Poincaré's Ether: C. Conventionalism Revisited

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Introduction

In his 1900 lecture "On the Principles of Mechanics," Poincaré imagined the following fable (1900b, p. 480; 1902, p.131): imagine beings living on an imaginary cloudy planet. They can never see the stars and therefore may think that their planet is the only object in the universe. How can they find out whether their planet rotates or stands still? Poincaré answers that for these beings the two conventions; "the earth turns round" (Copernican) and "the earth does not turn round" (Ptolemaic) are equivalent. Therefore no absolute motion can exist.

Poincaré seemed to have been inspired by Mach's ideas towards offering his conventionalist above point of view (see Mawhin, 1995). Mach protested against Newton's interpretation to his famous bucket experiment in terms of absolute motions and space. He philosophically demonstrated relative motions by stating the logical equivalence of the Copernican and Ptolemaic systems. However, unlike Mach, Poincaré examined the experimental equivalence of the two conventions for beings living in the cloudy planet. According to

Poincaré, beings living in the cloudy planet and performing experiments in order to discover whether their planet turns round or stands still, would always find out that the two conventions are completely experimentally equivalent. As a result of this suggestion, Poincaré had to philosophically and physically respond to a realist understanding by his audience over the years of the above conventionalist position: imagining a 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. Therefore, Poincaré's audience could not have accepted his reasoning.

In this paper I demonstrate that in light of Poincaré's special efforts to save his conventionalist view, he himself was also eventually not persuaded by his own arguments. He probably understood very well that his conventionalism was open to a kind of criticism regarding the possibility of the existence of an external being (standing outside his cloudy planet) for whom conventionalism did not hold any more. This criticism was embodied in the naïve and realist response of Poincaré's audience to his explanations. Poincaré's last resource was therefore the ether: the cloudy planet does not rotate with respect to absolute space but with respect to the ether. In my previous paper, "What characterizes Poincaré's ether?" I characterized Poincaré's obscure notion of the ether, which is based on Lorentz's stationary ether.

I start this paper by analyzing Newton's famous bucket experiment and Mach's solution in terms of relative motions. I then trace Poincaré's response to Mach's ideas and, his inner struggles and special efforts to save his conventionalist view.

The bucket experiment

Consider two systems, an inertial frame and a rotating frame. According to the Newtonian point of view, the inertial forces (like the centrifugal force) rise in the rotating frame relative to an inertial frame. The inertial frame is at rest or is moving relative to absolute space. In order to demonstrate this Newton suggested the well-known bucket experiment in his *Principia* (1729, p. 10; an English translation). The bucket experiment, including the stages not mentioned by Newton himself, is elucidated below (D'Inverno, 1993, pp. 121-123; Reichenbach, 1942, pp. 76-89):

1. First a bucket rotates, but the water does not, its surface remaining flat.
2. Then the frictional effects between the bucket and the water eventually communicate the rotation to the water. The centrifugal forces cause the water to pile up around the edges of the bucket and the surface becomes concave. The faster the water rotates, the more concave the surface becomes.
3. Eventually the bucket will slow down and stop, but the water will continue rotating for a while, its surface remaining concave.
4. Finally, the water returns to rest with a flat surface.

According to Newton, the surface of the water definitely shows that the water in the bucket is rotating (in an absolute circular motion) relative to absolute space. The water and the bucket are in absolute rotation. There cannot be only relative motion of the bucket and the water, with no absolute circular motion relative to absolute space, for the following reason.

Consider only relative rotation of the water and the bucket:

1. *The water is fixed when the bucket is rotating*: at first the bucket starts rotating, but the water does not yet rotate, its surface remaining *flat*.

2. *The water is rotating when the bucket is fixed*: when the bucket slows down and stops, the water will continue rotating for a while, its surface remaining *concave*.

Case number 2 is the exact opposite of case number 1. However, the surface of the water in 1 is flat and in 2 concave. Thus in case 2 we know that the water is rotating. The inertial force (the centrifugal force) rises when the water rotates relative to absolute space. When its surface is concave, the water rotates with respect to absolute space (when the surface of the water is flat the frame is inertial, and does not rotate relative to absolute space). Therefore, were the water to stand still and the bucket to rotate, then the sight for the eyes would be the same, but the centrifugal force would not be there (and hence the surface of the water is flat). A true state of rest with respect to absolute space can be recognized by the absence of the centrifugal force.

