Chapter 11
Einstein, Poincaré and the Origins of Special Relativity

Introduction

Two papers I translated in this book have had considerable notoriety thrust upon them because of the historical discussion of priority for the discovery of the theory of special relativity. The publication date of the first paper serves to establish a first-to-publish date for Henri Poincaré just a few months before Albert Einstein's publication and the second paper by Poincaré provides details for this discussion. The second paper (Poincaré, Sur la dynamique de l'électron, 1906a) is commonly called the Palermo paper, a reference to the journal in which it was published. The corresponding paper by Einstein (Einstein, Zur Elektrodynamik bewegter Körper, 1905)[1] is one of his famous series of papers from 1905.

Many gallons of ink have been used to argue about the position of Poincaré's and Einstein's 1905 papers in the discovery of special relativity and precedence for that discovery. A good deal of the ink in fact seems to be quite toxic which makes the discussion unattractive.

If, unlike me, you are interested in the discussion of precedence, then I hope that the translations of relevant papers by Poincaré provided in Part I contributes to your understanding of what Poincaré wrote.

I also find that discussion to be a distraction from several important topics that Poincaré does treat and which I do find interesting. In fact, the other chapters in Part II treat topics that I find both interesting and overlooked. What is an electron? What holds it together? What did Hendrik Antoon Lorentz and Henri Poincaré contribute to reworking electrodynamics without an ether and with discrete charges? Further, there are additional topics here that I haven't considered: Henri Poincaré in these papers is also trying to understand the origin of mass, and the unification of gravitation and electromagnetism. Any of these are meritorious in their own right.

[1]Quotations from Einstein's 1905 paper on special relativity used in this chapter are taken from (Einstein, The Collected Papers of Albert Einstein, 1989).

B. D. Popp, *Henri Poincaré: Electrons to Special Relativity*,
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Therefore, my reason for preparing this book is not to get involved in that discussion of precedence for special relativity; it is instead to point out some of the interesting things done by Poincaré (and Lorentz) that have been drowned out by the discussion. However, if I were to write this book ignoring the noise from the discussion, it would leave a rather large elephant in the room. The purpose of this chapter is therefore to acknowledge the presence of the elephant, look it over, and then get it out of sight.

A prominent feature of some contributions to this discussion is a checklist of items seen as necessary for having a full theory of special relativity. (The checklist may in some situations only be metaphorical. Alternatively, Jeremy Gray (Henri Poincare: a scientific biography, 2013, p. 368) writes, "the pro-Poincaré faction can… cut and paste their man's words into a fairly impressive list of insights.") Some items on the checklist are Lorentz transformations, demonstration that Maxwell's equations of electrodynamics are invariant under Lorentz transformation, and a statement that the speed of light is the same in all inertial reference frames. Checkmarks are then placed next to these items in a Poincaré column and in an Einstein column. In this approach to the comparison, there are many checks in the Poincaré column. Some contributors do see enough checks in the Poincaré column to assert that Poincaré did have a full theory of special relativity and maybe even some glimmers on the horizon in the direction of the general theory of relativity.

This checklist approach seems to have three main shortcomings. First, it passes over a sizeable portion of what Poincaré did write about that isn't needed for the special relativity checklist. Other chapters in this book help draw attention to some of this material that has been passed over. The next shortcoming is that the reductionist nature of a checklist leaves out consideration of holistic issues: what did Poincaré and Einstein each write in their respective papers about what they were trying to do and how they saw the items from the checklist fitting together. I agree with the statement in (Darrigol, The Mystery of the Einstein-Poincaré Connection, 2004, p. 618), "in order to compare Poincaré's and Einstein's theories properly one must read every one of their statements in context, taking into account both the inner logic of their investigations and the contemporary problematics to which they were responding." I hope the translations in Part I, and Chapters 9 and 10 are an aid to readers wishing to follow Darrigol's prescription. The third shortcoming lies in understanding how other people saw and worked with what Poincaré and Einstein had each written.

In this last case, the answer is fairly clear. Poincaré's paper from 1906 ("the Palermo paper") and his follow-up from 1908 seems to have largely languished until Edmund Whittaker (Whittaker, 1953) brought attention to them (discussed later in this chapter). In contrast, Einstein's readers, after a delay, tried to assimilate, write about and use Einstein's paper. First Hermann Minkowski in 1908 and then Arnold Sommerfeld, Paul Langevin and others went down this path. Their efforts and publications added weight behind Einstein's work. This path then became the history of the adoption and acceptance of the theory of special relativity. Books have been written about that history and I'm not going to look at it further here.

