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The Multiple-World Thought Experiment and Absolute Space

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INTRODUCTION

Ernst Mach looked upon Newton's notion of absolute space as a fiction of the imagination. For Mach, the positivist, the meaningfulness of the concept of absolute space and the detectibility of absolute motion were inextricably tied. Without a possible experiment to distinguish absolute from relative motion, both concepts "absolute space" and "absolute motion," in Mach's view, are bereft of physical meaning. They are at most useless metaphysical adornments to our physical theory.

Mach's analysis of the possibility of distinguishing absolute motion can be evaluated independently of his theory of meaning or his philosophy of science. Questions concerning the meaning of absolute space and its relationship to absolute motion, while important, shall not be considered in this paper. We direct ourselves to one class of thought experiments, concerned with detecting absolute motion in a hypothetical but physically possible universe.

The following is a summary of the paper's content and analysis. Mach's dismissal of the possibility of distinguishing absolute motion has been criticized through the use of a very clever thought experiment devised by Hans Reichenbach which we call the twin-world thought experiment. However, Reichenbach's argument has been shown to be inconclusive since the Machians can still maintain that the choice of the absolute reference frame is a matter of convention. Howard Stein extends Reichenbach's argument to a triple-world system and maintains that if the Machians accept his experiment and the concomitant hypothetical data the interpretation of that experiment must follow Newtonian lines, in so far as

[1] I wish to acknowledge Professors Joseph Agassi, Abner Shimony and Robert Cohen for reading an earlier version of this paper and making valuable comments.

there is a unique absolute frame of reference. In this paper I shall show that if the Machians accept Stein's triple-world system with its hypothetical data, they still need not accept a unique frame of reference. Furthermore, in order to reach the limit of possible interpretations, I extend the thought experiments of Reichenbach and Stein to a quadruple-world system. If the quadruple-world thought experiment and hypothetical data are accepted, the Machians cannot offer an interpretation of the data to support the relativistic view of space and motion. The four-world system is the highest order of earth-star systems which can be introduced into the thought experiment without being redundant. Finally, I shall argue that the plausibility of the multiple-world thought experiment is based upon a restricted view of the rotating worlds. When we introduce slight changes in the relative rotations of the earth-star systems, Reichenbach's argument fails to be conclusive.

1. *Interpretations of Newton's Bucket.* Mach's response to Newton's waterbucket experiment was to explain the source of the centrifugal effects simply by the relative rotation of the bucket with respect to the heavenly bodies (Mach, [1], 1960, p. 283). Mach went further and claimed that any centrifugal effect can be explained by the relative rotation of one body with respect to another.

For the purpose of this paper we shall consider the waterbucket in the following terms. The earth is at the center of some system of stars. The earth either exhibits or does not exhibit centrifugal effects. It either rotates or is stationary with respect to the stars. The rotating bucket is taken to be equivalent to the rotating earth.

Before proceeding any further, we introduce the following notation in order to simplify and keep track of the several interpretations to follow.

Rot (E_i, F_i)	means there is a relative rotation of earth E_i and star system F_i. This also can be expressed as Rot (F_i, E_i).
Res (E_iF_i)	means E_i is at rest with respect to F_i.
$CE(E_i)$	means centrifugal effects are observed on E_i
$\overline{CE}(E_i)$	means no centrifugal effects are observed on E_i.
Abs Res (F_i)	means that star system F_i is at rest with respect to absolute space, which is the same as saying it is at absolute rest.

Abs Rot (E_i) means earth E_i is in rotation with respect to absolute space which is the same as saying it is in absolute rotation.

From the above notation we can symbolize Newton's and Mach's interpretation of the bucket experiment, translated into the single earth-star system (Fig. 1). The phenomenon to be explained is the centrifugal effects on E_i when E_i rotates with respect to F_i, as contrasted with the disappearance of those effects when E_i is at rest with respect to F_i.

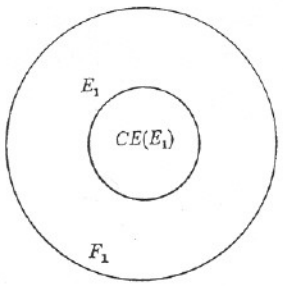

FIG. 1

Given: Rot(E_1, F_1); $CE(E_1)$
Interpretation of Results:
Newton: Abs Res(F_1); Abs Rot(E_1). Explanation of $CE(E_1)$ is Abs Rot(E_1).
Mach: Explanation of $CE(E_1)$ is Rot(E_1,F_1).

2. *Reichenbach's Double-World System.* Reichenbach introduces a twin-universe thought experiment in which case we are to imagine two earths in their individual star systems (Reichenbach, [2], 1958, p. 215). They are far enough apart to have no effect on one another but they can be observed. Each earth is at rest with the other star sphere but rotates with respect to its own. According to Mach's interpretation of the single-earth star system, centrifugal effects should appear on each earth. Reichenbach introduces some hypothetical empirical evidence, namely, that centrifugal forces are observed on the earth E_1 with star sphere F_1, but no effects are observed on E_2 with star sphere F_2. Mach can no longer hold his hypothesis that the explanation of the centrifugal effects is the relative rotation of earth to star sphere, if he accepts the dual-world system and the hypothetical data.