Mach's philosophical solution

According to Mach, inertial forces have their physical origin in the masses of the universe (the fixed stars, the bucket, etc). In 1893, in his treatise, *Mechanics: A Critical and Historical Account of Its Development*, he wrote the following comments on Newton's bucket experiment (Mach, 1893, p. 284; English translation):

> *The principles of mechanics can, indeed, be so conceived, that even for relative rotations centrifugal forces arise.*
>
> *Newton's experiment with the rotating vessel of water simply informs us, that the relative rotation of the water with respect to the sides of the vessel produces* no *noticeable centrifugal forces, but that such forces* are *produced by its relative rotation with respect to the mass of the earth and the other celestial bodies.*

Mach reasoned that a body in an otherwise empty universe could not be said to be in motion, since there was nothing to which the body's motion could be referred. If one could fix Newton's vessel and cause the sky of the fixed stars to rotate, both cases would become indiscernible one from the other; therefore the distinction made by Newton was an illusion.

Newton had overlooked the fact that case number 2 did not represent the opposite of case number 1. He had forgotten to take into consideration the whole sky and universe. For when rotating, we must consider the water not to revolve with respect to the resting bucket alone, but also with respect to the totality of the masses in the universe. Only then shall we present an equivalent but reverse picture. We should thus extend the two above cases to the following cases:

1. The water is fixed and the whole sky (of the fixed stars) is rotating.
2. The water is rotating and the whole sky (of the fixed stars) is fixed.

Such an extension would cause the two cases to be symmetric: in both cases the surface of the water would be concave. For in case number 1, if one could fix the bucket and cause the sky with the fixed stars to rotate, the surface of the water would be concave. The bucket has very little effect on the water's rotation since its mass is so small. The fixed stars contain most of the mass in the universe and this counteracts the fact that they are a very long way away.

Therefore this solution does not neutralize the centrifugal force. It will appear again in the water. Therefore, Mach suggested that, in case number 2, the centrifugal force is a consequence of the water's motion (uniform acceleration), and in case number 1, the centrifugal force should be understood as being an effect of the rotating sky, which is full of stars or masses. The rotating masses in the whole sky produce the centrifugal force experienced by the water. The conclusion is that we cannot know which of the two, the water or the sky, is rotating; both cases produce the same centrifugal force. Mach thus expressed a kind of equivalence principle: both explanations (given to cases 1 and 2) lead to the same observable effect (Reichenbach, 1942, p. 82): "What appears as action of inertia when the […water] is conceived as moving, appears as action of gravitation, when it is imagined as standing still and the earth [and fixed stars] as rotating."

Mach on annual and daily rotation of the earth

Mach explained his views regarding Newton's bucket experiment by discussing the annual rotation of the earth. Therefore according to Newton, the earth rotates relative to absolute space (the same as the bucket does) and this is the content of Copernicus' theory. Ptolemy's theory had been thus discarded when the Copernican system had been suggested. Or, the Ptolemaic universe had been exchanged with the new universe of Copernicus. Mach could not accept this explanation and thus reasoned the following (Mach, 1893, pp. 283-284; English translation):

> Relatively, *not considering the unknown and neglected medium of space, the motions of the universe are the same whether we adopt the Ptolemaic or the Copernican mode of view. Both views are, indeed, equally* correct*; only the latter is more simple and more* practical*. The universe is not* twice *given, with an earth at rest and an earth in motion; but only* once, *with its* relative *motions, alone determinable. It is, accordingly, not permitted us to say how things would be if the earth did not rotate. We may interpret the one case that is given us, in different ways.*

However, what about the daily rotation of the earth? Does the earth turn around? There are some effects that definitely seem to point toward the absolute rotation of the earth: such as the flattening at the poles (caused by the centrifugal force) and Foucault's pendulum experiment.

Consider the Foucault pendulum (a heavy bob attached to a long wire). This pendulum makes one complete revolution in 24 hours at the north and the south poles of the earth. Let this pendulum swing at the North Pole. The pendulum moves freely under the influence of gravitation. According to the laws of Newtonian mechanics a pendulum swinging in a plane must permanently maintain its plane of vibration in absolute space if all deflecting forces are excluded. The earth will rotate under the pendulum. To an observer on the earth the plane of the motion of the pendulum will appear to be rotating in the opposite direction relative to the direction in which the earth is rotating. If the earth were at rest but the heavens were in rotation, then, according to Newtonian concepts, the position of the plane of oscillation would not alter relative to the earth. The fact that it does so appears again to prove the absolute rotation of the earth.

