

# Length Matters (I)

## The Einstein–Swann Correspondence and the Constructive Approach to the Special Theory of Relativity

Amit Hagar\*

October 2, 2007

### Abstract

In this paper and its sequel I discuss a rarely mentioned correspondence between Einstein and W.F.G. Swann on the constructive approach to the special theory of relativity, in which Einstein points out that the attempts to construct a dynamical explanation of relativistic kinematical effects require postulating a minimal length scale in the level of the dynamics. I use this correspondence to shed light on several issues under dispute in current philosophy of spacetime that were highlighted recently in Harvey Brown's monograph *Physical Relativity*, namely, Einstein's view on the distinction between principle and constructive theories, and the philosophical consequences of pursuing the constructive approach to the special theory of relativity.

---

\*HPSC Department, IU (Bloomington), hagara@indiana.edu

# Contents

<b>1</b>	<b>Introduction</b>	<b>3</b>
<b>2</b>	<b>The principle–constructive distinction</b>	<b>4</b>
2.1	Einstein . . . . .	4
2.2	The constructive approach to STR . . . . .	7
2.2.1	Bell’s thread . . . . .	8
<b>3</b>	<b>The Swann–Einstein correspondence</b>	<b>11</b>
3.1	Background . . . . .	11
3.1.1	Swann’s constructive approach to STR . . . . .	12
3.1.2	Swann’s letter to <i>Nature</i> . . . . .	14
3.2	Swann’s letter to Einstein . . . . .	15
3.3	Einstein’s reply . . . . .	16
3.3.1	The German Version . . . . .	16
3.3.2	The English translation . . . . .	17
3.4	Swann’s reaction . . . . .	18
<b>4</b>	<b>Reading Einstein</b>	<b>19</b>
4.1	Lost in translation . . . . .	19
4.1.1	Stachel’s de-contextualization . . . . .	19
4.1.2	Brown’s interpretation . . . . .	20
4.2	A more accurate reconstruction of Einstein’s response . . . . .	21
4.2.1	Reading Einstein step by step . . . . .	21
4.2.2	Taking stock . . . . .	23
<b>5</b>	<b>Einstein and the constructive approach to STR</b>	<b>23</b>
5.1	The physics of despair . . . . .	23
5.2	Discontinuity . . . . .	25
<b>6</b>	<b>Length matters</b>	<b>27</b>
6.1	Minimal length in quantum gravity . . . . .	28
<b>7</b>	<b>Concluding remarks</b>	<b>29</b>
<b>8</b>	<b>References</b>	<b>31</b>

# 1 Introduction

Considerable attention has been drawn lately to the distinction, attributed to Einstein, between principle and constructive theories, and to the methodological importance it may have to the scientific practice. Viewed as part of the context of discovery, however, this distinction is rarely acknowledged as having any philosophical significance, with the exception of Howard (2004) who urges us to regard it as one of Einstein's most valuable contributions to 20th-Century philosophy of science. In this paper and its sequel I would like to demonstrate this significance, suggesting that while the principle-constructive distinction furnishes the physicist with an important methodological tool, it also carries a philosophical weight, to the extent that it serves as a demarcation mark in debates that may seem purely epistemological or metaphysical.

Admittedly, while Einstein was not the first to introduce the distinction between principle and constructive theories to theoretical physics, he definitely popularized it when reflecting along his career on the conception of STR. Expressing the novelty of the theory, Einstein ultimately chose the principle view over the constructive view, but his ambivalence with respect to this choice (and his misgivings about what he regarded as its unfortunate implications on the foundations of quantum mechanics) are well known (Schilpp 1949, Janssen 2000, Brown 2005ab). What is also well documented is the attempt, made by his contemporaries Lorentz and FitzGerald, to think about the kinematical phenomena of electromagnetism in constructive dynamical terms (see, e.g., Janssen 1995). Other physicists who expressed, along with Einstein himself — as some believe, dissenting constructive views of STR are less known in this context. They include Weyl, Pauli, and Eddington in the 1920s, W.F.G. Swann in the 1930s and the 1940s, and L. Janossy, and J.S. Bell in the 1970s.

In a recent monograph entitled *Physical Relativity*, Harvey Brown (2005a) adds himself to this distinguished list of unconventional views on STR, arguing that the universal constraint on the dynamical laws that govern the nature of non-gravitational interactions, namely, their Lorentz-covariance, is the true lesson of STR. My modest goal in this paper and its sequel is to examine two presumably contentious issues within Brown's controversial view. The first issue is purely historical, and concerns Einstein's attitude towards the constructive approach to STR. Reading Brown (2005a, pp. 113–114, 2005b) one gets the impression that Einstein's ambivalence with respect to his choice in the principle view to STR warrants annexing him to the constructive camp. Here I shall suggest an alternative interpretation, that also sheds new light on the way Einstein saw the dichotomy

between principle and constructive theories. The second issue is philosophical in character and regards the ontological and epistemological commitments behind the constructive approach. It arises from a famous claim, made by J. S. Bell (1976/1987, p. 77), and repeated by Brown at the outset of his book (2005a, p. 2), that the constructive approach enforces no commitment to a notion of a preferred frame, i.e., that one can, in Bell's words, adapt the Lorentzian *pedagogy* without accepting the Lorentzian *philosophy*. As we shall see, the current state of affairs in theoretical physics may put some constraints on this neutrality.

In order to achieve these goals I shall take my cue from a rarely cited correspondence between Einstein and the physicist W.F.G. Swann, mentioned only briefly in Stachel (2002) and in Brown (2005a). In this correspondence Swann presents Einstein with his constructive approach to STR, wherein rods and clocks are not introduced as primitive building blocks, or as “independent objects”, but are taken instead to be material bodies obeying the Lorentz-covariant laws of the quantum theory of matter. Einstein, in response, argues cryptically that any such constructive formulation of STR must, like the quantum theory, contain a fundamental measure of length. My main concern will be to examine how the postulation of a fundamental measure of length (which, according to Einstein, is an inevitable consequence of the constructive approach) bears on the two issues I have set forth to investigate here.

The paper is organized as follows. Section (2) offers an introduction to the distinction between principle and constructive theories. In section (3) I discuss the Einstein–Swann correspondence on the constructive approach to STR, and in sections (4) and (5) I set the record straight with respect to the putative historical consequences of this correspondence on the constructive programme. Before concluding, in section (6) I mention briefly some aspects that arise in current research on quantum gravity that bear on the neutrality of the constructive approach to STR with respect to the question of a preferred frame. These aspects are discussed in more detail in a sequel to this paper (Hagar 2007).

## **2 The principle–constructive distinction**

### **2.1 Einstein**

In his famous letter to the London *Times* from November 28, 1919, Einstein mentions a distinction between two types of scientific theories, namely “constructive”

and “principle” theories:<sup>1</sup>

We can distinguish various kinds of theories in physics. Most of them are constructive. They attempt to build up a picture of the more complex phenomena out of the materials of the relatively simple formal scheme from which they start out. Thus the kinetic theory of gases seeks to reduce mechanical, thermal and diffusional processes to the movement of molecules, i.e., to build them up of the hypothesis of molecular motion. When we say that we have succeeded in understanding a group of natural processes, we invariably mean that a constructive theory has been found which covers the processes in question.

Along with this most important class of theories there exists a second which I will call ‘principle theories’. These employ the analytic, not the synthetic method,. The elements which form their basis and starting point are not hypothetically construed but empirically discovered ones, general characteristics of natural processes, principles that give rise to mathematically formulated criteria which the separate processes or the theoretical representations of them have to satisfy. Thus the science of thermodynamics seeks by analytical means to deduce necessary conditions which separate events have to satisfy, from the universally experienced fact that perpetual motion is impossible.

The advantages of the constructive theory are completeness, adaptability and clearness. Those of the principle theory are logical perfection and security of the foundations. The theory of relativity belongs to the latter class. . .

What does this distinction amount to? According to Einstein, in a principle theory such as thermodynamics (TD) one starts from empirically observed general properties of phenomena, e.g., the non-existence of perpetual motion machines, in order to infer general applicable results without making any assumptions on hypothetical constituents of the system at hand. Another example of a principle theory in which one employs “the analytic, not the synthetic method” is STR. Its building blocks — that velocity does not matter and that there is no overtaking of light by light in empty space — are ‘not hypothetically constructed but empirically discovered’. Statistical mechanics (SM) and its predecessor the kinetic theory of gases, on the other hand, are constructive theories. They begin, says Einstein, with certain hypothetical elements and use these as building blocks in an attempt to construct models of more complex processes. Although ultimate understanding requires a constructive theory, admits Einstein in 1919, often progress in

---

<sup>1</sup>I quote the second, third, and fourth paragraphs from (Einstein 1919/1982, pp. 227–232).

theorizing is impeded by premature attempts at developing constructive theories in the absence of sufficient constraints by means of which to narrow the range of possible constructions. It is the function of principle theories to provide such constraint, and progress is often best achieved by focusing first on the establishment of such principles.

