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# Poincaré's Ether: A. Why did Poincaré retain the ether?

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This paper is divided into three parts, in which I suggest five answers to the question: Why did Poincaré retain the ether? These answers are based on Poincaré's own reasoning: the ether was required for the explanation of stellar aberration, to remove action-at-a-distance, to remove absolute rotation and absolute space from physics, to save broken theories and to save Poincaré's conventionalism. Poincaré's first reason can be seen as related to rectilinear and uniform motions. In 1905 Einstein managed to explain aberration without resource to ether. Special relativity crowned the final oblivion of the ether. Poincaré's four other reasons are centered on the solution to the following old problem: the principle of relativity is not valid for rotations and we thus can claim for absolute rotation. Poincaré struggled with this problem and could not solve it without resource to the ether. In General Relativity, Einstein could not solve it without returning to some kind of ether, either. I first discuss Poincaré's reasoning and in a future paper "Why did Einstein come back to the ether?" I discuss Einstein's solution to the problem of absolute rotation and his return to a revised form of Poincaré's ether.

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## Introduction

Between 1888 and 1900 Poincaré had already speculated as to the redundancy of the ether; however, he finally decided not to renounce it. He believed, on the one hand that the ether was a mere invention, a convenient hypothesis that could be omitted, and on the other hand, he could not omit this convention. He struggled with this issue within the framework of two different fields of research: The mechanical ether theories in optics (1889), and absolute and relative motion (1900a).

In the lectures he gave at the Sorbonne between 1887 and 1888 concerning the optical theories of light, Poincaré presupposed that there was a major problem concerning the ether models suggested in these theories, in that they were not able to meet all the needs of an optical theory of light. Poincaré therefore speculated, in the preface to his lectures, as to the possibility that one-day the ether would be rejected as useless (1889, pp. I-II):

> *It matters to us little whether the ether really exists; it is the matter of metaphysicians; what is essential for us is that everything happens as if it existed and that this hypothesis is convenient for the explanation of phenomena. After all, have we any other reason for believing in the existence of material objects? That too is only a convenient hypothesis; only it will never cease to be so, while a day will come no doubt in which the ether will be rejected as useless.*
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> *But on that very day, the laws of optics, and the equations, which translate them analytically, will remain true, at least as a first approximation.*

Later in 1900, at the Paris Congress of Physics, in his lecture “Relations between experimental Physics and Mathematical Physics,” Poincaré made the following statement (1900a, p. 1171): "And our ether, does it really exist? [Et notre ether; existe-t-il réellement?]". Poincaré's implicit answer was no, it did not really exist, because "we have invented the ether".But once it was invented we started to believe "to touch the ether with the finger". It became a real ponderable medium, and having the right experiments, "we [could] touch it closer still" (1900a, pp. 1171-1172).

Poincaré's above (1889) and (1900a) scientific reasoning, as expressed in two completely different contexts, were combined by him in his book *Science and Hypothesis* in 1902, to form a coherent line of thought according to which the ether might be useless (1902, pp. 180,215). This very likely influenced the young Einstein who read this book before 1905 to give up the ether.

In this paper I treat the following question: as Poincaré combined the above two thoughts in the same book to form the impression that the ether might be rejected as useless because one did not know if it really existed, why did he not abandon the ether in his later writings?

I suggest that the reason is the following: He did not manage to solve the problems, which necessitated the invention of the ether in the first place:

In (1900a) Poincaré saw the need for the ether in order to eliminate from physics instantaneous action-at-a-distance. Stationary ether (at absolute rest) was necessary for the explanation of aberration. Poincaré then suggested in the same lecture that we did not need stationary ether in order to explain aberration, but we only needed some kind of ether (not in absolute rest) in order to remove instantaneous action-at-a-distance. In his philosophical lecture held at Paris in 1900, "On the Principles of Mechanics" (1900b), which was also incorporated in (1902), Poincaré implicitly explained that we also needed some kind of ether for the purpose of eliminating absolute rotations.

Einstein managed to explain aberration without postulating the ether and thus eliminated absolute rest from physics. He later postulated an ether that was not in absolute rest in order to prevent instantaneous action-at-a-distance and absolute rotations. Einstein's solution and response to Poincaré's (1902) is dealt in my paper, "Why did Einstein come back to the ether?"