Instead, returning to the second shortcoming, I now want to look at what Poincaré and Einstein wrote in their papers about what they were trying to do. This is necessarily a discussion of what they wrote in a particular place at a particular time. It does not consider their notes and ideas before they were organized and exposed for publication; it does not consider how they presented their work at a different time in a later publication. Then, to frame the discussion, I will look at some of the earliest contributions to the back-and-forth discussion about priority and also recent discussion about the discussion, and bring the chapter to a close.

Poincaré on What He Was Trying to Do

To get a more holistic view of what Poincaré thought he was trying to accomplish it is useful to look at what he wrote in the introduction (Poincaré, Sur la dynamique de l'électron, 1906a). There he lays out his plan for the paper, and several key considerations or approaches to his work are evident.

Poincaré starts his introduction with a summary of the evidence—ending with Michelson's experiment—that it is impossible to detect experimentally the absolute motion of the Earth. He accepts this as an experimental law and calls it the Relativity Postulate. The contraction proposed by Lorentz and Fitz Gerald accounts for the results of Michelson's experiment; this must be generalized to the Lorentz transformation to bring it into agreement with the full generality of the Relativity Postulate. Since electromagnetic phenomena are not altered by the Lorentz transformations (Poincaré will prove in this paper that Maxwell's equations are covariant), Poincaré concludes that electromagnetic phenomena in stationary and moving systems are indistinguishable ("the exact image of each other").

In brief, Poincaré has forged a chain from experimental evidence, with the relativity postulate and the Lorentz transformation, to the indistinguishability of inertial reference frames.

Poincaré continues the introduction with an application of the Lorentz transformation to electrons and consideration of the experimental results of Walter Kaufmann. This leads Poincaré to consider the shape and electromagnetic mass of moving electrons. He arrives at the conclusion that subatomic charged particles subject only to electromagnetic forces are not stable. For them to be stable, some additional, non-electromagnetic force is required that is "[comparable] to a constant external pressure"—this force is now referred to as "Poincaré stress."

The evidence with which Poincaré started the introduction dealt with electromagnetic and optical phenomena. Next in the introduction, Poincaré considers whether the relativity postulate and Lorentz transformation apply to phenomena with a different origin (such as gravitational phenomena), whether inertial mass is solely of electromagnetic origin, and how Newton's law of gravitation might need to be modified to be consistent with the relativity postulate and Lorentz transformation.

Poincaré concludes the introduction by asking whether there is some underlying explanation for the appearance of the speed of light as the speed of propagation of gravitational phenomena. Since the speed of light appears in descriptions of electromagnetic phenomena and gravitational phenomena, is there a connection between the two?

This leads to an analogy to Copernicus's work at the end of the introduction that some people have found obscure. Before Copernicus, in the Ptolemaic system, the Earth was taken as the center of the solar system and the apparent position of the planets calculated based on their motion around the Earth. Copernicus recast the calculations of the apparent positions in terms of the Sun at the center of the solar system and the Earth and other planets revolving around the Sun. In the Copernican system the motion of the Earth in a circle around the Sun in 365 days was explicitly present and appeared in the calculation of the Earth's position. In the calculation of positions in the Ptolemaic system, the circular orbit of the Earth with a 365-day period was implicitly present in the calculation of the position of each planet. A person looking at the Ptolemaic calculations might have reasonably asked why certain patterns repeated for each of the planets. Therefore, in his analogy, Poincaré looks back to Copernicus who by placing the Sun at the center of the solar system used the annual circular motion of the Earth around the Sun to explain the identical, repeated circles and travel times in the Ptolemaic system. We can look forward and, anachronistically, rephrase Poincaré's question to ask whether the place of the speed of light in an underlying theory explains its seemingly separate appearance in both electromagnetic and gravitational phenomena.

In this synopsis of the introduction to (Poincaré, Sur la dynamique de l'électron, 1906a), we can recognize several considerations important to Poincaré.

The first consideration is experimental evidence.