It is hard to overestimate the importance Einstein's experts attribute to the three short paragraphs quoted above. Emphasizing Einstein's famous appreciation of the wide applicability of TD, Klein (1967) sees the distinction between principle and constructive theories as yet another indication of the inspirational power TD had on Einstein's thought, especially in conceiving STR. Janssen (2000) believes that the distinction epitomizes Einstein's ambivalence towards physics-theorizing in general. "Einstein resorted to the 'principle' type of theory", says Janssen, "when he did not have a strong vision of what a satisfactory [constructive – A.H.] model might look like". "Since he saw this type of theorizing essentially as a physics of desperation", concludes Janssen, "his methodological pronouncements later in life promote the 'constructive' approach, which had never gotten him anywhere, rather than the 'principle' approach that had led to all his great successes". Howard (2004) sees Einstein's distinction as his most original contribution to 20th-Century philosophy of science. "While the distinction first made its way into print in 1919", says Howard, "there is considerable evidence that it played an explicit role in Einstein's thinking much earlier".<sup>2</sup>

Howard argues further that in Einstein's hands the distinction between principle and constructive theories became a methodological tool of impressive scope and fertility. This point, while not appreciated as it should be in the philosophy of science community, is unproblematic. Einstein's attitude towards the constructive approach to theoretical physics in general and to STR in particular, on the contrary, is still under dispute. Indeed, the peculiar ambivalence Einstein demonstrates in this respect leads Brown (2005ab) to present him as a putative supporter of the constructive approach to STR.

---

<sup>2</sup>Here Howard refers to Einstein's remark on Boltzmann's entropy principle,  $S = k \log W$ , which served as the constraint that suggested his own light quanta hypothesis: "Boltzmann's magnificent idea is of significance for theoretical physics . . . because it provides a heuristic principle whose range extends beyond the domain of validity of molecular mechanics". (Einstein 1915, p. 262). See also Einstein's letters to Ehrenfest and Sommerfeld from 1907 and 1908, respectively, mentioned in (Brown 2005b, p. S85).

## 2.2 The constructive approach to STR

Several authors (Bell 1992, Brown 2003) have suggested that the dawn of the constructive approach to STR can be traced back to a letter, written in 1889 by G.F. FitzGerald, to the remarkable English auto-deduct, Oliver Heaveside, concerning a result the latter had just obtained in the field of Maxwellian electrodynamics. Some months later FitzGerald exploited the idea he had expressed in that letter, namely, that the distortions suffered by an electric field that surrounds a charged particle traveling through the ether may be applied to a theory of inter-molecular forces, to explain the baffling null result of the Michelson–Morley experiment. In this note appears for the first time a distinct precursor of the FitzGerald–Lorentz contraction — a cornerstone in the kinematic component of STR.

As Brown (2005a, p. 2) puts it, following Einstein’s brilliant 1905 work on the electrodynamics of moving bodies, and its geometrization by Minkowski (which proved to be so important to the development of the general theory of relativity), “it became standard to view the FitzGerald–Lorentz [contraction – AH] hypothesis as the right idea based on the wrong reasoning”. Brown strongly doubts that this standard view is correct, and in his monograph, *Physical Relativity* (Brown 2005a) he joins other physicists who expressed, along with Einstein himself — or so Brown claims, dissenting constructive views of STR.

Brown’s aim is to advocate what he calls “the big principle” of the constructive view: that the universal constraint on the dynamical laws that govern the nature of non-gravitational interactions, namely, their Lorentz–covariance, is the true lesson of STR. On this view, the explanatory arrow in STR between the structure of spacetime and the behavior of rods and clocks is reversed: if one could achieve a dynamical underpinning of this behavior with an ultimate Lorentz–covariant theory of matter, then the “mystery of mysteries” (i.e., how material bodies such as rods and clocks supposed to know which spacetime they are immersed in and hence to contract and dilate accordingly)<sup>3</sup> will be dispelled, and Minkowski spacetime will regain its appropriate status as a “glorious non-entity” (Brown & Pooley 2004).

---

<sup>3</sup>A rod immersed in a Minkowski spacetime is affected when set in motion while a rod immersed in Galilean spacetime is not.

### 2.2.1 Bell's thread

It is worth noting that Brown's big principle is neither a "no-go" phenomenological claim nor is it fully constructive,<sup>4</sup> hence it will not suffice to pin-point the difference between the constructive and the principle approaches to STR. This difference is, on final account, an epistemological one, and as such can be cashed out in terms of explanatory strategies. Taking our cue from Brown, who emphasizes that one of his motivations for adapting the constructive approach is the reversal of the explanatory arrow in STR from geometry to dynamics, it is instructive to confront the principle and the constructive views in the context of Bell's thought experiment that appears in the opening paragraphs of his famous *Lorentzian Pedagogy* paper (Bell 1976, pp. 67–68).<sup>5</sup>

Bell considers the following situation (see figure 1): three small spaceships, A, B, and C, drift freely in a region of space remote from other matter, without rotation and without relative motion, with B and C equidistant from A. On reception of a signal from A the motors of B and C are ignited and they accelerate gently. Let B and C be identical, and have identical acceleration programmes. Then (as reckoned by the observer A) they will have at every moment the same velocity and so remain displaced one from the other by a fixed distance.

Now suppose that one end of a taut thread is attached to the back of B and the other end to the front of C, assuming that the thread doesn't affect the motion of the spaceships. According to STR, the thread must Lorentz-contract with respect to A because it has relative velocity with respect to A. However, since the spaceships maintain a constant distance apart with respect to A, the thread (which we have assumed to be taut from the start) cannot contract; therefore a stress must form until for high enough velocities the thread finally reaches its elastic limit and breaks.

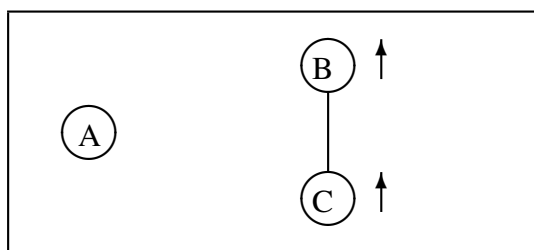


Figure 1

<sup>4</sup>The best way to view the big principle is as a restrictive *structural* principle. See Brown (2005a, p. 147).

<sup>5</sup>Bell mentions that credit to this thought experiment is due to Dewan and Beran (1959).



Bell (1976, p. 68) mentions that the knee-jerk reaction of one of his colleagues as well as the consensus in CERN's theory division was that the thread will *not* break. Further reflection, however, reveals that despite the views that deprive Lorentz-contraction of any reality STR predicts that (1) the thread *will* break, and (2) *all* the observers in this set-up, namely, A, B, and C, will agree on (1).<sup>6</sup> Setting aside the interesting sociological issues that the reactions to this thought experiment reveal, let us examine the two possible *explanations* one can give for facts (1) and (2).

The standard explanation to which the principle view of STR subscribes hinges the relativity of simultaneity (see, e.g., Dewan 1963, pp. 383–385) since B, for example, sees C drifting further and further behind (and, conversely, C sees B drifting further and further ahead) so that the given piece of thread can no longer span the distance between B and C.<sup>7</sup> Put differently, according to the principle view length-contraction is a result of the observation that the absolute, invariant distance measure in spacetime between two spatiotemporal events is the four dimensional interval, and that our spatial and temporal measurements of these events are nothing but covariant projections of this invariant measure on particular reference frames.<sup>8</sup>

How would the constructive approach explain the phenomenon of the breaking of the thread? One can look at things from A's point of view and regard the spaceships and the thread as material objects, obeying dynamical laws. Once set in motion relative to A, the material of the spaceships, and of the thread, will Lorentz-contract: a sufficiently strong thread would pull the spaceships together and impose FitzGerald contraction on the combined system. But if the spaceships are too massive to be appreciably accelerated by the fragile thread, the latter has to break when the velocities become sufficiently great.

The epistemological difference in the explanations adapted by the principle and constructive views is evident. The first explanation is geometrical, structural,

---

<sup>6</sup>Exactly *when* the thread breaks will depend on its mass, the mass of the spaceships, and their acceleration plan. See Cornwell (2005).

<sup>7</sup>One should imagine two clocks that are situated on the two points where the thread is hooked to B and C. If these clocks are synchronized when B and C are at rest relative to A, then when B and C start moving with velocity  $v$  relative to A in the direction that is depicted in figure 1, the clock at C will be *ahead* of the clock in B by  $lv/C^2$  where  $l$  is the distance between B and C. The relativity of simultaneity plays a similar role in explaining the "pole in the barn" paradox and the "twin paradox".