I first discuss Poincaré's answers to the question: Why did we invent the ether in the first place?

## To explain stellar aberration

We need the ether for the explanation of stellar aberration. Stellar aberration is concerned with starlight arriving at the planet earth. Light emanating from a distant star traverses space in a defined time. During this time, the telescope will be displaced by earth's annual motion. The astronomer is, therefore, obliged to alter the direction of the telescope in order to assure that the image of the star is formed on the lenses of the telescope. The apparent displacement of the telescope is expressed by "the aberration constant" v/c, where v is the velocity of the earth relative to the sun and c is the velocity of light.
In 1818 Fresnel postulated that in order to explain aberration, one was obliged to assume stationary ether: an ether wind or drift, penetrating freely through the pores of the earth, as suggested originally by Young. Young proposed that the ether would pass freely through the pores or interstices between molecules and atoms of matter. This was called an ether wind because the ether passed freely through matter like wind passing through a grove of trees. Considering stationary ether, the phenomenon of aberration results from the displacement of the telescope while light passes through it. The luminous waves do not participate sensibly at all in the motion of the telescope, if we suppose the telescope to be directed to the true position of the star. The image of this star is

found behind the lens, in a quantity equal to that traveled by the earth while the light traverses the telescope. If the ether is mobile and carried along with earth, the luminous waves participate sensibly in the motion of the telescope. Mobile ether is experimentally equivalent to not having ether at all.

Assuming stationary ether, we could - with the aid of the theory of aberration - disclose to first order in v/c the earth's absolute motion with respect to this ether. Many ether-drift experiments had been performed to detect earth's motion with respect to stationary ether, the most famous of which were Michelson's 1881 and Michelson and Morley's 1887 second order experiments. All gave negative results. Poincaré therefore reasoned that we should find an explanation to aberration, which eliminates the stationary ether. This way the theory of aberration would supply an explanation to the negative result of all ether-drift experiments.

Poincaré explained (1900a, p.1171): "This would still oblige us to fill, with the ether, the interplanetary space but not to make it penetrate into the midst of material media directly". We are obliged to fill with some kind of ether the interplanetary space in order to prevent action-at-a-distance (see next section), but we do not have to assume it to penetrate into material media, i.e. we do not have to assume it to be stationary and therefore at absolute rest. We do not have to assume stationary ether, because we can *potentially* explain aberration without the need for an ether that penetrates into material media.

Poincaré later asserted in his lecture given at Saint Louis, "The Present State and Future of Mathematical Physics": (1904a, p. 321):

> *Michelson has shown us, I have told you, that the physical procedures are powerless to put in evidence absolute motion; I am persuaded that the same is true of the*

*astronomic procedures however far one pushes precision. [...]*

*I believe the theorists, recalling the experiment of Michelson, may expect a negative result, and that they would make a useful work in constructing a theory of aberration which would explain this in advance.*

Poincaré did not manage to explain aberration in this way; he was led thus eventually to assume the ether in absolute rest. In addition, the problem dealt with in the next two sections necessitated this kind of ether. Poincaré had to make a compromise and decided that absolute rest was not equivalent to absolute space.

In his 1905 first paper on relativity, "On the Electrodynamics of Moving Bodies," Einstein succeeded in constructing this theory, and deriving the aberration constant from his theory of relativity without the need for the ether (1905, p. 912). By doing so, he met the need to explain the negative result of Michelson and Morley's experiment. I suggest that only after Einstein had possessed the aberration formula was he really able to abandon the stationary ether. Einstein could thus not accept Poincaré's compromise according to which we could talk of absolute rest, but not of absolute space, because he managed to give up a medium being in absolute rest in 1905 when he explained aberration.