Immediately in the first paragraph of the introduction, we see the importance of reasoning from experimental results. The names of two experimentalists are cited in this paragraph; two more are named on the following page. Based on Michelson's experiment, Poincaré states the Relativity Postulate; Poincaré calls it a postulate because it could still "be confirmed or rejected by more precise experiments."[2] The Lorentz contraction is presented as a way to take into account the result of Michelson's experiment. We then observe Poincaré reasoning from this experimental basis to see what can be deduced and developed.

Next in the introduction, Poincaré refers to experiments by Kaufmann (measuring the charge-to-mass ratio and the dependence of electron mass on velocity). Poincaré mentions Kaufmann twice in the introduction but does not mention him again in the body of this paper. In the paper, (Poincaré, La dynamique de l'électron, 1908), Poincaré mentions Kaufmann by name nine times including in the title of §X. This is a point of departure for discussing the properties (radius and mass in particular) under Lorentz transformation.

The second consideration is the work of others in the field.

[2]In my paraphrase, his postulate is a statement about what nature has shown us (by experiment or observation) and not a statement about how nature is, fundamentally.

Lorentz's earlier paper (Lorentz, Electromagnetic phenomena in a system moving with any velocity smaller than that of, 1904) is critical to this paper by Poincaré (Poincaré, Sur la dynamique de l'électron, 1905a). Poincaré builds on it and, throughout he corrects, amplifies and clarifies. Poincaré also summarizes the work by Max Abraham on electron shape and Paul Langevin on electromagnetic waves.

The third consideration is an attitude of modesty seen as respect or deference to his colleagues.

Consider the statement at the end of the introduction to (Poincaré, La théorie de Lorentz et le principe de réaction, 1900, pp. 252, p. 8). Poincaré indicates that his objections (concerning the need for Lorentz's theory to conserve momentum) allow Lorentz's theory to show its hidden virtues and asks the reader, "to forgive me for having presented at such length ideas with so little novelty." Poincaré's handling of his divergences from Lorentz discussed at length in Chapter 9 in the letters translated in Chapter 3 reinforce this point.

The fourth consideration is identifying and using invariants.

Although not evident from the introduction, it is clear from Poincaré's other work and again here that he chooses to look for invariants. Here, (Poincaré, Sur la dynamique de l'électron, 1906a, p. 168; p. 93), below equation 4′, Poincaré looks for invariants of the Lorentz group. He finds that $x^2 + y^2 + z^2 - (ct)^2$ is an invariant. (Recall that in the units chosen by Poincaré, $c = 1$.) This is the spacetime interval that is invariant in Minkowski space. He also finds several other invariants and they are given in equations (5) and (7).

The fifth consideration is retaining what is thought to be known and established and working effectively.

As specific examples this means conservation of momentum (*principe de réaction*) and conservation of energy—stated differently these are both invariants of motion—and Newton's law of gravitation. A key consideration in (Poincaré, La théorie de Lorentz et le principe de réaction, 1900) is that Lorentz's theory of electricity and magnetism of moving bodies be adapted to conserve momentum. In adapting to satisfy this consideration, Poincaré concludes that electromagnetic radiation must transport momentum.

The negative side of this consideration is that Poincaré continues to retain and use the term ether in (Poincaré, La dynamique de l'électron, 1908). In adopting the relativity postulate, Poincaré denies the possibility of detecting absolute motion and it would seem that the ether should be abandoned too. Einstein writes that the ether is "superfluous" and makes a clean break. Poincaré could have made a clean break too; he continues to use the term. A physicist seeking to understand a phenomenon can certainly have a preference for one reference frame over another even if nature and the phenomenon do not impose that preference. Still his continued use of the term ether, which may previously have been a useful consideration, is problematic.

Einstein on What He Was Trying to Do

Turning now to Einstein's introduction to his work (Einstein, Zur Elektrodynamik bewegter Körper, 1905), he starts with the statement of a problem. To illustrate the problem, he describes a scenario with interaction between a magnet and a conductor. In one version of the scenario, the conductor moves at a constant velocity past a stationary magnet. In the other version, the conductor is stationary while a magnet moves past at a constant velocity. In both versions a current is produced in the conductor and the resulting magnitude and direction of the current produced is the same. The current produced cannot be used to determine whether the magnet or the conductor is moving; only the velocity of whichever one is moving can be determined. In contrast to the phenomenon just described the description of the two versions in "electrodynamics—as usually understood at present—" is different. Einstein characterizes this difference as an asymmetry. And so in his problem statement in the first sentence he writes, "electrodynamics... when applied to moving bodies, leads to asymmetries that do not seem to attach to the phenomena."