According to Newtonian ideas, the earth thus turns around relative to absolute space because these effects are to be considered not as a result of motion relative to other masses, such as the fixed stars, but rather as resulting from absolute rotation in empty space. The following is Newton's fundamental assumption. If the earth were at rest, and if, instead, the heavens were to rotate in the opposite sense once around the earth's axis in 24 hours, then the centrifugal forces would not occur. The earth would thus not be flattened (the surface of the water in the bucket experiment would remain flat). This is an assumption that we can never verify experimentally. We can never cause the whole sky to rotate round the earth.

Mach responded to Newton's ideas in the following way (Mach, 1893, p. 283; English translation):

> *Let us now examine the point on which Newton, apparently with sound reasons, rests his distinction of absolute and relative motion. If the earth is affected with an* absolute *rotation about its axis, centrifugal forces are set up in the earth: it assumes an oblate form, the acceleration of gravity is diminished at the equator, the plane of Foucault's pendulum rotates, and so on. All these phenomena disappear if the earth is at rest and the other heavenly bodies are affected with absolute motion round it, such that the same* relative *rotation is produced. This is, indeed, the case, if we start* ab initio *from the idea of absolute space. But if we take our stand on the basis of facts, we shall find we have knowledge only of* relative *spaces and motions.*

We can explain Mach's last point of view by imagining two possibilities:

1. A case where the earth is rotating and the whole universe (i.e. the fixed stars) is at rest; and
2. A case where the universe rotates around the resting earth (even though causing the whole sky to rotate round the earth is again beyond any possible experiment).

In both cases, the effects of the flattening of the poles are apparent. In case number 1, the above effects would be the consequence of the earth's uniform acceleration relative to the non-rotating fixed stars. In case number 2, the above effects should be understood as the inertial effects of the rotating sky, full of stars or masses. In addition, from

Mach's standpoint, the position of the plane of oscillation of the Foucault pendulum should alter with respect to the earth even if it is at rest and the heavens rotating around it.

Poincaré struggles with Mach's above solution

Mach's above ideas seemed to inspire Poincaré. In 1902 Poincaré's *Science and Hypothesis*, containing his claims as to the equivalence between the rotation and non-rotation of the earth (round itself and round the sun), appeared. The following is the manner in which Poincaré's ideas were expressed in the above book (1902, p. 133):

> *[...] This affirmation: "the earth turns round," has no meaning, because no experiment permits its verification; since such an experiment, not only cannot be realized, nor dreamed by the most bold Jules Verne, but it cannot even be conceived without contradiction; or rather these two propositions: "the earth turns round" and: "it is more convenient to suppose that the earth turns round," have one sole and the same meaning; there is nothing more in one than in the other.*

This paragraph had appeared earlier in Poincaré's philosophical lecture at the Paris philosophy congress of 1900 (1900b, pp. 482-483); but it had not lead to such a storm as it was to lead two years later when it reappeared in *Science and Hypothesis*. The reason for this was, very likely, that the audience attending the Paris philosophy congress consisted mostly of philosophers, who were used to metaphysical formulations as the one above. However, when these pronouncements were reproduced unchanged in Poincaré's general book of 1902, which was intended for a general diverse audience, and understood literally, instead of having a metaphysical meaning, they acquired a realist-scientific meaning. This dual understanding and reception of Poincaré's above quoted words (by the audience attending the Paris philosophy congress and his readers of 1902) stemmed from what I have demonstrated in my first paper "Why did Poincaré retain the ether?": Poincaré's philosophy can be characterized as Conventionalist and realist at the same time (see brief summary in the introduction further above).

According to Mawhin (1995, pp. 3-10), in the same year that Poincaré's 1902 book was published, France witnessed the peak of the anti clerical movement. The reactionary religious journalists in France had been waiting for an opportunity like the one Poincaré's book provided: an affirmation, from a scientific authority, representing the official, scientific way of thinking, that would serve to calm the anti clerical move. Poincaré was known to be the voice of science and its prophet when speaking in 1904 about the state and future of science at Saint Louis, and earlier in 1900 about the state and transient character of scientific theories in the Paris physics congress (1900a, 1904a). Since "Poincaré - [was] often called on at the turn of the century to pronounce on the status of physics" (Pais, 1982, p. 94), people reading the above quoted paragraph in 1902 would have understood that scientists - he represented their voice - were not yet sure whether the earth rotated or not. People reasoned that if Poincaré was not yet sure whether the earth really turned round, maybe the Inquisition had been right to condemn Galileo for presupposing a hypothesis or a proposition that science could not and did not yet confirm. Journalists even questioned scientists as to whether it was true that the earth was not rotating, and that Galileo had been wrong.

