected outcome go to ‘the philosophical core of the issue.’ For Reichenbach, if Michelson-type experiments yielded a positive effect, ‘nothing would change’: a Lorentz-invariant theory of radiation could be maintained alongside a non-Lorentz-invariant theory of matter. Within the dynamical approach, the fact that the *particular* theories realized in nature *happen to be* Lorentz invariant is a mere coincidence. By contrast, for Einstein, if Miller’s result were to be confirmed, special relativity ‘would collapse like a house of cards’: the requirement that *any* possible theories of matter and radiation *must be* Lorentz invariant could not be upheld. special relativity amounts to nothing more than the imposition of this constraint. Even if different theories were realized in nature, ether-drift experiments would still yield a negative result, provided those theories are Lorentz invariant. Following a suggestion by Marc Lange (2016), if one wishes to frame special relativity in explanatory terms, one might speak of an *explanation by constraint*.[13]

References

Acuña, Pablo. 2016. “Minkowski Spacetime and Lorentz Invariance: The Cart and the Horse or Two Sides of a Single Coin.” *Studies in History and Philosophy of Modern Physics* 55:1–12.

Adlam, Emily, et al. 2025. *Constructive Axiomatics for Spacetime Physics.* Oxford: Oxford University Press.

Brown, Harvey R. 2005. *Physical Relativity: Space-time Structure from a Dynamical Perspective.* Oxford: Clarendon.

Brown, Harvey R., and James Read. 2022. “The Dynamical Approach to Spacetime Theories.” In *The Routledge Companion to Philosophy of Physics,* edited by Eleanor Knox and Alastair Wilson, 70–85. London, UK: Routledge.

Dorato, Mauro, and Laura Felline. 2010. “Structural Explanations in Minkowski Spacetime: Which Account of Models?” In *Space, Time and Spacetime: Physical and Philosophical Implications of Minkowski’s Unification of Space and Time,* edited by Vesselin Petkov, 175–194. Dordrecht: Springer.

Eddington, Arthur Stanley. 1923. *The Mathematical Theory of Relativity.* Cambridge: University Press.

———. 1925. *Relativitätstheorie in mathematischer Behandlung.* Translated by Alexander Ostrowski and Harry Schmidt. Berlin: Springer. German translation of Eddington 1923.

Einstein, Albert. 1905. “Zur Elektrodynamik bewegter Körper.” *Annalen der Physik,* 4th ser., 17:891–921. Repr. in CPAE, Vol. 2, Doc. 23.

———. 1914. “Zum Relativitäts-Problem.” *Scientia* 15:337–348. Repr. in CPAE, Vol. 4, Doc. 31.

———. “What is the theory of relativity?” *The Times.* November. 28, 1919. Repr. in CPAE, Vol. 7, Doc. 25.

———. “Geometrie und Erfahrung.” Lecture before the Prussian Academy of Sciences, January 27, 1921. *Sitzungsberichte der Preußischen Akademie der Wissenschaften.* Halbband 1, 123–130. Repr. in CPAE, Vol. 7, Doc. 52.

———. “Meine Theorie und Millers Versuche.” *Vossische Zeitung.* 1926. Repr. in CPAE, Vol. 15, Doc. 161.

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[13] Whether imposing a ‘constraint’ is in itself an ‘explanation’ remains controversial; indeed, Einstein seems to emphasize the heuristic role of such constraints (in restricting the number of possible candidates of admissible laws of nature) rather than their explanatory power; see Giovanelli (2020) for further discussion.

———. 1949. "Autobiographical Notes." In *Albert Einstein, Philosopher-Scientist: Philosopher-Scientist,* edited by Paul Arthur Schilpp, 2–94. Evanston, M.: The Library of Living Philosophers.

Giannoni, Carlo. 1971. *Einstein and the Lorentz-Poincaré Theory of Relativity.* In *PSA 1970,* edited by Roger C. Buck and Robert S. Cohen, 575–589. Dordrecht: Reidel.

Giovanelli, Marco. 2014. "'But One Must Not Legalize the Mentioned Sin: Phenomenological vs. Dynamical Treatments of Rods and Clocks in Einstein's Thought." *Studies in History and Philosophy of Science. Part B: Studies in History and Philosophy of Modern Physics* 48:20–44.

———. 2020. "'Like Thermodynamics before Boltzmann': On Einstein's Distinction between Constructive and Principle Theories." *Studies in History and Philosophy of Science. Part B: Studies in History and Philosophy of Modern Physics* 71:118–157.

———. 2023. "Reality and Appearance: Einstein and the Early Debate on Reality of Length Contraction." *European Journal for Philosophy of Science* 13.

Grünbaum, Adolf. 1955. "Logical and Philosophical Foundations of the Special Theory of Relativity." *American Journal of Physics* 23:450–464.

———. 1963. *Philosophical Problems of Space and Time.* Dordrecht, Boston/London: Reidel.

Janssen, Michel. 2002. "Reconsidering a Scientific Revolution: The Case of Einstein Versus Lorentz." *Physics in Perspective* 4:421–446.

———. 2009. "Drawing the Line between Kinematics and Dynamics in Special Relativity." *Studies in History and Philosophy of Science. Part B: Studies in History and Philosophy of Modern Physics* 40:26–52.

Lalli, Roberto. 2012. "The Reception of Miller's Ether-drift Experiments in the USA." *Annals of Science* 69:153–214.

Lange, Marc. 2016. *Because without Cause: Non-causal Explanations in Science and Mathematics.* New York: Oxford University Press.