<sup>8</sup>Note that in order to further derive the Lorentz metric one must also assume the isotropy of spacetime, an assumption which is hidden in the synchronization procedure using light signals that the relativity of simultaneity is based upon. See Brown (2005a, pp. 77–80).

and non-causal; the second is dynamical and causal. Brown, apparently, believes that the first is mysterious:

What is required if the so-called spacetime interpretation is to win over this dynamical approach is that it offers a genuine explanation of universal Lorentz covariance. This is what is being disputed. Talk of Lorentz covariance ‘reflecting the structure of spacetime posited by the theory’ and of ‘tracing the invariance to a common origin’ needs to be fleshed out if we are to be given a genuine explanation here, something akin to the explanation of inertia in general relativity. Otherwise we simply have yet another analogue of Molière’s dormative virtue. . . . (Brown 2005a, p. 143)

From our perspective, of course, the direction of the explanation goes the other way around. It is the Lorentz covariance of the laws that underwrites the fact that the geometry of spacetime is Minkowskian. (Brown & Pooley 2004, p. 84)

Brown’s complaint, in effect, is that Minkowski spacetime fails to supply a *constructive* (i.e., causal-dynamical) explanation to relativistic effects such as breaking of the thread.

Now, this claim is true but it is also vacuously so: after all, the geometrical structure cited by the principle view is nothing more than a *description* of the fact that the physics of non-gravitational interactions is Lorentz-covariant (Brown’s Big Principle). Furthermore, rarely within this approach does one find the claim that Minkowski spacetime *causes* the thread to break.<sup>9</sup> Recall that according to Einstein on this view one is not engaged in postulating some hidden mechanism behind observed phenomena. Rather, the explanation of the breaking of the thread in Bell’s thought experiment that this view subscribes to is very similar to the geometrical explanation that appears, e.g., in (Putnam 1975, pp. 295–296), where, if one wants to explain why a round peg cannot fit through a square hole, one points to geometric features of the peg and the board rather than solving the equations for the motion of all the atoms in the peg and the board.

Brown seems to believe that the constructive view is explanatorily superior to the principle view, but it is only by restricting explanations to *causal-dynamical* explanations that one can justify this claim. Unfortunately, it is not clear that such a restriction could be justified independently of one’s support in the constructive

---

<sup>9</sup>In another place Brown (2005a, p. 24) cites Nerlich (1976, p. 264): “It is because space-time has a certain shape that worldlines lie as they do”. Maybe Nerlich does intend “because” here to ascribe causal powers to spacetime. But someone with more caution might simply remain silent about causation.

view, and, moreover, it is not clear that, if one restricts oneself to the relevant level of description, the constructive explanation is really an explanation. One is reminded of Putnam’s famous dictum: the explanation of an explanation is not an explanation since even if one could actually write down those solutions to the equations for the detailed motion of all the atoms in the peg and the board, such a “micro–explanation” would include a lot of details that are irrelevant to the question,<sup>10</sup> and it would fail to provide any meaningful kind of understanding. Rather, it is more appropriate to view constructive explanations as consistency proofs, mere demonstrations that casual–dynamical models are *possible* for the phenomenon at hand.<sup>11</sup>

Be that as it may, instead of delving further into a debate on the alleged superiority of one explanatory view over the other,<sup>12</sup> I shall set this matter aside and turn to examining the two issues I have set forth to investigate in this paper.

### 3 The Swann–Einstein correspondence

In this section I shall discuss a historical anecdote, mentioned briefly in Brown (2005a, pp. 119–120), that regards a short correspondence Einstein had in early 1942 with the physicist W.F.G. Swann concerning the constructive approach to STR. I will use this correspondence to draw some interesting conclusions on Brown’s project.

#### 3.1 Background

W. F. G. Swann (1884–1962) was born in England, he was educated at Brighton Technical College, the Royal College of Science, University College, Kings College and the City Guilds of London Institute. Swann came to the US in 1913 as

---

<sup>10</sup>Obviously, these details should include no geometrical notions — see also section (5.2).

<sup>11</sup>This view of constructive explanations as consistency proofs was prevalent among 19th Century mathematical physicists such as Maxwell and Poincaré, and is even advocated by W.F.G. Swann (1940, p. 276), another proponent of the constructive approach to whom the following sections are devoted. Swann, in his inimitable style, compares the relation between constructive explanations and their respective phenomenological principles to the logical justification that “our old grandmothers remedies to our ailments as children” receive in terms of the fundamentals of bacteriology, physiology and chemistry.

<sup>12</sup>Such a debate threatens to deteriorate since, paraphrasing the debate between Brown & Pooley (2004) and Balashov & Janssen (2003), one’s man horse is the another’s cart. I attend to this issue elsewhere (Hagar, in preparation).

head of the Physical Division of the Department of Terrestrial Magnetism at the Carnegie Institute in Washington. Later he was Professor of Physics at the University of Minnesota, the University of Chicago and Yale, where he became Director of the Sloane Laboratory. He was appointed the Director of the Bartol Research Foundation in 1927.<sup>13</sup>

Swann advocates his constructive view on STR as early as 1912 in two papers with lengthy titles he publishes in the *Philosophical Magazine* (Swann 1912ab). He returns to this view years later in a series of papers published during the 1930s and 1940s in *Reviews of Modern Physics* (and in which he cites no one else but himself). It is this view which he also repeats in his correspondence with Einstein in 1942 and in his letter to Eddington that preceded it.

### 3.1.1 Swann's constructive approach to STR

Here is Swann in a representative quote from (Swann 1930, pp. 261–263):

If we strip from the theory [STR — AH] all the concepts incidental to its historical development; the fundamental outstanding dogma which remains is that the laws of nature — the differential equations — shall remain invariant under the transformation (1)–(4) [the Lorentz transformations — AH]. *Once we have written down some proposed laws*, the test of this conclusion is a matter of pen and paper, and not of experiment. . . . It is true that the principle of the restricted relativity owed its formulation to a belief that the coordinates associated with the various systems corresponded to the actual measures; but, once formulated, the working content of the theory, involving as it does the mathematical invariance of the laws, is independent of this hypothesis.

---

<sup>13</sup>A man of many talents, W.F.G. Swann was an accomplished cellist, founder of the Swarthmore Symphony Orchestra, a former assistant conductor of the Main Line Orchestra and former director of the Philadelphia Academy of Music. By the time of his appointment in Bartol, Swann had already distinguished himself as an excellent teacher, an outstanding researcher, and an emerging leader of the scientific community. Although Swann is perhaps best known for his experimental and theoretical efforts in the area of cosmic ray physics, his research interests touched on many other disciplines such as condensed matter physics, relativity, and charged particle acceleration. In his capacity as a professor he is perhaps best known as the advisor of E. O. Lawrence who subsequently was awarded the Nobel Prize for developing the cyclotron. Lawrence followed Swann from Minnesota, to Chicago, and then to Yale where he received his Ph.D. Altogether Swann had over 250 publications including a popular science book *The Architecture of the Universe*. In 1967 the International Astronomical Union honored Swann when it gave his name to a crater on the lunar surface at 52 north latitude and 112 east longitude.

Up to 1941 Swann’s idea that the fundamental tenet of STR is the Lorentz covariance of the laws of physics was exemplified solely with electrodynamics. In 1941 he augmented his view with the claim that “relativity itself would provide no explanation of the [Lorentz–FitzGerald — AH] contraction were the story not capable of amplification by additional arguments based fundamentally upon the existence in nature of some such theory as the quantum theory” (Swann 1941b, p. 197). In a footnote to this statement Swann mentions that already in his 1912 papers he had made the case for this claim when showing that the mere invariance of the electromagnetic equations, with the electrons regarded as singularities in them, was insufficient to explain the Lorentz contraction (Swann 1912b, pp. 93–94). A relativistically invariant force equation was necessary in addition to the invariance of the field equation, but as time progressed it became more and more evident that “no obvious force equation following the lines of classical electrodynamics could be expected to provide the story of atomic and intermolecular forces in such a manner as to determine, ultimately, the form and equilibrium of a material body” (Swann 1941b, p. 197, fn. 4).

Swann’s intuition for the quantum nature of the cohesive forces in matter is mentioned already in (Swann 1941a), and the motivation for it already appears in 1912, but this intuition is spelled out in full for the first time only in (Swann 1941b, p. 201), where he discusses the physical changes that a material rod will suffer when set in motion (I extensively quote Swann here since his correspondence with Einstein relies heavily on this passage):

When I start the rod in motion, all sorts of acoustical vibrations are set up. Of course, these will die down in time, but while I might be, perhaps unjustifiably, content if they should die down so as to leave the rod at its original length as measured in  $S$  [when the rod is at rest — AH], I am at loss to know how the rod decides that it must settle down to a new length determined by the FitzGerald–Lorentz contraction. . . . It seems that quantum theory, if relativistically invariant in form, possesses the power to give the necessary answer. Consider the rod before the motion was imparted to it. What determines its form and stability? According to the quantum theory, these are determined by its being in a “ground state”. Now the discussion given above . . . tells us that if the equations are invariant and we have in  $S$ , one solution for, let us say, the  $\psi$  function, satisfying the usual conditions of continuity, etc., then associated with this solution we have an infinite number of other solutions obtainable from it by a Lorentz transformation, and *these are all possible states in the system  $S$* . . . . The ground state for our rod moving in a velocity  $v$  is the state obtainable by a Lorentzian transformation from the ground state of the rod before the motion was imparted.