Following the discussion of symmetry in relative motion in electrodynamics in the first paragraph, Einstein observes in the second paragraph the failure to detect absolute motion of the Earth relative to the ether. Einstein says that this is a similar kind of example. Here the experimental results show that the ether (or equivalently absolute motion) cannot be detected. The phenomenon (aberration) is symmetric; it cannot show whether the distant star that is the source of the light is stationary and the Earth is moving or vice versa.

Einstein uses these two examples of symmetry as a basis for a conjecture that the phenomena do not have any properties corresponding to absolute rest. Accepting this conjecture, he raises it to the status of a postulate that he calls "the principle of relativity." He adds a second postulate to this: in empty space light always travels with a definite velocity independent of the motion of the emitting body. Armed with these two postulates, Einstein would seem to be ready to apply them to electrodynamics to investigate the consequences. Instead, he turns his attention to clocks and coordinate systems in the following section and says that insufficient attention to them is at the root of the difficulties. And that is the conclusion of the introduction.

At the time of writing this introduction and for the next several years, Einstein was employed as a patent examiner in the Swiss Patent Office in Bern. He was therefore familiar with the organization used in drafting patents. In general, that organization has an abstract, a statement of the field of the invention, a discussion of the prior art (meaning relevant, published work in the field of the invention) along with a discussion of an unresolved problem or opportunity in the prior art, a brief description of the invention addressing this problem or opportunity, a detailed description of the invention and finally the claims setting out the boundaries that characterize the invention. Looking at the beginning of Einstein's article in Annalen der Physik and applying this analogy with patent drafting, we see that Einstein has indicated the field of his work (electrodynamics, Maxwell's theory as currently understood), provided a brief statement of the problem present in the prior art (asymmetries in the treatment of phenomena involving relative motion) and then a brief description of the "invention" (the postulate of relativity and the postulate that the speed of light is a universal constant). He accomplishes this in a few more than 400 words; for comparison, a patent abstract (which Einstein does not provide) must preferably not exceed 150 words.

On the other hand, he has not identified or discussed the prior art, that is the scientific literature in the field. Famously, we do not know which (if any) works by Lorentz or Poincaré, or anyone else, he was familiar with. Seen one way, this allows some mythologizing to exist. As an undergraduate physics major, I heard that Einstein was in some way more philosopher, working on a different plane than ordinary physicists, and this was reflected in his considerations of symmetry, simultaneity and the speed of light. A stated consequence is that without Einstein's work on the subject special and general relativity would not have been developed until decades later and would have a substantially different form. Seen another way, the absence of a discussion by Einstein of what was in the prior art complicates our assessment and understanding of his reasoning and his understanding of the context of his theory. Both perspectives make assessment of priority more difficult.

A patent examiner, including Einstein, examining a patent application would look at the prior art (e.g. references and citations) disclosed in an application and would on their own search the published literature for additional prior art to identify the knowledge available to a person working in the field. The examiner organizes the result of this search in a search report. Comparison of the invention against the knowledge available to a person working in the field allows the examiner to determine whether the claimed invention is novel and nonobvious. It seems very curious that Einstein has not done this in his own work.

In the section following the introduction, Einstein starts his detailed description of the invention. There, he famously instructs his readers on how to tell time (and the importance of simultaneity). "We have to bear in mind that all our propositions involving time are always propositions about simultaneous events. If, for example, I say that 'the train arrives here at 7 o'clock,' that means, more or less,' the pointing of the small hand of my clock to 7 and the arrival of the train are simultaneous events."[3] This lesson in telling time applies to a person with a watch in hand standing on the platform next to the train pulling into the station. The situation becomes more complicated if the observer, clock and event are at separate locations. Here, Einstein uses surveyor's rods and light signals to set out a reference frame with synchronized clocks.

[3] An alternate translation, "We must take into account that all of our judgments in which time plays a role are always judgments about simultaneous events. If, for example, I say, 'That train arrives here at 7 o'clock,' it essentially means, 'The train arriving and the small hand of my watch pointing to 7 are simultaneous events.'" provided by Ken Kronenberg. Personal communication, December 2016.

