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Heuristics versus norms: On the relativistic responses to the Kaufmann experiments

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ABSTRACT

The aim of this article is to provide a historical response to Michel Janssen's (2009) claim that the special theory of relativity establishes that relativistic phenomena are purely kinematical in nature, and that the relativistic study of such phenomena is completely independent of dynamical considerations regarding the systems displaying such behavior. This response will be formulated through a historical discussion of one of Janssen's cases, the experiments carried out by Walter Kaufmann on the velocity-dependence of the electron's mass. Through a discussion of the different responses formulated by early adherents of the principle of relativity (Albert Einstein, Max Planck, Hermann Minkowski and Max von Laue) to these experiments, it will be argued that the historical development of the special theory of relativity argues against Janssen's historical presentation of the case, and that this raises questions about his general philosophical claim. It will be shown, more specifically, that Planck and Einstein developed a relativistic response to the Kaufmann experiments on the basis of their study of the dynamics of radiation phenomena, and that this response differed significantly from the response formulated by Minkowski and Laue. In this way, it will be argued that there were, at the time, two different approaches to the theory of relativity, which differed with respect to its relation to theory, experiment, and history: Einstein's and Planck's heuristic approach, and Minkowski's and Laue's normative approach. This indicates that it is difficult to say, historically speaking, that the special theory of relativity establishes the kinematical nature of particular phenomena. Instead, it will be argued that the theory of relativity should not be seen as a theory but rather as outlining an approach, and that the nature of particular scientific phenomena is something that is open to scientific debate and dispute.

1. Introduction

Recently, Michel Janssen (2009) has argued, by means of three historical cases, that the special theory of relativity establishes that various phenomena, previously thought to require an explanation in terms of the dynamics of the system displaying the behavior, can in fact be given an entirely kinematical explanation, and that this entails that the relativistic study of these phenomena is completely independent of the system's dynamics. One of these cases concerns Walter Kaufmann's experiments on the velocity-dependence of the electron's mass. While Hendrik Lorentz and Max Abraham attempted to account for Kaufmann's results in terms of the dynamics of the electron, special relativity shows, according to Janssen, that the phenomenon is independent of the dynamics underlying the system displaying it, and that it is rather a consequence of the relativistic space-time in which the system displays this behavior. Janssen argues for this claim, more specifically, by means of three historical claims: (i) that Albert Einstein's (1905a) derivation of the relativistic equations describing the velocity-dependence of mass shows that he saw that the phenomenon was purely kinematical; (ii) that the relativistic account of the velocity-dependence of mass was mainly elaborated and accepted on the basis of theoretical considerations; and (iii) that the work by Max von Laue clearly shows the kinematical nature of the phenomenon because it makes use of Hermann Minkowski's space-time geometry, which forms the natural interpretation of the theory of special relativity.

In this article, I will argue that the historical development of the theory of special relativity argues against Janssen's claims (i)-(iii). By means of a discussion of how different adherents of the principle of relativity (Einstein, Max Planck, Minkowski and Laue) responded

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to the issues raised by Kaufmann's experiments, I will argue, in particular, for the following claims: (i) that both Einstein and Planck did not consider the phenomenon to be purely kinematical in nature, and that dynamical considerations, based on their study of radiation phenomena, did play an important role in the development of their response to Kaufmann's experiments; (ii) that besides theoretical considerations, experimental and historiographical factors also played an important role in the establishment of a relativistic account of the experiments; and (iii) that this shows that both Einstein and Planck adhered to a heuristic approach to the theory of relativity that differed profoundly from what I will call Minkowski's normative approach, and that therefore, historically speaking, we should not see the Minkowskian framework as necessarily offering the natural interpretation of the theory of relativity. Through the elaboration of these three points, I will then argue that Laue's work does not completely address the issues raised by Kaufmann's experiments, but rather sidesteps them in certain ways, because of its use of the Minkowskian approach. By contrasting the Minkowskian normative approach with the Einsteinian heuristic approach, I will then conclude that it is difficult to claim that the theory shows that the velocity-dependence of mass is kinematical in nature. The historical discussion rather shows that such characterizations of the nature of a phenomenon are dependent on a particular scientist's aims and interests, and are therefore open to scientific debate and dispute.

In order to achieve this, I will proceed as follows. I will start in section 2, with a short discussion of Janssen's general philosophical claims and his historical discussion of the Kaufmann experiments. After that, I will turn to a discussion of the historical episode (section 3), in which I will focus on Janssen's historical claims (i)-(iii). In section 4, I will then elaborate some concluding remarks.