When discussing this passage, Brown (2005a, p. 121), notes that in it Swann has forcefully demonstrated the power of the constructive approach to STR. First, the relativity principle is the consequence of the Lorentz covariance of the quantum dynamics, rather than the other way round. Second, the universality of the behavior of rods and clocks emerges as a consequence of the dynamical argument, as long as matter of any constitution is assumed in principle to obey quantum theory.<sup>14</sup>

Detecting an opportunity to propagate his view to a larger readership, Swann repeats the above words almost verbatim in a letter he sent to *Nature* on September 23, 1941, which was also the pretext for his correspondence with Einstein on the subject.

### 3.1.2 Swann's letter to *Nature*

In the second half of 1941 *Nature* hosted an exchange between the mathematical physicist J.H. Jeans and Sir Arthur Eddington. The former had just re-read Eddington's (1939) *The Philosophy of Physical Science* and was struck by Eddington's views on the *a priori* character of the fundamental laws of nature. Jeans reports that he had read Eddington "with great admiration, but also with grave doubts as to whether his philosophical position is not wholly unsound" (Jeans 1941, p. 140). The focus of the heated exchange that ensued between the two distinguished physicists on the pages of *Nature* (and that attracted the attention of others, such as Herbert Dingle) was the status of the light postulate of STR and the null result of the Michelson–Morley experiment. It is here where Swann enters the stage, and in a letter to *Nature*, written in September but published only in December that year (Swann 1941c, p. 692), he spells out his own view on the role of the null result of the Michelson–Morley experiment in the foundations of STR.

Swann's view on this role is rather odd-sounding: he claims that there would be meaning to STR even if the Lorentz–FitzGerald contraction were not to hold, and the result of the Michelson–Morley experiment were non-null. What Swann meant here is that it is a purely mathematical fact that Maxwell's equations are Lorentz covariant. This fact, however, does not imply in itself that the transformed variables appearing in the Lorentz transformations refer to physical quantities actually measured by an inertial observer moving at the appropriate velocity  $v$  rel-

---

<sup>14</sup>Several years later in a pedagogical paper published in the *American Journal of Physics*, Swann (1960a, pp. 59–61) emphasizes this point when he explicitly constructs an "electron-dial" clock in his discussion on the twins paradox.

ative to the original frame. After all, STR, on Swann’s view, while securing the Lorentz covariance of the equations, does not tell us how rods and clocks behave in motion.<sup>15</sup>

Brown (2005a, p. 120) admits that here Swann may have overstated his view. Indeed, these remarks by Swann are baffling precisely because on his view, the Lorentz contraction is a result of the Lorentz covariance of the quantum theory of matter. But if the covariance of *all* the dynamical laws of nature is what follows from STR, as Swann claims, then the Lorentz contraction *must* hold if STR is to hold any physical meaning.

Replying to Swann, Eddington traces the solution to the Swann’s version of Brown’s “mystery of mysteries” (i.e., “how a rod decides its extension when it is given a different motion” (Eddington 1941, p. 692)) to the law of gravitation. The connection to quantum theory, according to Eddington, is that it supplies us with a common standard for a measure of length, because “it is only in quantum theory that a method has been developed of describing material structure by pure numbers . . . Thus appeal must be made to quantum theory for the definition of the interval  $ds$ , which is the starting-point of relativity theory” (Eddington 1941, p. 693).

### 3.2 Swann’s letter to Einstein

Swann, it appears, was not impressed with Eddington’s reply, and a month after his letter to *Nature* was published, he wrote to Einstein.<sup>16</sup> In addition to mentioning his *Nature* letter, Swann enclosed one of his earlier *Review of Modern Physics* article on the constructive view to STR from 1941, and asked for Einstein’s opinion on this view:<sup>17</sup>

I thought you might be interested in the enclosed in view of its relation of quantum theory to relativity. I gave a digest of it in *Nature*, December 6, and there is a comment by Eddington in the same issue. I find it very difficult

---

<sup>15</sup>Swann goes on and restates his idea that if a co-moving observer adopts coordinates that match the moving rod (and clock) associated with a solution to the dynamical equations generated by the Lorentz symmetry group from the solution of these equation that describes a rod at rest, then the quantum description of the moving rod (and clock) by the co-moving observer is exactly the same as the description of the stationary rod by an observer associated with its rest frame.

<sup>16</sup>Swann’s documented relation with Einstein had started a year earlier, when he tried to get an academic position for an acquaintance of Einstein, Felix Ehrenhaft.

<sup>17</sup>As can be seen from the page numbers to which Swann refers in his reaction to Einstein’s reply (see below), the enclosed *Rev. Mod. Phys.* paper was Swann’s (1941b).

to ascertain whether he agrees or disagrees. It seems that he agrees but does not like to.

As I see it, he wishes to deny the credit of the solution of the paradox to the quantum theory and give it to something more deep-seated, of which the quantum theory is an outcome. With this, of course, everyone must agree in principle, but the situation seems to me a little like one in which someone should give credit to a person A for a solution of a certain paradox, while somebody else claimed that it was A's ancestors to whom the credit should be given because it was they who were responsible for the existence of A.

Do not feel obligated to reply to this letter unless there is something you really wish to say about it, as I am only sending you the paper for your general interest (Swann 1942a).<sup>18</sup>

Einstein's response arrived in three weeks, and as we shall see, contained some very interesting, albeit cryptic, remarks on the constructive view that Swann was advocating.

### 3.3 Einstein's reply

#### 3.3.1 The German Version

Einstein's response from January 24, 1942 to Swann's letter and to his *Rev. Mod. Phys.* article (and maybe even to Swann's letter to *Nature*) was written in German and reads as follows:

Ich habe erst jetzt die mir freundlich übersandte Arbeit ansehen können. Mir scheint deren Inhalt war nicht unrichtig, doch in gewissem Sinne irreführend.

In der speziellen Relativitäts-Theorie werden (idealisierte, aber doch im Prinzip als realisierbar aufgefasste) Maßstäbe und Uhren als selbständige physikalische Objekte behandelt, die — als verknüpft mit den Koordinaten der Theorie — in die Aussagen der Theorie mit eingehen. Dabei ist zunächst über die strukturellen Naturgesetze nichts weiter ausgesagt, als dass sie mit Bezug auf so definierte Koordinatensysteme Lorentz-invariant sein sollen.

Es ist zunächst bewusst darauf verzichtet, Maßstäbe und Uhren unter Zugrundelegung von Struktur-Gesetzen als Lösungen zu behandeln. Dies ist

---

<sup>18</sup>All quotes appearing here, including Einstein's letter, are verbatim, and are reprinted from the original letters that can be found in Einstein's archive in the Hebrew University in Jerusalem, and in the W.F.G. Swann Archive at the American Philosophical Society, Philadelphia, PA. I thank Charles Greifenstein from the APS Library for his kind help in accessing the relevant letters.



darum wohlbegründet, weil die (prinzipielle) Existenz solcher als Maßstäbe für Koordinaten dienlicher Objekte vom Standpunkt unserer Erfahrungen besser begründet erscheint als irgendwelche besonderen Strukturgesetze, z.B. die Maxwell'schen Gleichungen.

Fasst man die Sache so auf, so hat der Michelsonversuch sehr wohl mit der speziellen Relativitäts-Theorie zu tun, sobald man das Prinzip von der Konstanz der Lichtgeschwindigkeit oder (darüber hinaus) die Maxwell'schen Gleichungen hinzunimmt.

Wenn man aber Maßstäbe und Uhren nicht als selbständige Objekte in die Theorie einführen will, so muss man eine strukturelle Theorie haben, in welcher eine Länge fundamental eingeht, die dann zur Existenz von Lösungen führt, in denen jene Länge bestimmend eingeht, sodass es nicht mehr eine kontinuierliche Folge ähnlicher Lösungen gibt. Dies ist zwar bei der heutigen Quantentheorie der Fall, hat aber nichts mit deren charakteristischen Zügen zu tun. Jede Theorie, welche eine universelle Länge in ihrem Fundament hat und auf Grund dieses Umstandes qualitativ ausgezeichnete Lösungen von bestimmter Ausdehnung liefert, würde in bezug auf die hier ins Auge gefasste Frage dasselbe leisten. (Einstein 1942)

### 3.3.2 The English translation

Translated to English, Einstein's letter reads as follows:<sup>19</sup>

Only now I have been able to look at the work that you so kindly sent to me. It seems to me that its content was not incorrect, but still in a certain sense misleading.

In special theory of relativity measuring rods and clocks (idealized, but in principle conceived as realizable) are treated as independent physical objects, which, linked as they are to the coordinates of the theory, will enter into the propositions of the theory. At first there is nothing stated about the structural laws of nature other than the fact that they should be Lorentz-invariant with reference to coordinate systems so defined.

Measuring rods and clocks are consciously not treated as solutions under the basis of structural laws [this sentence is a little ambiguous in the original]. This is well justified because from the point of view of our experiences, the (in principle) existence of those objects that can serve as measures for

---

<sup>19</sup>I thank Jutta Shickore and Sandy Gliboff (HPSC, IUB) for their help in translating Einstein's letter into English.

coordinates appears better justified than any particular structural laws, e.g. Maxwell's equations.