Mawhin pointed out that Poincaré's name, as a great authority of science, served the reactionary journalists who represented religious interests in France at the beginning of this century. These journalists sought to demonstrate to the general public what they themselves had already suspected out of reading Poincaré's 1902 book: that Poincaré, the great auxiliary of the grand Inquisitor, had alluded negatively to Galileo, who had, therefore, been justly condemned. Poincaré's ideas then led to endless debates. Poincaré - being a liberal and very tolerant - was very angry. He repeatedly stated that he had "never had this thought; it is in fact good that Galileo fought, because, without him, astronomy and celestial mechanics would not have developed" (1909, p. 5).

Poincaré was completely amazed to discover that some people (1905, pp. 184-186): "[...] Have thought they saw in them [in Poincaré's words concerning the equivalence dealt above] the rehabilitation of Ptolemy's system, and perhaps the justification of Galileo's condemnation." Poincaré explained his views again and again (for instance, 1904b, 1905, 1909). Poincaré explained that the choice of the first proposition ("the earth turns round") stems from the fact that it reveals "true relations that the other conceals from us;" therefore it is "physically more true than the other, since it has a richer content" and therefore it could explain phenomena, such the flattening of the poles and the rotation of Foucault's pendulum, and other diverse and seemingly unconnected phenomena (1905, p. 185):

> *For the Ptolemaist, all these phenomena have no connection among them; for the Copernican, they are generated by one and the same cause. In saying, the earth turns round, I affirm that all these phenomena have an intimate relation [among them], and that is true, and that remains true [...]*

As for the rotation of the earth round the sun (ibid):

> *Here again we have three phenomena, which for the Ptolemaist are completely independent, and which for the*

> *Copernican are referred back to the same origin; these are the apparent displacements of the planets on the celestial sphere, the aberration of the fixed stars, the parallax of these same stars. Is it by chance that all the planets admit an in equality whose period is a year, and that this period is precisely equal to that of aberration, precisely equal also to that of the parallax? To adopt Ptolemy's system is to answer, yes; to adopt that of Copernicus is to answer, no; this is to affirm that there is a bond among the three phenomena [...]*

Also in Ptolemy's system the motions of the planets cannot be explained by the action of central forces; and celestial mechanics is therefore impossible. Celestial mechanics reveals to us so many "true relations" among all the celestial phenomena that one cannot adhere to the proposition of the immobility of the earth from a physical point of view though one is perfectly free to choose this proposition from the point of view of metaphysics. Poincaré then concluded that (1905, p. 186):

> *The truth, for which Galileo suffered, remains therefore the truth, although it has not altogether the same meaning as for the vulgar, and its true meaning is much more subtle, more profound and richer.*

Although it is not the truth of realism, it is a conventionalist truth according to which, no absolute space, time and velocity could ever be realized and have any sense. In the conventionalist world, we could not know what the real world is, and moreover, whether a real world exists at all. However, we are free to believe that such a real world exists. Poincaré's notion of truth is therefore the following: The Ptolemaic and Copernican conventions are equivalent and thus have no absolute meaning. However, this equivalence does not demonstrate that the Ptolemaic convention is physically correct. It only demonstrates the following: we cannot claim that there is only one absolute possibility for describing phenomena, for otherwise we advocate the idea of absolute motion.

Nevertheless, as Poincaré's philosophy was understood, it could have led to a realist external being standing outside Poincaré's cloudy world and knowing that thick clouds forever cover this world. For this external being the two conventions regarding the rotation of the earth were not equivalent at all, who could readily decide between the two, and might very well conclude that there was absolute space and that the earth is not rotating around its own axis and around the sun. This being could very well correspond to religious beliefs. For instance it could correspond to Newton's absolute space, which he identified with God's infinite organs. According to Newton, God is an external being, present outside the universe, but absolute infinite space is his sensorium. In order to eliminate absolute space, Poincaré exchanged the ether for absolute space.

In the next three papers I discuss Einstein's General Relativistic solution to the problem of uniform rotation. I ask the following question: Was Einstein able to solve the problem without returning to some kind of ether?

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