2. Janssen's discussion of the Kaufmann experiments

The following statement perfectly summarizes the essential novelty of Einstein's Special theory of Relativity (*STR*), according to Janssen (2009, p. 26): “Einstein was the first to formulate clearly the new kinematical foundation for all of physics inherent in Lorentz's electron theory” (Stachel et al., 1989, p. 253). The theory's main accomplishment, on this reading, was that it showed that relativistic phenomena such as time dilation and length contraction are purely kinematical. That a phenomenon is kinematical means, on Janssen's view, that “it is just an instance of some generic feature of the world, in this case instances of default spatio-temporal behavior” (2009, p. 27). Janssen elaborates this claim by means of a distinction between two kinds of kinematical phenomena: phenomena are kinematical in the broad sense if they are “independent of the specifics of the dynamics”; they are kinematical in the narrow sense if they are “an example of standard spatio-temporal behavior” (2009, p. 28). STR now shows that certain phenomena are kinematical in both senses, which entails that nothing more is to be learned from them: “[u]nless one challenges the classification of the phenomenon as kinematical in this sense — and the *universality* of the relevant feature will militate strongly against that — there is *nothing* more to learn from that particular phenomenon, neither about the specific system in which it occurs nor about the generic feature it instantiates” (Janssen, 2009, p. 27; original emphasis).

Janssen's argument for this claim consists of three particular historical episodes in which STR established the kinematical nature of particular phenomena previously thought to require a dynamical account[2]: refraction in moving media and the Fresnel drag coefficient (2009, p. 29–32); the Kaufmann experiments and the velocity-dependence of mass (2009, p. 32–41); and the Trouton-Noble experiment (2009, p. 41–47). Each of these cases shows, according to Janssen, how STR explains these phenomena “by identifying the kinematical nature (rather than the cause)[3] of the relevant phenomena” (2009, p. 28). As such, the best way to clarify and illustrate Janssen's general claim is through a historical and philosophical discussion of one of these cases, namely the Kaufmann episode. The main reason for discussing this episode is that, as Janssen points out, it has not yet received the philosophical attention it deserves, especially since the Kaufmann experiments were central to the debate in the scientific community at the time.[4] Moreover, while they were taken by Poincaré, Lorentz and others to pose serious issues for the theory of relativity at the time (see (Miller, 1981, p. 334–335) and (Staley, 2008, chapters 6 and 7)), relatively little has been written about the development of a relativistic response. Finally, the discussion of the historical episode suggests an interesting point, which is that the elaboration of a relativistic theory really only started in the years after the publication of Einstein's (1905a). The main reason for discussing Janssen's philosophical claim from a historical perspective is that he himself also favours this approach: he describes his work as “a brand of philosophy of physics informed by (conceptual) history of physics” (2009, p. 28).[5]

Pre-relativistic treatments of the Kaufmann experiments. Between 1901 and 1906, Walter Kaufmann carried out a series of experimental measurements of the exact dependence of the electron's mass on its velocity, with the goal to provide insight into the electron's constitution. Such a dependence was first hinted at by J. J. Thomson, who claimed that if the electron moves through its own electromagnetic field, it should experience a decrease in velocity as if it had gained mass (Staley, 2008, p. 219) (Miller, 1981, p. 46). While Thomson presented this as merely a mathematical hypothesis, the idea gained physical meaning a few years later. The first to elaborate the physical content of this dependence was H. A. Lorentz (1899). In the first part of this article Lorentz presents a new, simplified, formulation of the transformation equations for coordinates and electric and magnetic fields he had proposed in his *Versuch* (1895). In the second part, he then elaborates some of the physical consequences of the deformation hypothesis he had presented earlier in response to the result of the Michelson-Morley experiment, by considering its implications for a particular example, i.e. an oscillating electron. Determining the specific transformation equations for the forces and accelerations involved in such a system then leads him to suggest that the mass of an electron in motion depends on its velocity. Janssen formulates Lorentz's hypothesis as follows:[6]

[2] These are the specific examples that Janssen presents as arguments for his general claim. His reason for discussing these is that they have not received the philosophical attention they deserve (Janssen, 2009, p. 29) in comparison with e.g. the Michelson-Morley experiment, which, he claims, also backs up his claim (Janssen, 2009, p. 48).

[3] Such causal interpretations of STR, as offered for example by Harvey Brown in his (2005) book, are the main foil of Janssen's argument. In short, Brown's dynamical account of special relativity comes down to the claim that the relativistic phenomena should not be accounted for in terms of space-time geometry, but rather in terms of the dynamics underlying these phenomena.

[4] As we will see, Kaufmann was the first to discuss Einstein's (1905a) relativity article, and it was mainly in the context of the issues raised by the experiments that Einstein's work was elaborated, discussed and criticized (Staley, 2008, p. 242–243).

[5] Besides his (2009), Janssen also has an extensive article on this case with Matthew Mecklenburg (2006).

[6] See Janssen and Mecklenburg (2006, p. 75–80) for a more extensive discussion of how Lorentz arrives at this claim.