Poincaré could not have abandoned the fixed ether as long as he had not succeeded in deriving the aberration constant from the principle of relativity; and hence on the basis of the assumption that the aberration phenomenon is only dependent upon relative movements. Poincaré did try to solve the problem of aberration in his lectures at the Sorbonne from 1906-1907 "On the Limits of Newton's Law," in his popular review article, "The Dynamics of the Electron" and in his 1909 lecture, "The New Mechanics" (1906-1907, pp. 216-217; 1908, pp. 560-562; 1909, pp. 5-6): Consider two opposite stars, where one of these stars performs oscillations with greater apparent amplitude than the other. A comparison between the amplitudes would enable one to discover earth's absolute motion. Poincaré's solution for that problem was that Lorentz's contraction hypothesis causes the two amplitudes to be measured, by an astronomer on earth, as being equal (as a result of the contraction). Therefore, no absolute motion can ever be disclosed. But Poincaré always relied ether in order to explain why aberration is a relative phenomenon.

Einstein's success in deriving the aberration formula, as it appears in his first paper on relativity in 1905 was, historically, one of the greatest achievements of Einstein's paper. He had succeeded in solving a problem, which had occupied the best scientific minds throughout the nineteenth century, scientists such as: Larmor, Lodge, Rayleigh, Lorentz, Poincaré and others.

## To remove instantaneous action-at-a-distance

We need the ether in order to eliminate instantaneous action-at-a-distance. Instantaneous Action-at-a-distance is inconsistent with the constant light velocity. If light velocity was infinite then it would not have taken several years for light to arrive to us from a very distant star. We would thus arrive at instantaneous action-at-a-distance (1900a, p. 1171): "We know whence comes our belief in the ether. If it takes several years for light to arrive to us from a removed star, it is no longer upon the star nor is it upon the earth; it must be sustained somewhere, and supported, so to speak, by some material". Poincaré explained it in a more mathematical language. Since mechanics is based on differential equations (continuous interactions), there must be a medium that transfers the interactions, for otherwise we would have dealt in mechanics with finite difference equations, interactions that jump from one place to the other immediately (1900a, p. 1171):

> *[...] in ordinary mechanics, the state of the system studied depends only on its state at the moment immediately preceding; the system satisfies then certain differential equations. Against this, if we did not believe in the ether, the state of the material universe would have depended not only upon the state immediately proceeding, but also upon more ancient states; the system would have satisfied equations of finite differences. It is to escape this exemption of the general mechanical laws that we have invented the ether.*

Action-at-a-distance is foreign to mechanics. According to the electromagnetic world-picture that was the prevailing one between 1900 and 1905, we assume that all the forces (mechanical and electromagnetic) - whatever their origin - are of electromagnetic origin. In 1900 Lorentz therefore proposed a theory of gravitational attraction, according to which this attraction was propagated with the velocity of light. In 1905 Poincaré arrived at the conclusion that gravitational attraction transmitted a gravitational wave moving with the velocity of light. This conclusion was compatible with the electromagnetic world-picture, because electromagnetic fields also propagate at the velocity of light. As a consequence, the velocity of light was common to the law of gravitational attraction and to the laws of electromagnetism (Granek, 1998). Gravity cannot be propagated with an infinite velocity and we can never have instantaneous action-at-a-distance.

## To save broken theories

We need the ether for saving broken theories. In a philosophical lecture held at Paris in 1900, "On the Principles of Mechanics," Poincaré explained this by making up imaginary scientists living on an imaginary cloudy planet and discovering scientific theories the way Copernicus and Ptolemy had done (1900b, pp. 480-482; see introduction further above). At first, these people thought that their earth was immobile. But this assumption would bring with it many difficulties. They looked upon the centrifugal forces as real. From their standpoint, these forces did not contradict the laws of mechanics. They attributed the centrifugal forces to the mutual actions of the bodies. However, they did not see these forces vanish at great distances. Far from it, centrifugal forces increased indefinitely with distance. They then tried to apply all their physical knowledge and methods in order to save their hypothesis, but grave difficulties ensued. So "they would soon imagine then some kind of a very subtle environment, analogous to our ether" (1900b, p. 481) which would somewhat solve the problem: all bodies would be placed in it, and which would exercise on them a repulsive action. In addition, the laws of mechanics presented no symmetry even though space is symmetrical. Scientists could distinguish between right and left when observing cyclones. Cyclones always turn in the same direction, whereas should the planet be immobile, they would turn indifferently in any direction for reasons of symmetry. Scientists thus invented more entities and went on accumulating complications. Nevertheless the problems would pile up, and a moment would come when these difficulties would be so innumerable and insurmountable that a long-awaited Copernicus would arrive and sweep them all away with a single blow. If we consider the Copernican convention, all the inertial effects and the cyclones are explained very simply without the need to invoke a "*coup de pouce*".