If one looks at the issue this way, the Michelson experiment does indeed have something to do with special theory of relativity, as soon as one adds the principle of the constancy of the velocity of light or (furthermore) Maxwell's equations.

But if one does NOT [underlined in the original] introduce rods and clocks as independent objects into the theory, one has to have a structural theory in which a length is fundamental, which then leads to the existence of solutions in which that length plays a determinant [constitutive] role, so that a continuous sequence of similar solutions no longer exists. This is the case in today's quantum theory but has nothing to do with its characteristic features. Any theory that has a universal length in its foundation, and because of this produces qualitatively distinct solutions of a certain extension, would do the same with regard to the question under examination here.

Before we set forth to decipher this response and to analyze its implications on some of Brown's claims, let us end this anecdote with Swann's reaction to Einstein's reply.

### 3.4 Swann's reaction

Swann seems to have asked for a translation of Einstein's letter, and this translation, which apparently was done by an amateur,<sup>20</sup> is enclosed in Swann's archives. One can only lament on this infelicity since Einstein's original German version of the letter is, to say the least, non-transparent, and as we shall see, an unqualified translation could easily (and actually did) lead to misunderstanding of Einstein's entire point.

Swann's reaction to Einstein's letter came a little more than a fortnight later, and it marks the end of his documented discussions with Einstein's on the constructive approach to STR.<sup>21</sup> In his letter Swann (1942b) admits that the point he was making "did not depend specifically upon all of those features of the quantum

---

<sup>20</sup>The translation Swann got looks awkward to a native German speaker, and shows lack of knowledge of the context and subject matter.

<sup>21</sup>It appears that Swann maintained contact with Einstein and even visited him in 1950 in Princeton, to discuss a public talk he (Swann) was preparing at the Franklin Institute. No record of this meeting exists, apart from a letter Swann sent to Einstein after the meeting took place, to which he attached his planned talk, in order to thank Einstein and to allow him to veto any part of the talk that regarded Swann's reconstruction of Einstein's work on the theories of relativity.

theory which are of interest in the atomic structure”, and he agrees with Einstein on the necessity of the constructive theory defining a length. Nevertheless, Swann claims that there are two additional reasons why one should look at quantum theory.

First, the theory displays a unique ability to supply a (relativistically invariant) measure of length (here Swann gives Bohr’s hydrogen atom model as an example where the fundamental length would have been the radius of the first electronic orbit). Second, the theory allows us, using this measure of length, to determine what will be the ground state of the rod:

It is this power to fix a length which is a special aspect of the determination of structural form and that is why, in speaking of the rod, I give the quantum theory, on page 201 [Swann 1941b — AH], the credit of determining that it shall be in a *ground state* [underlined by Swann — AH]. It seems to me that it is this act of the quantum theory which is significant and which is another aspect of its power to fix a length. (Swann 1942b)

Swann ends his letter with an apologetic tone:

Please do not feel that it is necessary to reply to this letter. Of course, it is always a pleasure to hear from you on these matters, but I do not think there is any very great divergence of view point in this instance.

from which it is clear that Swann had interpreted Einstein’s response as sympathetic to his (constructive) explanation of the Lorentz–FitzGerald contraction with a Lorentz covariant quantum theory of matter!

## 4 Reading Einstein

Admittedly, Einstein’s letter to Swann is not one of his famous letters. Nor is it one of his most transparent. In effect, while mentioned only twice in the vast literature on the foundations and history of STR, this letter was misunderstood on both occasions. In this section we shall display these misunderstandings, and then set the record straight.

### 4.1 Lost in translation

#### 4.1.1 Stachel’s de-contextualization

In his recent *Einstein from ‘B’ to ‘Z’*, John Stachel (2002) devotes a chapter to “Einstein and the Quantum”. Einstein’s letter to Swann appears here for the first

time in a rather misplaced context. Stachel brings the letter as evidence to the claim that Einstein (in his attempts to explore the possibility that a field theory based upon a continuous manifold, the principle of general covariance and partial differential equations, could provide an explanation to quantum phenomena) sometimes indicated that a fundamental length might be needed to explain the existence of stable structure in such a field theory. He then (mis)quotes only the *last* paragraph of the letter (Stachel 2002, p. 394).

But clearly, by now the reader can appreciate that Einstein's letter to Swann, while it may be classified as pertaining to Einstein's views on the relations between relativity theories and quantum mechanics, is *not* in any way meant to indicate what Stachel asserts it does.

While the omission of the letter's first part (along with its context and attitude towards the constructive approach) is understandable from an editorial perspective, it appears to have led Brown to claim that Einstein — while skeptic about the role quantum theory — nevertheless *agreed* with Swann that a dynamical explanation of the Lorentz-FitzGerald contraction was wanting.

#### 4.1.2 Brown's interpretation

Brown (2005a, Ch. 7), devoted as it is to the dissenting, unconventional, voices on relativity, is a wonderful starting point for any future research on the constructive approach to STR. Brown's inclusion on the Einstein–Swann correspondence in this chapter, however, is somewhat misleading. That Einstein expressed misgivings about his choice in the principle view is, of course, supported by textual evidence. I strongly doubt, however, that one can count Einstein's letter to Swann as such an evidence (see below), but even if one choosed to do so, there exists another, more interesting problem. Reading Brown one gets the impression that Einstein was attracted to the constructive view to STR in general, but refrained from embracing Swann's version of it because of his suspicion of quantum theory.<sup>22</sup> Yet the evidence for this narrative is nothing else but the paragraph (mis)quoted by Stachel:

It is known that Swann corresponded with Einstein on the foundations of SR; in Stachel (1986) p. 378 [this part appears also in Stachel 2002, p. 394 – AH], part of a 1942 letter from Einstein to Swann is cited in which he discusses the possibility of a constructive formulation of the theory wherein rods and clocks are not introduced as 'independent objects'. Einstein argues in this letter that any such theory must, like the quantum theory, contain an

---

<sup>22</sup>Brown's view on this suspicion is documented also in Brown (2005a, pp. 187–190).

absolute scale of length. It would be interesting to know more about this correspondence. (Brown 2005a, p. 120, fn. 19)

## 4.2 A more accurate reconstruction of Einstein's response

### 4.2.1 Reading Einstein step by step

Let us look more carefully at Einstein's response to Swann. The first thing to note is that from the very beginning, Einstein, in his famous style, is criticizing Swann without saying so explicitly when he writes in the opening sentence:

... It seems to me that the content [of Swann work — AH] was *not incorrect but still in a certain way misleading*. [my italics — AH]

I cannot refrain from making an analogy between Einstein's attitude to Swann's work and his reaction to Reichenbach's *Relativity and A Priori Knowledge* (1920), where Einstein, when asked whether he considers true what Reichenbach had asserted, mischievously answered "I can only answer with Pilate's famous question: 'what is truth?'" (Schilpp 1949, p. 676).

The second paragraph presents the principle view of STR, in which measuring rods and clocks are treated as idealized (but in principle realizable) *primitives*, i.e., independent, unanalyzed physical objects. On this view nothing is said about the dynamical laws of nature other than the fact that they should be Lorentz-invariant with reference to coordinate systems defined by the primitive rods and clocks. Note that here Einstein restates the epistemological priority, under the principle view, of the geometrical symmetries of spacetime over the symmetries of the dynamical laws. To paraphrase Brown again, it is quite clear here which is the cart and which are the horses.

The next paragraph justifies this principle view: measuring rods and clocks are "consciously" (i.e., on purpose) not treated as solutions to the dynamical laws (i.e., solutions to the equations of motion) — as Swann would have it — and this view is well justified since on the basis of our experience (e.g., the null result of the Michelson–Morley experiment – see below — or the empirical content of the relativity principle), the in principle existence of these primitives as measures of coordinates (i.e., as representing the geometry of spacetime) seems to be better justified than any given dynamical theory of matter that one may come up with. This last sentence reminds us of the agnosticism of the principle view with respect to the actual dynamical model for relativistic phenomena.

However, in Swann's amateurish translation the first sentence of this paragraph was translated as saying "We at first consciously desist from treating measures

and clocks as solutions by taking structural laws as basis”. This was apparently interpreted to imply that instead of taking rods and clocks as primitives, as the former paragraph suggests, one should take the dynamical laws as a basis. Clearly this is not what Einstein meant here, as can be seen from the German version and from the place of this paragraph in the letter (Einstein turns to the constructive view only two paragraphs later).

Next comes another blow to Swann’s view: if one looks at the issue this way (i.e., *given* the existence of rods and clocks), then the Michelson experiment does indeed have something to do with special theory of relativity, as soon as one adds the principle of the constancy of the velocity of light or (furthermore) Maxwell’s equations.

It is only in the last paragraph where Einstein finally reverts to the constructive view. Unfortunately, this is the most obscure paragraph in the letter, and any minor changes in its translation can result in totally different interpretations.