With the synchronized clocks and surveyed framework in place, he can then use the two postulates (the relativity postulate and that the speed of light in empty space is a universal constant, independent of movement of the emitter) to determine the Lorentz transformations as a consequence.

As with Poincaré above, in this synopsis of the introduction to (Einstein, Zur Elektrodynamik bewegter Körper, 1905), we can recognize several considerations important to Einstein.

Directly with the first sentence, Einstein brings up the importance of alignment between natural phenomenon and theoretical explanation. He rejects a theoretical explanation that is asymmetric for a natural phenomenon that is symmetric. When a conducting coil moves past a stationary magnet at a constant velocity, a certain current is produced in the coil and the same current is produced when a magnet moves past a conducting coil at a constant velocity. An essential minimum constraint on the theory is that the theory correctly explains the magnitude of the current in both configurations. Einstein is further demanding that the explanation intrinsic to the theory be symmetric for both configurations. His consideration of this symmetry in the phenomenon motivates him to incorporate the principle of relativity into his theory.

The second consideration is that the speed of light is constant. Where Poincaré anticipates some underlying connection or significance for the speed of light, Einstein promotes it to a fundamental, universal constant.

The third consideration relates to reference frames. Here Einstein starts by explaining how to tell time at one point: it involves the simultaneity of the hands on his watch and the position of the train next to him and then sets out a reference frame with synchronized clocks. The importance of simultaneity becomes clear now because two events that are simultaneous in one reference frame might not be simultaneous in a different reference frame moving with a constant velocity. This leads to aptly emphasizing the importance of identifying the relevant reference frames and correctly using them. This is a key step in understanding many paradoxes presented in special relativity. Is the half-life of the meson formed high in the Earth's atmosphere measured in the reference frame of the observer on the Earth's surface or in the reference frame of the meson traveling at a high velocity relative to the observer?

The Start of the Dispute: Edmund Whittaker

The title of E. T. Whittaker's book, "A History of the Theories of Aether and Electricity, the Modern Theories, 1900–1926" (Whittaker, 1953), is curious. In fact, it is a second volume; about 50 years earlier Whittaker wrote a first volume covering a long swath of the history of physics with understanding of the ether as an organizing theme. The preface to this second volume starts, "The purpose of this volume is to describe the revolution in physics which took place in the first quarter of the 20th century." For a book covering this period, the use of ether in the title seems anachronistic. Whether you look to Poincaré (Poincaré, Sur la dynamique de l'électron, 1906a) or Einstein (Einstein, Zur Elektrodynamik bewegter Körper, 1905), ether appears to receive a death blow at the beginning of the quarter-century he proposes to cover. For Poincaré, the failure to detect absolute motion relative to the ether leads to the Relativity Postulate. This makes the ether unnecessary for Poincaré, although it does continue to appear in his writing, in some cases just to argue for the impossibility of the properties it would be required to have. For his part, Einstein writes, "introduction of a 'light ether' will prove superfluous" because there is no space at absolute rest. How can a book about physics in the 20th century have ether in the title?

The title of the second chapter of Whittaker's book is likewise curious, and also provocative; it is "The Relativity Theory of Poincaré and Lorentz." Why isn't it, Einstein's Theory? A plausible first reaction might be that Whittaker is trying to completely write Einstein out of the history of physics. Referring to the table of contents, we can see that Einstein's name appears there nine times in subchapter titles. So, we see that Einstein has not been written out, but his position in the history of both special and general relativity has been greatly marginalized. Within the second chapter, Einstein's name appears five times. When it first appears, Whittaker writes, "In the autumn of [1905]… Einstein published a paper which set forth the relativity theory of Poincaré and Lorentz with some amplifications, and which attracted much attention." The same paragraph ends with the second mention of Einstein's name and credits him with modifications made to the formulas for aberration and Doppler effect. (Einstein's name appears once more in this context and twice in connection with the formula "$E = mc^2$.") It is a stunning demotion and calling it provocative seems like understatement.