One could understand this fable in an allegorical way: the 19th century physicists struggled with the problems of the electrodynamics and optics of moving bodies and even invented an ether for this purpose. Copernicus would be a man that would sweep away all 19th century efforts including the invention of the ether. In this way one could rightly suggest that Copernicus would stand for Einstein. However, until 1912 Poincaré did not believe Copernicus had already arrived, nor did he regard himself as Copernicus. It is important to mention that he also did not regard Einstein as Copernicus either (Granek, 1998, chapter 6.3). He did not think that Einstein found a way to eliminate the ether. Therefore, from Poincaré's point of view, we still needed the ether in the science of mechanics and of the electrodynamics of moving bodies. If the Copernican theory allegorically stands for the then 1900 new electron theory, we still needed the ether in order to save broken theories that were intimately related to "Copernicus' theory": the theory of stellar aberration, the mechanics of uniform rotations and physics of action-at-a-distance interactions.

## To save conventionalism

We need the ether to save conventionalism. According to Poincaré's philosophy of conventionalism, absolute motion and space are dismissed by the equivalence of the Ptolemaic and Copernican systems. The two propositions, "the earth turns round" and "it is more convenient to suppose the earth turns round," both have one and the same meaning (1904b). This elicits a contradictory logically consistent possibility: The earth does not rotate. This is logically and empirically equivalent to the possibility according to which the earth does rotate. If we consider relative motions only, we would have no means of knowing which of the propositions, or rather conventions, is true, because there is no meaning in speaking of truth here. One convention cannot be truer than the other, for otherwise we would be accepting the existence of absolute space. It can only be more convenient.

According to Poincaré, if we had insisted on adhering to the convention "the earth stands still and it is the sky which rotates," concerning the daily rotation of the earth round itself, we would have only complicated physical theories (1904b): "If the earth was not turning round itself, one would have to admit that the stars describe in 24 hours an immense circumference that would have taken light hundreds of years to pass". Thus the convention: "the earth stands still" is not a convenient proposition, while the convention "the earth rotates" is convenient.

Poincaré's above conventionalist solution does not rigorously eliminate absolute motion and space from physics. In order to demonstrate this I shall return to Poincaré's cloudy planet. Suppose that one day, a group of inhabitants on Poincaré's cloudy planet discover a dynamics equivalent to Newton's dynamics as a result of assuming that it is more convenient to suppose that their planet turns round. Over the centuries they develop technology, and a few years later they finally find a way to build a spaceship. They build this spaceship and send astronauts to find out why their planet's sky is always grayish in color. The spaceship takes off and manages to go beyond the grayish planet's sky. The astronauts suddenly discover that their sky is actually covered with clouds. They come back home and bring with them a video film illustrating this last revolutionary discovery.

From the way Poincaré related his parable, the two above conventions ("the earth rotates" and "the earth stands still") are experimentally equivalent only for beings living under the permanent cloudy sky and who are unable to leave their planet's soil. Thus, A layman can claim that, according to Poincaré's philosophy, it should be assumed that there is a reality, inaccessible to us, but accessible to some being standing outside Poincaré's cloudy planet. Although for us the two conventions, "the earth turns round" and "the earth does not turn round" are equivalent, imagining this being, standing outside Poincaré's cloudy world and knowing that thick clouds forever cover this planet, he could readily choose between the two conventions, and he might conclude that the earth rotates or else stands still with respect to absolute space. "This only makes the two alternative descriptions empirically equivalent. They are not logically equivalent, nor is there a straightforward way of making them logically equivalent […]. Their equivalence is internal, and unlikely to persist if an external point of view becomes possible" (Ben-Menahem, 2000, p. 21).

We thus still need to imagine a medium analogous to the 19$^{th}$ century ether when we treat earth's daily rotation, so that we will not have to talk of the planet's absolute motion with respect to absolute space, but with respect to the ether.

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