The first sentence of this paragraph is a conditional sentence, with a short antecedent and a long and winding consequent. The short antecedent is, in paraphrase, preparing the stage for what, in Einstein’s view, happens when one does *not* wish to take measuring rods and clocks as primitives, i.e., when one insists, contra all what was said before in the letter, to follow the constructive approach to STR. The long and winding consequent, again in paraphrase, is a logical chain that follows from the constructive view. First, the dynamical theory that one utilizes in order to construct the kinematical effects (and to explain the geometry of spacetime) must establish a fundamental measure of length. Second, this (here “this” is ambiguous — either this fundamental measure of length, or the fact that the dynamical theory has such a measure length) leads to the existence of solutions (of the dynamical equations) in which length plays a constitutive role. Third, since this fundamental length appears in the solutions to the equations of motion, a continuous sequence of similar solutions no longer exists (note that the negation “no longer exists” can be equally interpreted as quantifying over “continuous”, or over “similar”, or over both).

The second sentence of the last paragraph is straightforward and says that the introduction of a fundamental measure of length is indeed the case with today’s quantum theory but has nothing to do with its characteristic features. The final sentence then says that *any* theory which has a universal length in its foundations and because of this circumstance yields qualitatively distinguished or distinct solutions of a certain extent would do the same with respect to the question under examination here.

## 4.2.2 Taking stock

We can divide Einstein’s response to Swann into four distinct parts. The first is the opening sentence that sets the tone: Swann’s view on the role of the Michelson–Morley experiment, and on the role quantum theory plays in dynamically explaining the Lorentz–FitzGerald contraction is, according to Einstein, misleading. The second is the description of the standard, principle, view of STR, where rods and clocks are taken as primitives, and the explanation of the Lorentz–contraction is a geometrical one. The third is the admission that one can reject the principle view and adapt the constructive view instead, and the warning that such a move entails several non–trivial consequences, at least one of them being discontinuity. The final part is the observation that *any* attempt to dynamically explain spacetime geometry (irrespective of quantum theory) will have the same consequences.

The first conclusion from this reconstruction is that, contrary to what Swann wanted to believe, in his letter Einstein was expressing little sympathy to Swann’s view. This may be a warning sign against the broader claim Brown is making throughout his project regarding Einstein’s views on the principle–constructive distinction. I shall examine this claim in detail in the following section (5). The second conclusion is more philosophical. His letter to Swann gives us a rare opportunity to discuss what Einstein saw as an inevitable result of the constructive approach to STR. Deferring the analysis of these issues to the sequel article, I briefly comment on them in section (6).

# 5 Einstein and the constructive approach to STR

## 5.1 The physics of despair

A recurrent theme in Brown’s project is the claim that Einstein expressed, throughout the years from 1907 and at least until 1949, a certain “unease” with respect to his choice in the principle view of STR:<sup>23</sup>

When Einstein formulated his 1905 treatment of relativistic kinematics, the

---

<sup>23</sup>Einstein’s misgivings are voiced in Einstein’s (1907) letter to Ehrenfest, Einstein’s (1908) letter to Sommerfeld, Einstein’s (1919) letter to the London *Times*, Einstein’s (1921) famous paper on *Geometry and Experience*, and several quotes from Einstein’s reflections in his *Autobiographical Notes* (Schilpp 1949). In some of these quotes Einstein mentions that the example he had in his mind when retreating to the principle view of STR was TD, where, although no assumptions on the constitution of matter are made, few phenomenological and restrictive principles suffice to predict the behavior of bulk matter.

template in his mind was thermodynamics. This was because a more desirable ‘constructive’ account of the behaviour of moving rods and clocks, based on the detailed physics governing their microscopic constitution, was unavailable. The price to be paid was appreciated by Einstein and a handful of others since 1905. (Brown 2005b, p. S85)

Einstein’s choice in the principle view, says Brown (2005b, p. S87–S89), was a choice of despair. Since several months before the publication of “The electrodynamics of moving bodies” Einstein has written another revolutionary paper claiming that electromagnetic radiation has a granular structure, the assumption, prevalent among his contemporaries, that Maxwellian electrodynamics is strictly true, had lost his trust. If Maxwell’s equations were thought by Einstein as incompatible with the existence of the photon, then there was no sense in trying to write down a constructive, dynamical, theory for relativistic kinematical effects on the basis of classical electrodynamics as the latter could not be regarded as the complete theory of the constitution of matter. Einstein would have preferred a constructive account of the relativistic effects of length contraction and time dilation, but in 1905 the elements of such an account were unavailable.

Now let us ignore Einstein’s documented ambivalence with respect to the constructive approach, and suppose for the sake of the argument that the question regarding Einstein’s opinion is not only historically important but also unequivocally decidable. Let us even grant Brown’s narrative above. Yet a puzzle still remains. Indeed, if, as Brown argues, Einstein was so *in favor* of the constructive approach to STR and saw the principle view of 1905 as a choice of despair, then why, years later in his letter to Swann, after a relativistic quantum theory of matter has become available, he was still reluctant to acknowledge its implications on his choice?

Brown (2005a, p. 114) side-steps this embarrassing question by suggesting that Einstein’s “long-standing distrust” and hostility towards quantum theory prevented him from recognizing the progress in the theory and its implication on the formulation of STR. However, as we can see from the last paragraph of his letter to Swann and from other writings I shall quote below, Einstein was troubled not with quantum theory *per se*, but with what he regarded as a *general* feature of the constructive approach to STR, namely, the fact that *any* such attempt to dynamically explain the geometrical structure of spacetime would entail the departure from the physics of the continuum.



## 5.2 Discontinuity

There is no doubt that the principle–constructive dichotomy was a major theme in Einstein’s view on STR, and Brown (2005a) is an excellent example of the fruitfulness of the attempts to reconstruct this view within its framework. But there exists a parallel, even more important, dichotomy with which one can describe Einstein’s lifework, namely, continuum– or noncontinuum– based physics.

As Holton (1972) and Stachel (1993) note, at first glance most of Einstein’s work pertains to the physics of the continuum in both its physical and its philosophical aspects: his conclusion, based on STR, that direct–interaction theories are no longer tenable once one recognizes the existence of a maximum signal velocity (Schilpp 1949, p. 61), his forty years long search for a unified field theory of gravitation and electromagnetism, and the field theoretic account of gravitation given in the general theory of relativity (GTR). On the other hand, discontinuity and discreteness also played an important role in Einstein’s work — e.g., classical atomism as embodied in his work on Brownian motion, his light–quanta hypothesis, and his contribution to the Bose–Einstein statistics.

Stachel (1993, p. 276) remarks that the spacetime arena *unifies* the continuum and the discrete since both (continuous) fields and (discontinuous) atoms find their home in the spacetime continuum. This leads him to discuss what Einstein saw as the alternative to continuum–based physics which does not take spacetime as a primitive. Einstein referred to such physics as “purely algebraic”:

. . . [O]ne does not have the right today to maintain that the foundation [of theoretical physics – AH] must consist in a *field theory* [emphasis in the original] in the sense of Maxwell. The other possibility, however, leads in my opinion to a renunciation of the spacetime continuum and to a purely algebraic physics. . . . For the present, however, instinct rebels against such a theory. (Einstein to Paul Langevin, October 1935, in Stachel 1993, p. 285)

To be sure, it has been pointed out that the introduction of a space-time continuum may be considered as contrary to nature in view of the molecular structure of everything which happens on a small scale. It is maintained that perhaps the success of the Heisenberg method points to a purely algebraic method of description of nature, that is to the elimination of continuous functions from physics. Then, however, we must also give up, by principle, the space-time continuum. It is not unimaginable that human ingenuity will some day find methods which will make it possible to proceed along such a path. At the present time, however, such a program looks like an attempt to breathe in empty space. (Einstein 1954/1982. p. 319)

The alternative continuum–discontinuum seems to me to be a real alternative; i.e., there is no compromise. By discontinuum theory I understand one in which there are no differential quotients. In such a theory space and time cannot occur, but only numbers and number–fields and rules for the formation of such on the basis of algebraic rules with exclusion of limiting processes. Which way will prove itself, only success can teach us. (Einstein to H.S. Joachim, August 1954, in Stachel 1993, p. 287)

In his essay Stachel exposes Einstein’s ambivalence towards the physics of the discontinuum, and it is against *this* background that I suggest to read Einstein’s letter to Swann. As we have seen, the difference between the principle and the constructive views is mainly epistemological: while the former foster structural explanations (and in the case of STR, geometrical ones) of the sort “what is the structure of the world like if certain principles are to hold in it?”, the latter promote causal–dynamical explanations. However, if one adapts the constructive approach to STR, aiming to dynamically explain spacetime geometry itself, one *cannot* assume any geometry in one’s explanans. For this reason, I believe, Einstein argues in his letter to Swann that his constructive approach to STR must introduce a fundamental measure of length. Furthermore, taking into account Einstein’s views on the continuum–discontinuum distinction, one can also understand why, according to Einstein, a departure from continuum–based physics is the mark of *any* such constructive theory.<sup>24</sup>

Note that on this view Einstein’s reaction to Swann’s letter is definitely not meant to express hostility to quantum theory *per se* on the basis of his “long–standing distrust”, nor should it be interpreted as expounding the (false) claim that quantum theory is inconsistent with the continuum.<sup>25</sup> Rather, I believe that here Einstein is expressing his worries about the consequences of the attempt to construct spacetime structure from a more fundamental theory. For noncontinuum–based physics would be the kind of physics Swann would end up with if he refused to take spacetime structure as fundamental and exchanged the explanans for the explanandum, no matter what dynamical theory he would use.