At this point a digression seems well justified. Whittaker (A History of the Theories of the Aether and Electricity, The Modern Theories, 1953, p. 51), writes, "In 1900 Poincaré,[3] referring to the fact that in free ether the electromagnetic momentum is $(1/c^2)$ times the Poynting flux of energy, suggested that electromagnetic energy might possess mass density equal to $(1/c^2)$ times the energy density: that is to say, $E = mc^2$ where E is energy and m is mass." His footnote 3 is a reference to (Poincaré, La théorie de Lorentz et le principe de réaction, 1900) translated in Part I. In that paper, Poincaré is concerned with the transport of momentum by electromagnetic radiation, which he shows is necessary for conservation of momentum. He does relate this to the Poynting vector; he does not take the additional step of connecting the momentum of the electromagnetic radiation to an inertial mass. As Whittaker continues his discussion on the following page, he references in footnote 4 (Einstein, Das Prinzip von der Erhaltung der Schwerpunktsbewegung und die Traegheit der Energie, 1906). In the introduction to that paper, Einstein states that "the conclusion that the mass of a body changes with the change in its energy content… is the necessary and sufficient condition for the law of the conservation of motion of the center of gravity to be valid" in systems with both mechanical and electromagnetic processes. This is closely related to the statement that conservation of momentum requires that electromagnetic radiation carry momentum. Einstein in the next sentence states, "the simple formal considerations that have to be carried out to prove this statement are in the main already contained in a work by H. Poincaré" and references (Poincaré, La théorie de Lorentz et le principe de réaction, 1900).[4] Up to a point Einstein and Poincaré follow similar reasoning. Einstein takes the additional step of relating the inertial mass and the energy. Had Poincaré thought of it, it would have been a small step beyond what he had done to relate the momentum of the electromagnetic radiation to an inertial mass and show that the mass is equal to E/c^2. He didn't take the step. We need to be careful not to credit Poincaré with a discovery that is implicit in the physics but not explicit in his writing because our knowledge of subsequent work allows us to see what is close at hand but not firmly grasped. As for Whittaker's statement quoted above, I have not found support, which is clear and does not need hindsight, in the paper by Poincaré he referenced, or in other papers I looked at.

Returning to the analogy of patent examination used above, it can be seen that there is one thing of value that Whittaker has provided in this chapter: a search report. In the footnotes, among other citations, Whittaker cites the following from before July 1905: (Poincaré, La théorie de Lorentz et le principe de réaction, 1900), (Poincaré, Électricité et optique, 1901), (Poincaré, L'état actuel et l'avenir de la physique mathématique, 1904), (Poincaré, Sur la dynamique de l'électron, 1905a), (Lorentz, Electromagnetic phenomena in a system moving with any velocity smaller than that of, 1904), two earlier works each by Poincaré and Lorentz and one work by Joseph Larmor. In preparing a search report, the patent examiner looks for the most relevant published sources from before the priority date and avoids accumulating redundant sources. Unlike a patent examiner, Whittaker was not explicitly preparing a search report, instead he was citing references that support his historical narrative of the development of the theory. This does not answer questions about what Einstein knew about this context, and when he knew it; it does show that other people were publishing papers on questions that in hindsight we can recognize as related.

Inclusion of a source in a search report indicates that the source needs to be considered in evaluating the patent but does not demand a particular conclusion by the examiner. Also, the examiner may well find things that were not unknown to the inventor; this reflects a difference in their roles and perspectives.

There is a place for the patent examiner to provide a written opinion on the patentability of the patent application and to reject, object or grant the application. In this chapter of his book, Whittaker has written his view of the historical development of the theory of special relativity. It is that view and the perceived provocation, that led to the voluminous discussion of priority.

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[4]This appears to be the only citation by Einstein up to at least 1920 of a publication by Poincaré.

Contemporary Reactions from Physicists

Some of the earliest reactions to Whittaker's demotion of Einstein came from physicists whose remarks seem to get slipped into other writings as short paragraphs.

Chronologically the first reaction appears to be from Louis de Broglie. It came roughly within the year after publication of Whittaker's book and appeared in a preface that de Broglie wrote for volumes IX and X of Poincaré's collected papers (de Broglie, 1954). In a paragraph in the preface, de Broglie wrote:

> *"Poincaré's celebrated paper on the Dynamics of the Electron published in 1906 in the minutes of the mathematics circle of Palermo, after having been summarized in a Note to the Minutes [of the Académie des sciences], is still very interesting to reread today. Commenting on the Lorentz transformation and the ideas of the illustrious Dutch physicist on the contraction of moving bodies and on local time, Henri Poincaré completely developed the new dynamics of the electron which followed from it: he made a connection to the theory of electromagnetic radiation that Paul Langevin had just laid out in a beautiful work and he compared the various assumptions that one could make about the structure of the electron and its deformation resulting from its movement. Poincaré thus established the new relativistic dynamics of the electron on a solid base which even now has many applications: he thus accomplished a work of major importance, but at the same time, perhaps because he was more mathematician than physicist, he did not grasp the general viewpoint supported by a minute critique of the measurement of distances and times that the young Albert Einstein discovered with an inspired intuition and which led to a complete transformation of ideas about space and time. Poincaré did not take this decisive step, but he is, with Lorentz, the one who most contributed to making it possible. Let us remark on an important point from Poincaré's paper: the discovery of the fact that an electron as Lorentz had conceived it is not stable under the action of electromagnetic forces alone, that its stability requires the involvement of another force, of unknown nature, deriving from a potential proportional to the volume of the electron. This 'Poincaré pressure', which can be interpreted as indicating the incomplete nature of our usual understanding of the electromagnetic field, still has even now all of its importance and it is often a question in the most recent works on the structure of the electron. This was a major discovery in physics by the leading mathematician."*

In the first edition in 1962 (Jackson, Classical Electrodynamics, 1962), Jackson wrote on page 353, "By supposing that all matter was essentially electromagnetic in origin and so transformed in the same way as Maxwell's equations, Lorentz was able to deduce the contraction law (11.10). Then Poincaré showed that the transformation of charges and current densities could be made in such a way that all the equations of electrodynamics are invariant in form under Lorentz transformations. In 1905, almost at the same time as Poincaré and without knowledge of Lorentz's paper, Einstein formulated special relativity in a general and complete way, obtaining the results of Lorentz and Poincaré, but showing the ideas were of much wider applicability. Instead of basing his discussion on electrodynamics, Einstein showed that just two postulates were necessary one of them involving a very general property of light." This statement does not appear in the third edition (Jackson, Classical Electrodynamics, 1999).

Chapters 15 and 16 of The Feynman Lectures on Physics, vol. 1 (Feynman, Leighton, & Sands, 1963) contain scattered references to contributions by Poincaré to special relativity. Most notably, Chapter 16 starts, "In this chapter we shall continue to discuss the principle of relativity of Einstein and Poincaré." The following paragraph in that chapter quotes Poincaré's statement of the principle of relativity from (Poincaré, L'état actuel et l'avenir de la physique mathématique, 1904).[5]

Gerald Holton's Response to Edmund Whittaker

The first specific response to the provocation by Whittaker comes from Gerald Holton (Holton, 1960), which falls chronologically between the quotes from de Broglie and Jackson above. In his paper, Holton takes up the challenge in the last titled section "Whittaker's Account of the Origins of Einstein's Work." Holton states the topic of the dispute as, "to what extent Einstein's work was original rather than anticipated by, or specifically based on other published work." In (Whittaker, 1953), there is not a comparable statement of intent; maybe Whittaker saw this as a case of near simultaneous, independent discovery and told the history from the perspective of the first to submit a manuscript to the publisher or again maybe Whittaker was biased against Einstein, due to his attachment to the ether that extended to the title of his book, because Einstein called the ether superfluous (see above) whereas Poincaré had not fully abandoned it. It seems very hard to read into (Whittaker, 1953) a suggestion of misconduct by Einstein.

Holton does not indicate what use "of other published work" was suggested by Whittaker—although he does repeatedly insist that Einstein had not seen or read (Lorentz, Electromagnetic phenomena in a system moving with any velocity smaller than that of, 1904)—and refers instead to bias and the need to analyze Whittaker's work by dealing "with the prior commitments and prejudices of the scholar himself." (Holton, 1960, p. 634) Holton then provides seven main findings from considering Whittaker's work in light of potential bias.

Instead of considering that direction further, I want to turn to what Holton both does and does not say about Poincaré's work. After Holton notes that Whittaker has not recanted his earlier provocation, Holton states that Whittaker "repeats that Poincaré in a speech in St. Louis, USA, in September 1904(27) had coined the phrase 'principle of relativity.'" Footnote 27 cites (Poincaré, L'état actuel et l'avenir de la physique mathématique, 1904) and the English translation by G. B. Halsted in (Poincaré, The Principles of Mathematical Physics, 1905b). Holton in this quote is denying that Poincaré coined (or at least used) the phrase "principle of relativity" in 1904. About a page later in his second finding, he again refers to (Poincaré, L'état actuel et l'avenir de la physique mathématique, 1904). He first states that it "turns out