Newton's interpretation of the asymmetry between the world systems would simply be an extension of his interpretation of the single earth-star system. Earth E_1 is in rotation with respect to absolute space, while the other earth E_2 is at absolute rest.

Reichenbach contends that we have two alternatives for our interpretation. We may choose between saying the centrifugal effects are due to the absolute rotation of the earth E_1 and saying that those effects are due to the absolute rotation of F_1. But he does maintain that his thought experiment and the data indicate the presence of absolute space.

> We find that if the conditions are realized which were assumed by Newton, there exists absolute space, but its state of motion cannot be determined. (Reichenbach, [2], 1958, p. 216).

Reichenbach's double-world system and the several interpretations are summarized in Figure 2.

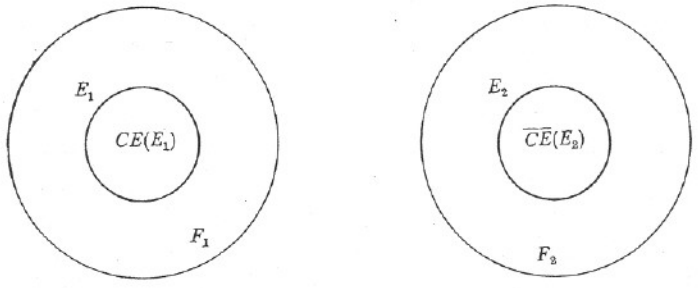

FIG. 2

Given: $\text{Rot}(E_1,F_1)$; $\text{Rot}(E_2,F_2)$; $\text{Res}(E_2,F_1)$; $CE(E_1)$; $\overline{CE}(E_2)$
Interpretation of results:

Newton: Abs Res (F_1), Abs Rot(E_1); from which it follows Abs Res(E_2), Abs Rot(F_2).

Mach: Mach's interpretation fails since "the explanation of $CE(E_i)$ is $\text{Rot}(E_i,F_i)$" is inconsistent with the hypothetical data "Rot (E_2, F_2) and $\overline{CE}(E_2)$."

Reichenbach: As an alternative interpretation to that of Newton Reichenbach proposes the following:
Abs Res (E_1), Abs Rot (F_1); from which it follows that Abs Rot (E_2), Abs Res (F_2). The explanation of $CE(E_i)$ is Abs Rot (F_i).

Reichenbach leaves us with two alternative interpretations. The Machians can rightly argue that if space is absolute then it must be possible at least in theory to determine which of Reichenbach's alternative interpretations is the correct one. If not then the notion of absolute rotation is relativized within some constraints. Howard Stein takes up the challenge (Stein, [3], 1967).

3. *Stein's Triple-World System.* Stein introduces a thought experiment with three earth-star systems. The first two systems are identical to those introduced by Reichenbach.

In his third earth-star system stars F_3 and earth E_3 are at rest relative to one another and star system F_3 is at rest with respect to F_1, while it rotates with respect to F_2. Stein introduces a new piece of hypothetical data which states that there are no centrifugal effects on E_3. The summary of Stein's thought experiment is presented in Figure 3.

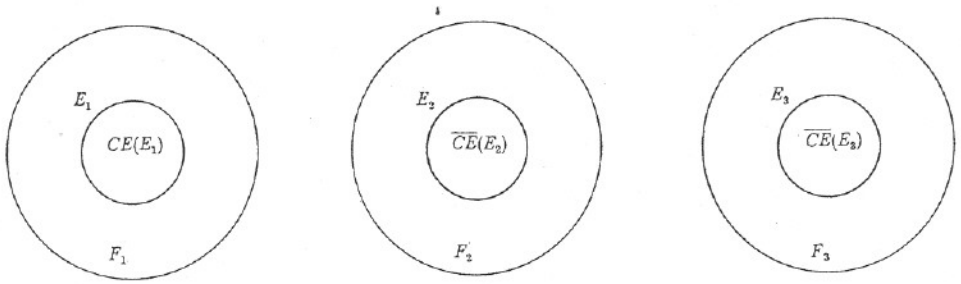

FIG. 3

Given: Rot (E_1,F_1), Rot (E_2,F_2), Res (E_1,F_2), Res (E_2,F_1), Res (E_3,F_3), Res (F_1,E_3), $CE(E_1)$, $\overline{CE}(E_2)$, $\overline{CE}(E_3)$.

Newton would interpret the data just as in the case of the double-world system with the added condition: Abs Res(F_3) and Abs Res(E_3). But now we can distinguish between Newton's interpretation and Reichenbach's alternative interpretation.

If Reichenbach's alternative interpretation is correct then star system F_3 and its absolute rotation should produce centrifugal effects on E_3. This is inconsistent with the data. Stein's point against Reichenbach is that the choice of whether E_1 or F_1 is at absolute rest is not arbitrary as long as we can distinguish the interpretations in some possible world.