I realize, of course, that the temptation to use Einstein’s hostility to quantum

---

<sup>24</sup>Exactly when did Einstein start to consider the problem of formulating statements about the discontinuum without calling into aid the continuum spacetime is still unclear. Stachel (1993) cites Einstein’s letter to Walter Dällenbach from November 1916 as the first direct evidence, but suggests (p. 281) that Einstein may have started to think upon this question well before his work on general relativity.

<sup>25</sup>If one *assumes* that quantum dynamics is enacted on a background spacetime continuum, then of course it is consistent with the continuum.

theory as a “catch–all” narrative is strong: it is well known that Einstein was accused of “rigid adherence to classical theory”, and similarly to Brown, most commentators interpret this rigidity as manifest in Einstein’s view of quantum theory as incomplete (Bohr in Schilpp 1949, p. 235), or in his reluctance to abandon the notion of separability (Howard 1985), or even in his prejudice for causality (Fine 1986, pp. 100–103). But the correct interpretation of this rigidity was given by Einstein himself:<sup>26</sup>

The opinion that continuous fields are to be viewed as the only acceptable basic concepts, which must also [be assumed to] underlie the theory of material particles, soon won out. Now this conception became, so to speak, “classical;”, but a proper, and in principle complete, *theory* has not grown out of it. . . . Consequently there is, strictly speaking, today no such thing as a classical field–theory; one can, therefore, also not rigidly adhere to it. Nevertheless, field theory does exist as a program: “Continuous functions in the four–dimensional [continuum] as basic concepts of the theory.” Rigid adherence to this program can be rightfully be asserted of me. (Schilpp 1949, p. 675)

## 6 Length matters

Setting these historical issues aside, I would like to end with matters more philosophical. The amazing fact is that Einstein had an intuition about problems yet to come almost 50 years in advance, and his idea of a “purely algebraic physics” has turned out to be almost prophetic, as is sometimes acknowledged in the quantum gravity literature:

To my great surprise, I recently learned from an essay by John Stachel [here the author cites Stachel (1993) – AH], that the ideas explored here are very similar to the ones that Einstein was exploring near the end of his career. Apparently, these ideas remained obscure because Einstein did not have the mathematical tools to carry them to fruition, and discussed them only orally or in letters. . . . I was able to resist the urge to retitile this paper ”On some

---

<sup>26</sup>In this passage Einstein directly responds to the “friendly accusation” made by Pauli:

The theoretical determination of the fine structure constant is certainly the most important of the unsolved problems of modern physics. We believe that any regression to the ideas of classical physics (as, for instance, to the use of the classical field concept) cannot bring us nearer to this goal. (Pauli in Schilpp 1949, p. 158)

ideas of Professor Einstein,” but given the unconventional nature of my proposal, I am happy for the moral support. Einstein, after all, was often ahead of his time. (Crane 1995)

Even more surprising is the fact that Einstein’s insight about minimal length has also turned out to be correct.

## 6.1 Minimal length in quantum gravity

One can identify two possible conditionals in the last paragraph of Einstein’s letter to Swann. The first says that any constructive approach to STR must depart from the continuum and employ a notion of a fundamental length (call this conditional LENGTH). The second says that any theory that employs such a fundamental length must break the continuous Lorentz symmetry (call this conditional BREAK). In section (5) I have suggested that Einstein believed that LENGTH holds. Whether Einstein thought BREAK is true is an open historical question.

But the interesting *philosophical* (and mathematical) question is whether LENGTH and BREAK *are* true. This question is of crucial importance, especially in the context of the attempts to unify quantum theory and GTR. Indeed, as Brown himself admits (Brown 2005a, p. 151, p. 171, pp. 176–177), there exists a tension between the dynamical approach to STR and the structure of GTR. Recall that the local validity of STR is derived from what Brown calls (2005a, pp. 169–172) the Strong Equivalence Principle (SEP). This tension between the dynamical approach and GTR is manifest in two of the following three possibilities: (i) SEP is fundamentally true; (ii) SEP is only phenomenology true (i.e., in a certain limit) but its violations are undetectable; and (iii) SEP is not only fundamentally false but also phenomenologically false, and its violations may be detected in certain scenarios. Clearly, that LENGTH may be true is inconsequential here, but if BREAK were true, then option (i) would be false, and Brown’s big principle would cease to be fundamental. Note also that Brown’s detachment from the epistemological interpretation of STR constrains him to deny (ii).<sup>27</sup>

While I admit I couldn’t find any *a priori* argument for the truth of LENGTH or BREAK, the remarkable (contingent?) fact is that the current theoretical landscape in quantum gravity has vindicated Einstein’s belief in LENGTH: a large

---

<sup>27</sup>Notably, Bell, at least at some points along his career (e.g., Bell 1986, 48–50), supported Bohmian mechanics — a theory that violates STR but also incorporates a dynamical mechanism that prevents us from detecting this violation, and thus employs exactly the type of Lorentzian philosophy from which Brown is detaching himself.

number of convincing semiclassical considerations indicate that in a quantum theory of gravity the Planck length  $L_p \equiv \sqrt{\hbar G/c^3} \sim 1.6 \cdot 10^{-35} m$  should play the role of minimal observable length (Garay 1995). This is indeed the case in most, if not all, tentative quantum theories of gravity, e.g., string theory (Smolin 2001, pp. 179–193), canonical quantum gravity (Butterfield and Isham 2001) and loop quantum gravity (Rovelli 2004, pp. 249–259).

Whether or not the current state of affairs in theoretical and experimental high energy physics vindicates BREAK, however, is still an open question — perhaps the most fascinating and crucial question in the quantum gravity research program.<sup>28</sup> How high are the stakes here, it seems, was already clear to Einstein:

I consider it entirely possible that physics cannot be based upon the field concept, that is, on continuous structures. Then *nothing* will remain of my whole castle in the air including the theory of gravitation, but also nothing of the rest of contemporary physics. (Einstein to Besso, August 1954, translated in Stachel 1993, p. 286)

## 7 Concluding remarks

Defending them with textual evidence, in this paper I have made the following historical observations:

- Einstein’s letter to Swann can be interpreted as a warning against the consequences of pursuing a constructive approach to spacetime theories such as STR. This approach, says Einstein, leads to (1) an introduction of a fundamental length scale, (2) an algebraic view of nature, and (3) a departure from continuum–based physics.
- Einstein’s 1905 choice in the principle view of STR may have signified a choice of despair, but his reluctance to embrace the constructive approach in his later years can be interpreted as a “rigid adherence” to continuum–based physics.

These observations lead me to conjecture that notwithstanding his appreciation of the constructive approach to theoretical physics in general, in the context of STR Einstein would have still preferred the geometrical explanation of the relativistic kinematical effects as fostered by Minkowski’s spacetime structure over

---

<sup>28</sup>For a detailed examination of this question and its consequence on Brown’s approach the reader is referred to a sequel to this paper (Hagar 2007).

the dynamical explanation that Brown advocates. I fully realize, however, that Einstein's view on this matter, if at all important today, is open to different interpretations due to his documented ambivalence regarding the two dichotomies discussed here.

Additional support to these observations can be found in Einstein's views on the separability principle. It is well known that Einstein regarded this principle as constitutive to any physical theory since it provides a clear cut criterion for individuation: one can draw the lines between the parts of the universe anywhere one wants — “there are “joints” everywhere” (Einstein 1948, cited in Howard 1993, p. 239). Field theory does this in the most extreme possible fashion, adds Howard, by regarding every infinitesimal region of spacetime as a separate system characterized by its own, separate state. Howard then notes that loss of separability, brought by quantum mechanics, also signified the departure from the spatiotemporal description of nature. The analysis presented here allows one to include Einstein's reluctance to abandon the continuum within the same realistic research program which Howard (1993) describes — a research program that prevented him from fully supporting to the constructive approach to STR.

It is a remarkable fact that although there is no *a priori* argument for it, Einstein's belief that the attempt to explain geometry with dynamics will lead to breakdown of continuity, is vindicated by the current state of affairs in quantum gravity. Whether the constructive approach will lead to breakdown of Lorentz symmetry is still an open question. Naturally, the competing theories of quantum gravity have yet to supply us with definite predictions that can elevate the research in this domain from pure mathematics to actual science (for a progress in this directions see Amelino Camelia (2002)). But even under this proviso, and thanks to Einstein who had prophetically opened up these questions in his letter to Swann, the analysis presented here puts interesting constraints on the advocates of the constructive approach to STR: in their theoretical choices within the domain of quantum gravity they would have to take into account that length matters.<sup>29</sup>

---

<sup>29</sup>Thanks to Harvey Brown for several discussions throughout the years and for interesting comments on this paper, Giovanni Amelino Camelia for email correspondence, Itamar Pitowsky for insightful suggestions, Bill Demolpoulos for constructive skepticism, and Meir Hemmo for particularly stimulating brainstorming sessions on the constructive approach to STR and for helpful comments on earlier drafts. I am also grateful to Sandy Gliboff and Jutta Shickore for their kind help in translating Einstein's letter and in matters historiosophical, and to an anonymous referee who insisted that the length of this paper matters . . .

