Einstein's Ether: F. Why did Einstein Come Back to the Ether?

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According to conventional wisdom, Poincaré failed to derive a relativity theory mainly as a result of his stubborn adherence to the ether. In (1905) Einstein constructed a relativity theory that was based on the assertion that the ether was superfluous. In 1908 Minkowski formulated the theory of the "absolute world". The nineteenth century ether no longer existed. A new kind of ether (space-time) came into being. One could keep on maintaining the ether, and at the same time strip it of the notion of absolute rest. Einstein seemed to agree, and after 1916 he returned to the ether. In 1920 he combined Minkowski's absolute world concept and Mach's ideas on rotational movements: in order to cancel action-at-a-distance, the inertial interactions between matter and fixed stars should be mediated by a medium. Einstein called Mach's medium "Mach's ether". In this paper I demonstrate that Einstein's 1920 reasoning hardly differed from the one Poincaré had presented prior to 1905. Thus, whil Einstein was a hero because he did away with the ether, this situation lasted a few years only. This is not to underestimate the magnitude of

Einstein's achievement, but to emphasize the limits of simplistic comparisons between Einstein and Poincaré.

Introduction

Mach himself had already noticed the problem regarding instantaneous action-at-a-distance (Mach, 1893, pp. 295-296; English translation):

> *Nobody would believe that the chance disturbance—say by an impact—of one body in a system of uninfluenced bodies which are left to themselves and move uniformly in a straight line, where all the bodies combine to fix the system of coordinates, will immediately cause a disturbance of the others as a consequence.*

And the relative motion (1893, p. 282): "[…] is determined by a *medium* in which K exists. In such a case we should have to substitute this medium for Newton's absolute space". Therefore (Mach, pp. 282-283):

> *We should [...] have to picture to ourselves some other medium, filling, say, all space, with respect to the constitution of which and its kinetic relations to the bodies placed in it we have at present no adequate knowledge. In itself such a state of things would not belong to the impossibilities. [...] we might still hope to learn more in the future concerning this hypothetical medium; and from the point of view of science it would be in every respect a more valuable acquisition than the forlorn idea of absolute space.*

Einstein solved Mach's problem by using Poincaré's ideas and Minkowski's ideas (see my three papers "Poincaré's ether" for

Poincaré's ideas). He corrected Poincaré's reasoning and he called Mach's "hypothetical medium" the ether (as Poincaré did), but Einstein's ether was not at absolute rest. Einstein then identified this new ether with space-time in accordance with Minkowski's "absolute world" concept:

Minkowski formulated the theory of the "absolute world" in his lecture, "Space and Time" (1908, p. 107): the laws of nature are invariant under the Lorentz group. The words "Relativity Postulate" mean the requirement of invariance under the Lorentz group. The postulate means that only the four-dimensional world (*i.e.*, space-time) in space and time is given by phenomena. Projection in space and in time may still be undertaken with a certain degree of freedom. Therefore, Minkowski called the postulate of relativity, "the postulate of the absolute world" (*Postulat der absoluten Welt*). The Lorentzian nineteenth century ether, corresponding to the idea of absolute rest, no longer existed; however a new kind of ether (*i.e.* the space-time substratum) did exist. Minkowski's ether, the four-dimensional space-time, lacked the idea of motion. It did not include the idea of absolute rest. One could maintain the ether, and yet at the same time strip it of the notion of absolute motion. One could call it ether if one wished to use this name.

Einstein was inspired by the above ideas, and suggested the curved space-time of the general theory of relativity as that medium, calling it the ether. The Machian point of view concerning the problem of rotation in physics demanded a medium that would convey the Machian-Einsteinian inertial and gravitational effects. This medium was termed "Mach's ether" by Einstein (see quotation below). Therefore, the problem of rotation demanded a solution in the form of the ether. This conclusion had already been reached by Poincaré in 1900. In 1920 Einstein repeated Poincaré's claims of (1900), which had been reprinted in his popular book (1902), which Einstein, as it will be recalled (see my paper "Poincaré's ether part A"), had read before 1905. I shall examine this state of affairs.