[5]The translation quoted by Feynman is accurate but does not exactly follow the translation by G. B. Halsted published in (Poincaré, The Principles of Mathematical Physics, 1905b) and in (Poincaré, The Value of Science, 1907), or the translation by J. W. Young in (Poincaré, The Present and the Future of Mathematical Physics, 1906b).

not to enunciate the new relativity principle" and then provides a direct quote from Halsted's translation starting, "'the principal of relativity, according to which the laws of physical phenomena should be the same whether for an observer fixed or for an observer carried along in a uniform motion [of] translation...'." Astonishingly, this is the same statement used in full by Feynman (Feynman, Leighton, & Sands, 1963) at the beginning of chapter 16, as noted above. On the other hand, Holton does not cite (Poincaré, Sur la dynamique de l'électron, 1906a); this work would be highly relevant to any discussion of independent discovery, but would not be relevant to discussion of the bases of Einstein's work since it had been submitted for publication but not yet published at the time Einstein submitted his paper. In an article communicated by Gerald Holton, Arthur Miller (A study of Henri Poincaré's "Sur la Dynamique de l'Électron", 1973) does discuss this article by Poincaré, but the general tone seems less than kind.

Conclusion

Provocation of the Einstein camp by Whittaker was met by provocation of the Poincaré camp by Holton; polemic was met with polemic; and the ink started to flow. The result is on the whole unappealing.

The translations in Part I accompanied by the discussion in the two previous chapters, Chapters 9 and 10, can help the reader do their own careful alignment of what Poincaré and Einstein each wrote in 1905. This is a necessary step for any meaningful comparison and the result will certainly show areas of substantial agreement, allowing for differences in modes of expressing their ideas.

Poincaré's writing is clear but concise. It still leaves plenty of room for his readers to fill in steps and look between the lines, a point that was brough up late in Chapter 10. This contributes an interesting challenge in reading Poincaré as there is also room for misinterpretation or misunderstanding. It also provides insight into how Poincaré reasoned and mustered his arguments.

Chapter 10 looks at points where Poincaré appeared to be well positioned for making clear predictions or breaking from formerly useful ideas that had lost their place. This may lead you to ask, along with me, "Why doesn't he just say that there is no need for an ether that cannot be detected?" The section "Attitude" in that chapter mentions some reasons (although it might be better to call it speculation) why he didn't. There is no satisfactory answer. Perhaps the reason is that Poincaré saw his role in physics as collecting, cataloging and explaining, and as excluding predicting and extrapolating. That could also point the direction to an answer to the question, "Why didn't Poincaré make a response in some form to Einstein's 1905 and 1906 papers?"

My discussion of (Poincaré, Sur la dynamique de l'électron, 1906a) in Chapter 9 indicates in footnotes sections from (Einstein, Zur Elektrodynamik bewegter Körper, 1905) that may align with Poincaré's work being discussed. It may show areas where Poincaré is ahead of Einstein; it does show areas, notably Einstein's sections 1 and

2, that don't seem to have anything with which they could be aligned in (Poincaré, Sur la dynamique de l'électron, 1906a).

When Poincaré wrote about the space-time invariant and invariance of the continuity equation for charge, he may have been close to anticipating four-vectors introduced by Minkowski two years later. Poincaré certainly wrote about a variety of subjects—notably electron shape and stability—that were outside the more focused scope covered by Einstein. The discussion in Chapter 9 of the "first divergence" of Poincaré from Lorentz and his proof of the space-time invariant indicates that Poincaré understood the Lorentz transformations as transformations between coordinate systems including time and three spatial coordinates and even understood that this resulted in mixing space and time coordinates. Poincaré's discussion of local time in (Poincaré, La théorie de Lorentz et le principe de réaction, 1900) also needs to be mentioned in this context. It is still clear that Poincaré did not give the consideration to time and the impact on simultaneity of this mixing that Einstein did.

It therefore has to be noted that Poincaré has no dramatic statements about trains arriving in stations, no discussion of simultaneity and no suggestion that conclusions about simultaneity depend on the inertial reference frames selected. There does not seem to be anything in Poincaré's writing translated in Part I of this book that is comparable to (Einstein, Zur Elektrodynamik bewegter Körper, 1905) sections 1 and 2.

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