## 8 References

- Amelino Camelia, G. (2002), A quantum gravity phenomenology: Status and prospects, *Modern Physics Letters A*17: 899–922.
- Balashov, Y. & Janssen, M. (2003), Critical notice: presentism and relativity, *British Journal for the Philosophy of science* 33: 251–274.
- Bell, J. S. (1976), How to teach special relativity, *Progress in Scientific culture* 1. Reprinted in Bell (1987) pp. 67–80.
- Bell, J. S. (1986), An interview in the BBC, in P.C.W Davies & J. R. Brown (eds.) *The Ghost in the Atom: A Discussion of the Mysteries of Quantum Physics* pp. 45–57. Cambridge: Cambridge University Press.
- Bell, J. S. (1987), *Speakable and Unspeakable in Quantum Mechanics*, Cambridge: Cambridge University Press.
- Bell, J. S. (1992), George Francis FitzGerald, *Physics World* 5: 31–35. Abridged by Denis Weare from a lecture in 1989.
- Brown, H. (1993), Correspondence, invariance and heuristics in the emergence of special relativity, in S. French and H. Kamminga (eds.) *Correspondence, Invariance and Heuristics*, pp. 227–260, Kluwer Academic Publishers.
- Brown, H. (2005a), *Physical Relativity*, Oxford: Oxford University Press.
- Brown, H. (2005b), Einstein’s misgiving about his 1905 formulations of STR, *European Journal of Physics*, 26: S85–S90.
- Brown, H. & Pooley, O. (2001), The origin of the spacetime metric: Bell’s Lorentzian pedagogy and its significance in general relativity, in C. Callender & N. Huggett (eds.) *Physics Meets Philosophy at the Planck Scale* pp. 256–274, Cambridge: Cambridge University Press.
- Brown, H. & Pooley, O. (2004), Minkowski spacetime—a glorious non-entity, in D. Dieks (ed.) *The Ontology of Spacetime* pp. 67–92, Amsterdam: Elsevier.
- Butterfield, J. & Isham, C. (2001), Spacetime and the philosophical challenge of quantum gravity, in C. Callender & N. Huggett (eds.) *Physics Meets Philosophy at the Planck Scale* pp. 33–89, Cambridge: Cambridge University Press.
- Cornwell, D.T. (2005), Forces due to contraction on a cord spanning between two spaceships, *Europhysics Letters* 71(5): 699–704.
- Crane, L. (1995), Clock and category: Is quantum gravity algebraic? <http://xxx.arxiv.org/gr-qc/9504038>.
- Dewan, E. and Beran, M. (1959), Notes on stress effects due to relativistic contraction, *American Journal of Physics* 27: 517–518.
- Dewan, E. (1963), Stress effects due to Lorentz contraction, *American Journal of Physics* 31: 383–386.
- Eddington, A. (1939), *The Philosophy of Physical Science*, Cambridge: Cambridge University Press.
- Eddington, A. (1941), Philosophy of physical science, *Nature* 148: 692–693.
- Einstein, A. (1907), Bemerkung zur Notiz des Haerrn P. Ehrenfest. Translated in Einstein (1989), Doc 47, 236–237.
- Einstein, A. (1908), Letter to Sommerfeld, Document 73 in M. Klein (ed.) *The Collected Papers of Albert Einstein, Vol. 5. The Swiss years: Correspondence, 1902–1914 (English Supplement)*, Princeton: Princeton University press.

- Einstein, A. (1915), Theoretische Atomistik. In Die Kultur der Gegenwart. Ihre Entwicklung und ihre Ziele. Paul Hinneberg, ed. Part 3, Mathematik, Naturwissenschaften, Medizin. Section 3, Anorganischen Naturwissenschaften. E. Lecher, ed. Vol. 1, Die Physik. Emil Warburg, ed. Leipzig and Berlin: B. G. Teubner, 251-263.
- Einstein, A. (1919), Time, space, and gravitation *Times* (London), 28 November 1919, pp. 13–14, reprinted as What is the theory of relativity?, in Einstein (1982) pp. 227–232.
- Einstein, A. (1921), Geometry and Experience, reprinted in Einstein (1982) pp. 232–246.
- Einstein, A. (1942), Letter to W.F.G. Swann, Item 20–624 in the Einstein Archive. Enclosed also in Swann (1942ab).
- Einstein, A. (1954/1982), *Ideas and Opinions*, New York: Crown.
- Einstein, A. (1989), *The Collected Papers of Albert Einstein, Vol. 5. The Swiss years: Writings, 1900–1909 (English Supplement)*, Princeton: Princeton University press.
- Fine, A. (1986), *The Shaky Game*, Chicago: University of Chicago Press.
- Garay, L. (1995), Quantum gravity and minimum length, *International Journal of Modern Physics A*10: 145-165.
- Hagar, A. (2007), Length matters (II): Quantum gravity and the constructive approach to the special theory of relativity. Unpublished manuscript.
- Hagar, A. (In preparation), The Cart or the Horses? Dynamical versus Structural Explanations in Modern Physics.
- Holton, G. (1972), On trying to understand scientific genius, *American Scholar*, 41: 95–110.
- Howard, D. (1985), Einstein on locality and separability. *Studies in the History and the Philosophy of science* 16: 171–201.
- Howard, D. (1993), Was Einstein a realist?, *Perspectives on Science* 1: 204–251.
- Howard, D. (1998), Astride the divided line: Platonism, empiricism, and Einstein's epistemological opportunism, *Poznan Studies in the Philosophy of the Sciences and the Humanities*, 63: 143–163.
- Howard, D. (2004), Einstein's philosophy of science, *Stanford Encyclopedia of Philosophy*, available at <http://plato.stanford.edu/entries/einstein-philscience/>.
- Janssen, M. (1995), *A comparison between Lorenz's ether theory and special relativity in the light of the experiments of Trouton and Noble*. Ph.D dissertation. University of Pittsburgh.
- Janssen, M. (2000), The Old Sage vs. the Young Turk. Talk slides.
- Jeans, J. H. (1941), The philosophy of physical science, *Nature* 148: 140.
- Klein, M. (1967), Thermodynamics in Einstein's thought, *Science* 157: 509–516.
- Nerlich, G. (1976), *The Shape of Space*, Cambridge Cambridge University Press.
- Putnam, H. (1975), Philosophy and our mental life. In *Mind, Language, and Reality*, Vol. 2, pp. 291–303 Cambridge: Cambridge University Press.
- Rovelli, C. (2004), *Quantum Gravity*, Cambridge: Cambridge University press.
- Schilpp, P.A. (1949), *Albert Einstein, Philosopher–Scientist*, New York: Open Court.
- Stachel, J. (1993), The other Einstein: Einstein contra field theory, *Science in Context*, 6(1): 275–290.
- Stachel, J. (2002), *Einstein from 'B' to 'Z'*, Boston: Birkhauser.
- Swann, W.F.G. (1912a), A deduction of the effects of uniform translatory motion from the electrical theory of matter, without the employment of the transformation of the electromagnetic equations, *Philosophical Magazine* S6, 23(133): 65–86.



- Swann, W.F.G. (1912b), The FitzGerald Lorentz contraction and an examination of the method of determining the motions of electrons, when considered simply as singularities moving so as to satisfy the electromagnetic scheme, *Philosophical Magazine* S6, 23(133): 86–94.
- Swann, W.F.G. (1930a), Relativity and the aether drift, *Physical Review* 35: 336–346.
- Swann, W.F.G. (1930b), Relativity and electrodynamics, *Review of modern Physics* 2(3): 243–304.
- Swann, W.F.G. (1940), The significance of scientific theories, *Philosophy of Science* 7: 273–287.
- Swann, W.F.G. (1941a), The relation of theory to experiment in physics, *Review of modern Physics* 13: 190–196.
- Swann, W.F.G. (1941b), Relativity, the Fitzgerald–Lorentz contraction, and quantum theory, *Review of modern Physics* 13: 197–202.
- Swann, W.F.G. (1941c), Philosophy of the physical science, *Nature* 148: 692.
- Swann, W.F.G. (1942ab), Letters from a correspondence with A. Einstein, William Francis Gray Swann Archive, American Philosophical Society, Philadelphia.
- Swann, W.F.G. (1960), Certain matters in relation to the restricted theory of relativity, with special reference to the clocks paradox and the paradox of the identical twins, *American Journal of Physics* 28: 55–64, 319–323.