Einstein returns to the ether

After 1916, Einstein returned to a revised form of the ether concept as a result of the general theory of relativity. In a letter to Lorentz dated 17 June 1916, Einstein wrote (quoted in Miller, 1986, p. 55; see also Kostro, 1988, p. 238):

> *I agree with you that the general relativity theory admits of an ether hypothesis as does the special relativity theory. But this new ether theory would not violate the principle of relativity. The reason is that the state [...metric tensor] = Aether is not that of a rigid body in an independent state of motion, but a state of motion which is a function of position determined through the metrical phenomena.*

In 1920 at a lecture in Leiden, Einstein explained why a revised notion of the ether was required in physics. He repeated Poincaré's claims of 1900, presented at the Paris physics congress, and which were reproduced in *Science and Hypothesis* (1902), according to which ether is required in order that movements do not take place with respect to empty space (see my paper, "Poincaré's ether part B" for Poincaré's reasoning; Einstein, 1920, p. 11):

> *[...] there is a weighty argument to be adduced in favour of the ether hypothesis. To deny the ether is ultimately to assume that empty space has no physical qualities whatever. The fundamental facts of mechanics do not harmonize with this view. For the mechanical behaviour of a corporeal system [Newton's bucket experiment]*

hovering freely in empty space depends not only on relative positions (distances) and relative velocities, but also on its state of rotation, which physically may be taken as a characteristic not appertaining to the system in itself. In order to be able to look upon the rotation of the system, at least formally, as something real, Newton objectivizes space. Since he classes his absolute space together with real things, for him rotation relative to an absolute space is also something real. Newton might no less well have called his absolute space "Ether"; what is essential is merely that besides observable objects, another thing, which is not perceptible, must be looked*

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* Newton already thought there was a need for an ether to negate action-at-distance interactions. In 1693, in a letter to Bentley, Newton wrote (quoted in Jourdian, 1915, p. 252):

> *That gravity should be innate, inherent, and essential to matter, so that one body may act upon another at a distance through a vacuum, without the mediation of anything else, and by and through which their action and force may be conveyed from one to another, is to me so great an absurdity that I believe no man who has in philosophical matters a competent faculty of thinking can ever fall into it. Gravity must be caused by an agent acting constantly according to certain laws, but whether this agent be material or immaterial I have left to the consideration of my readers.*

In the Scholium, at the end of the eleventh section of the first book of the *Principia*, Newton explained that this agent might be the ether (Jourdian, 1915, p. 238):

> *I here use the word attraction for any endeavor whatever made by bodies to approach each other; whether that endeavor arise from the action of the bodies themselves as tending mutually to, or agitating each other by spirits emitted; or whether it arises from the action of the ether or of the air or of any medium whatever [...]*

> *upon as real, to enable acceleration or rotation to be looked upon as something real.*

Poincaré postulated ether as possessing the following mechanical quality: the ether is at absolute rest. Already in 1905 Einstein eliminated the notion of absolute rest. In 1920 he saw the need for an ether so that there would be no rotation with respect to absolute space. However, Einstein held that this ether, without its Lorentzian properties, did not contradict the theory of relativity (1920, p. 7):

> *[…] the whole change in the conception of the ether, which the special theory of relativity has brought about, has consisted in taking away from the ether its last mechanical quality, namely, its immobility.*

Einstein corrected the following misconception held by 19th century scientists, asserting that absolute space was beyond the scope of physics. In contrast, absolute rest was an acceptable physical notion.

Einstein also objected to the conception of action-at-a-distance, like the one mediated through empty space by the fixed stars to the bucket. He therefore added the revised form of Poincaré's (1900) ether (which he named "Mach's ether"), which served as Mach's 1893 medium for the effects of the inertia of the fixed stars (see part C; 1920, pp. 11-12).

> *It is true Mach tried to avoid having to accept as real something which is not observable by endeavouring to substitute in mechanics a mean acceleration with reference to the totality of masses in the universe in place of an acceleration with reference to absolute space. But inertial resistance opposed to relative acceleration of distant masses presupposes action at a distance; and as the modern physicist does not believe that he may accept*

> *this action at a distance, he comes back once more, if he follows Mach, to the ether, which has to serve as a medium for the effects of inertia. But this conception of the ether to which we are led by Mach's way of thinking differs essentially from the ether conceived by Newton, by Fresnel, and by Lorentz. Mach's ether not only* conditions *the behaviour of inert masses, but* is also conditioned *in its state by them.*

The above quality of Mach's ether stems from the general relativistic qualities (1920, p. 12):

> *The metrical qualities of the continuum of space-time differ in the environment of different points of space-time, and are partly conditioned by the matter existing outside of the territory under consideration.*

This situation excludes action-at-a-distance, and brings back the ether in its new form ("Mach's ether") as the general relativistic space-time. Einstein concluded (Einstein, 1920, p. 15):