To summarize our inquiry thus far, the results of the triple-world system thought experiment are based upon two pieces of hypothetical empirical evidence. (i) Centrifugal effects do not appear on E_2. (ii) Centrifugal effects do not appear on E_3. Reichenbach's thought experiment shows that Newton's interpretation and Mach's interpretation are not equivalent. There could, in theory, be a crucial test. But the test would not show *the* state of absolute rest, only that there is such a state. By adding another earth-star system and another piece of data Stein shows that we can distinguish the absolute rest frame.

But as Stein recognizes we can still maintain an alternative interpretation by modifying Reichenbach's argument. Let us suppose that the necessary and sufficient conditions for the appear-

ance of centrifugal effects are: (i) The earth and star-system must be in relative rotation with respect to one another. (ii) The stars must be in absolute rotation. This interpretation would explain the appearance of centrifugal effects on E_1 and the non-appearance of such effects on E_2 and E_3.

4. *The Quadruple-World System.* In the spirit of Reichenbach and Stein we introduce a fourth earth-star system (E_4,F_4).[2] They are at rest with respect to one another and at rest with respect to E_1. Centrifugal effects appear on E_4. Introducing the fourth earth-star system makes the modified interpretation false. Newton's interpretation still satisfies all the data. The quadruple-world system is summarized in Fig. 4.

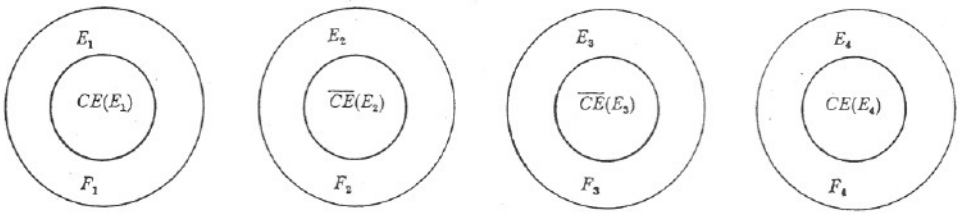

FIG. 4

Given: For worlds 1, 2 and 3 the relative motions are the same as in the triple-world system previously given.
For world 4, Res (E_4,F_4), Rot (F_1,E_4), $CE(E_4)$.

What this series of thought experiments shows is that Mach's and Newton's interpretation of centrifugal effects can be empirically distinguished within the hypothetical world of earth-star systems. It makes explicit the kind of data one would anticipate in the multi-world system for Newton's interpretation to succeed and Mach's to fail.

While Reichenbach is able to prove that Mach's explanation fails to be equivalent to Newton's, his results do not allow us to conclusively select the absolute frame of reference. This leaves the notion of absolute space as a convention which wouldn't satisfy the Newtonians. Stein extends Reichenbach's argument and

[2] After having written this paper it has been brought to my attention that Professor John Earman introduced the quadruple-world system in his article "Who's Afraid of Absolute Space?" *Australian Journal of Philosophy*, Vol. 48, No. 3 (December, 1970), pp. 305-306. I first referred to the multiple-world *gedanken-experiment* and extended it to four worlds in my disseration *The Nature and Function of Gedankenexperimente in Physics*, Boston University (May, 1970).

of E_1 to F_1 goes from V_3 to V_1.

The following possibilities are evident:

(i). The absolute rotation of F_1 is not the entire cause of the centrifugal effects on E_1.

(ii). We can have a change in the effect (centrifugal effect) without a change in the cause (absolute rotation of F_1).

If we accept the principle that with a change in the effect there must be a change in the cause, then the diminution of the centrifugal effects cannot be explained by Reichenbach's alternative hypothesis.

The plausibility of Reichenbach's alternative interpretation was based upon a constant rate of rotation of Earth E_1 with respect to its star-system F_1.

If F_1 is in rotation with respect to absolute space then changes in the rotation of E_1 should not alter the absolute rotation of F_1. But by changing the rotation of E_1 we alter the centrifugal effects of E_1. If Reichenbach's alternative interpretation is correct, then there is a change in the effect without a change in the cause.

6. *Conclusion.* Our analysis of the multiple-world experiment emphasizes the importance of establishing with great care the conditions under which critical thought experiments are to be conceived, interpreted, and evaluated.

For example, in setting up the original experiment, hypothetical data was introduced into the second earth-star system. The data is even contrary to what we believe should occur. But the justification for introducing the data is rooted in the kind of question we ask, namely, is there a possible state of affairs consistent with Newton's laws of motion and which is in accord with our observations which would allow us to distinguish Mach's explanation for centrifugal effects from Newton's. The burden of proof rests on the Newtonians. If the Machians accept the hypothetical data, the Newtonians come out ahead in the dual-world *gedankenexperiment* only to the extent that Mach was mistaken when he claimed his explanation was empirically indistinguishable from Newton's.

References

[1] Mach, Ernst, *The Science of Mechanics*, translated by T. J. McCormack, La Salle, Illinois: Open Court, 1960.

[2] Reichenbach, Hans, *The Philosophy of Space and Time*, translated by Maria Reichenbach and John Freund, New York: Dover Press, 1958.

[3] Stein, Howard, "Newtonian Space-Time," *Texas Quarterly*, X, No. 3 (Autumn, 1967), pp. 174-200.

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