Lorentz, Hendrik Antoon. 1895. *Versuch einer Theorie der electrischen und optischen Erscheinungen in bewegten Körpern.* Leiden: Brill.

Michelson, Albert A. 1881. "The Relative Motion of the Earth and the Luminiferous Ether." *American Journal of Science* 22:120–129.

Michelson, Albert A., and Edward W. Morley. 1887. "On the Relative Motion of the Earth and the Luminiferous Ether." *American Journal of Science* 34:333–345.

Miller, Dayton C. 1925a. "Ether-Drift Experiments at Mount Wilson." *Proceedings of the National Academy of Sciences of the United States of America* 11:306–314.

———. "Report on ether drift experiments." *Annual report of the national academy of sciences,* 48–49.

Morley, Edward W., and Dayton C. Miller. 1905a. "On the Theory of Experiments to detect Aberrations of the Second Degree." *Philosophical Magazine* 9-6th Series:669–680.

———. 1905b. "Report of an Experiment to Detect the Fitzgerald-Lorentz Effect." *Proceedings of the American Academy of Arts and Sciences* 61:321–328.

Padovani, Flavia. 2009. "Relativizing the Relativized a Priori: Reichenbach's Axioms of Coordination Divided." *Synthese* 181:41–62.

Reichenbach, Hans. 1920. *Relativitätstheorie und Erkenntnis apriori.* Berlin: Springer. Tr. as Reichenbach 1965.

———. 1921. "Bericht über eine Axiomatik der Einsteinschen Raum-Zeit-Lehre." *Physikalische Zeitschrift* 22:683–687. Tr. as Reichenbach 2006, Doc. 4.

———. 1922a. "Der gegenwärtige Stand der Relativitätsdiskussion: Eine kritische Untersuchung." *Logos* 22:316–378. Tr. as Reichenbach 1978, Vol. 2, Doc. 44.

———. 1922b. "La signification philosophique de la théorie de la relativité." *Revue philosophique de la France et de l'étranger* 93:5–61. Tr. as Reichenbach 2006, Doc. 10.

———. 1922c. "Relativitätstheorie und absolute Transportzeit." *Zeitschrift für Physik* 9:111–117. Tr. as Reichenbach 2006, Doc. 7.

———. 1924. *Axiomatik der relativistischen Raum-Zeit-Lehre.* Vieweg: Braunschweig. Tr. as Reichenbach 1969.

———. 1925. "Über die physikalischen Konsequenzen der relativistischen Axiomatik." *Zeitschrift für Physik* 34:32–48. Tr. as Reichenbach 2006, Doc. 12.

———. 1926. "Ist die Relativitätstheorie widerlegt?" *Die Umschau* 30:325–328. Tr. as Reichenbach 2006, Doc. 14.

———. 1928. *Philosophie der Raum-Zeit-Lehre.* Berlin/Leipzig: Walter de Gruyter. Tr. as Reichenbach 1958.

———. 1958. *The Philosophy of Space and Time.* Edited by Maria Reichenbach. Translated by Maria Reichenbach and John Freund. New York: Dover Publ.

———. 1965. *The Theory of Relativity and a priori Knowledge.* Edited and translated by Maria Reichenbach. Berkeley: University of California Press.

Reichenbach, Hans. 1969. *Axiomatization of the Theory of Relativity.* Edited and translated by Maria Reichenbach. With a foreword by Wesley C. Salmon. Berkeley: University of California Press.

———. 1978. *Selected Writings: 1909–1953.* Edited and translated by Maria Reichenbach. 2 vols. Dordrecht: Reidel.

———. 2006. *Defending Einstein: Hans Reichenbach's Writings on Space, Time, and Motion.* Edited by Steven Gimbel and Anke Walz. Cambridge et al.: Cambridge University Press.

Ryckman, Thomas. 2005. *The Reign of Relativity: Philosophy in Physics 1915-1925.* Oxford/New York: Oxford University Press.

Rynasiewicz, Robert. 2005. "Weyl vs. Reichenbach on *Lichtgeometrie*." In *The Universe of General Relativity,* edited by A. J. Kox and Jean Eisenstaedt, 137–156. Boston: Birkhäuser.

Schlick, Moritz. 1915. "Die philosophische Bedeutung des Relativitätsprinzips." *Zeitschrift für Philosophie und philosophische Kritik* 159:129–175.

———. 1921. "Kritizistische oder empiristische Deutung der neuen Physik? Bemerkungen zu Ernst Cassirers Buch: *Zur Einsteinschen Relativitätstheorie*." *Kant-Studien* 26:96–111.

———. 1923. *Die Relativitäatstheorie in der Philosophie.* In *Verhandlungen der Gesellschaft Deutscher Naturforscher und Ärzte,* edited by Alexander Wittig, 58–69. Leipzig: Voge.

Science Service. 1925. "Relativity Theory Falls If Experiments True, Says Einstein." *The Science News-Letter* 7:1.

Tomaschek, Rudolf. 1924. "Über das Verhalten des Lichtes außerirdischer Lichtquellen." *Annalen der Physik,* 4th ser., 378:105–126.

Weyl, Hermann. 1920a. "Die Diskussion über die Relativitätstheorie." *Die Umschau* 24:609–611.

———. 1920b. "Elektrizität und Gravitation." *Physikalische Zeitschrift* 21:649–650.

———. 1924. "Review of Reichenbach 1924." *Deutsche Literaturzeitung* 45:2122–2128.

Zilsel, Edgar. 1925. "Review of Reichenbach 1924." *Die Naturwissenschaften* 13:407–409.