> *Recapitulating: we may say that according to the general theory of relativity space is endowed with physical qualities; in this sense, therefore, there exists ether. According to the general theory of relativity space without ether is unthinkable; for in such space there not only would be no propagation of light, but also no possibility of existence for standards of measuring rods and clocks, nor therefore any space-time intervals in the physical sense. But this ether may not be thought of as endowed with the quality characteristic of ponderable media, as consisting of parts which may be tracked through time. The idea of motion may not be applied to it.*

Kostro wrote (1988, p. 239) that "on the basis of the principle of equivalence of energy and mass Einstein arrived at the conclusion that there is no qualitative difference between the real physical space and ponderable matter composed of particles. Real physical space, as an active field possessing energy (and therefore also mass) constitutes an active matter […] an ether". Kostro then quoted Einstein who said in 1930 (Kostro, 1988, p.239):

> *[…] that now it appears that space will have to be regarded as a primary thing and that matter is derived from it, so to speak, as a secondary result. Space is now having its revenge, so to speak, and is eating up matter.*

Although Poincaré did not arrive at the equivalence of energy and mass (see Granek, 2000), in 1909 he had suggested a conception quite similar to Einstein's above reasoning. Poincaré suggested the following conception of matter, which was based on the electromagnetic world-picture views: inertia of matter (electrons) was the inertia of the ether, caused by self-induction. The ether's inertia (apparent mass of the electron) increased with velocity and became infinite when the velocity tended towards that of light. The real mass of the electron stayed constant but it was negligible in relation to the apparent mass and could be considered as null. Therefore, if the apparent mass was the mass that constituted matter, we could almost claim there was no matter anymore (1909, p. 11):

> *In this new concept, the constant mass of matter disappeared. The ether alone, and not matter anymore, was inertial. Only the ether opposed to a resistance to motion, thus one could say: there was no matter, there were only holes in the ether.*

The reasoning that Einstein gave for his adherence to a new kind of ether seemed to indicate that Poincaré inspired Einstein when he revived the notion of the ether. Since Einstein used the name "ether," and supplied the same reasons that Poincaré had provided in his writings as to why one should adhere to the ether, Einstein thus returned to the 19th century concept of the ether, but stripped of it its most important characteristic: a medium in a state of absolute rest. Einstein thus came extremely close to Poincaré's ideas after 1915.

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References

Einstein, A. (1905) "Zur Elektrodynamik bewegter Körper", *Annalen der Physik*, **17**, 891-921.

Einstein, A. (1920) Äther und Relativitätstheorie. Lecture Presented on 5th May, 1920 in the University of Leyden (Berlin: Springer).

Granek, G. (2000) "Poincaré's Contributions to Relativistic Dynamics", *Studies in History and Philosophy of Modern Physics*, **31**, 15-48.

Jourdian, P.E.B. (1915) "Newton's Hypotheses of Ether and of Gravitation", *The Monist*, 25, part I79, part II 237, part III 418.

Kostro, L. (1988) "Einstein and the ether", *Electronics & Wireless World* **94**, 238-239.

Mach, E. (1893) *Mechanics: A Critical and Historical Account of Its Development*, transl. T. J. McCormack (La Salle: Open court), 1960.

Miller, A. I. (1986) *Imagery in Scientific Thought: Creating twentieth-Century Physics* (Cambridge: MIT Press).

Minkowski, H. (1908) "Raum und Zeit (lecture delivered on the 80th assembly of German Natural Scientists and Physicians, at Cologne on 21 September 1908), *Physikalische Zeitschrift*, **10**, 104-111 (1909).

Poincaré, H. (1900) "Sur les relations entre la physique expérimentale et la physique mathématique", *Revue génerale des sciences pures et appliquées*, 21, 1163.

Poincaré, H. (1902) *La science et l'hypothése* (Paris: Flammarion); revised edition 1968. Based on the one edited by Gustave Le Bon, 1917.

Poincaré, H. (1909) "La mécanique nouvelle" (conference of the French Association for the Advancement of Sciences, Lille, 1909), *Comptes-rendus des Sessions de l'Association française pour l'avancement des sciences, congrès de Lille*, 38-48; reprinted in *Poincaré* [1924], 1-17. All page references are to this source.

Poincaré, H. (1924) *La mécanique nouvelle. Conférence, memoir et note sur la théorie de la relativité* (Paris: Gauthier-Villars);Introduction by Edouard Guillaume.