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INTRODUCTION

The discussion between advocates of absolute space and those of relative space does not exclusively belong to the history of science. The theory of relativity has transformed the subject of this controversy into an important problem of physical sciences. However, this influenced the formulation of the problem. Thus formerly one asked whether space was absolute or not; now the question seems to be whether it is possible to build a physical theory that would yield a model of relative space (or space-time)? In both cases the basic issue remains the same. Many scientists, impressed by the great success of the special and the general theory of relativity, find it quite natural nowadays that future theory of physical sciences should be "relativistic" to the utmost: it should make no reference to absolute space at all. On the other hand, no physical theory which would be a model for relative space has been so far constructed.

A similar situation existed shortly after the onset of Classical Mechanics. Newton's mechanics used the notions of absolute space and absolute time and his understanding of these concepts took on a philosophical importance of its own. Simultaneously, Leibniz criticized the concepts of absolute space and time because of his general philosophical attitude. However, Leibniz's views remained but a programme, whereas Newton created a physical theory, i.e., a mathematical model of reality. There was a severe conflict between the philosophies of these two thinkers; in the ensuing controversy Samuel Clarke was a prominent exponent of Newton's view.

The polemics between Leibniz and Clarke is of interest today not only to professional philosophers to which the interesting article of H. Erlichson[1] may bear witness; it was published, incidentally, in a journal devoted to the educational and cultural aspects of physical science.

The prevailing view now is that with the rise of the theory of relativity, Newton's notion of absolute space was defeated and Leibniz's concept of relative space triumphed. This view is expressed in the following statement by H. Erlichson:

> Leibniz, Mach and the modern physicists hold that the inertial properties of matter can only be due to the other matter in the universe[2].

It must be strongly emphasized at the very beginning of the present article that the authors do not share this point of view. As has been stated above, no mathematical model of Leibniz's relative space has been so far worked out. There exist, however, numerous models of absolute space (or space-time), for example the special and the general theory of relativity. It is precisely the fact that philosophers, as well as physicists, so often misunderstand the idea of Leibniz's relative space and its relation (or the lack of it) to mathematical physics which has prompted the writing of this article.

Moreover, the discussion of Leibniz's polemics with Clarke seems to the authors a fitting occasion to consider a few interesting, or so they think, philosophical problems. One of the many negative results of the overwhelming influence of neopositivism on the mind of the physicist is a certain monotony of thinking when it comes to considering the foundations of natural science. "Observability" and "measurability" are the alpha and the omega of many physicists; usually they fail to see that the mere use of these words does not elucidate anything. It is to be hoped that when discussing the views of the founders of modern physical science, the authors shall not be at least reproached for speaking of things "unobservable"; in other circumstances it would, for sure, be difficult to avoid a severe rebuke.

ARE SPACE AND TIME THINGS OR PROPERTIES OF THINGS?

Philosophical views are usually expressed in ordinary language. This sounds like a platitude — which it is — since, after all, the use of ordinary language in philosophy is an understandable and legitimate practice, provided the language is genuinely "ordinary", i.e., commonly understood, and that words are used with their customary meaning. The question in the title of this section is phrased in ordinary language; the authors hope it is understandable.

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[1] H. Erlichson, *American Journal of Physics*, Vol. 35, p. 89, 1967.

[2] H. Erlichson, *ibid.*, p. 92.

According to Newton, time and space are things. This means that "the instants of time are objects analogous to events, but different from them. As such they do have properties, but are not the properties of anything; in particular, they are not the properties of events. In consequence... time exists independently of the material world" [3].

Similar remarks can be made about space. The opposite view is best expressed by Leibniz's own words: "As for my own opinion, I have said more than once that I hold space to be something merely relative, as time is; that I hold it to be an order of co-existences as time is an order of successions" [4].

It is not clear what exactly is to be understood by "co-existence". It seems that Leibniz unwittingly identifies coexistence with simultaneity. Attention needs to be drawn to the fact that simultaneity is a kinematic concept, whereas words like "existence" or "co-existence" in common speech possess connotations that go far beyond kinematics.

It is possible that the passionate resistance that was awaken by the thesis of the relativity of simultaneity had its origin in the unconscious identification of simultaneity with coexistence. It seems that the acceptance of the relativity of coexistence would really contradict the meaning that is usually attached to be word "existence".

Obviously, Leibniz can hardly be blamed for not distinguishing between coexistence and simultaneity; it is not the aim of the present article to suggest that. Yet, it ought to be realized that such a distinction is indispensable.

Of Clarke's objections against the philosophy of Leibniz only two will be considered; both are extremely important and both, as can be almost certainly assumed, were suggested by Newton himself.

The first argument is the existence of inertia: "If space was nothing but the order of things coexisting, it would follow that if God should remove in a straight line the entire material world, with any swiftness whatsoever, yet it would always continue in the same place, and that nothing would receive any shock upon the most sudden stopping of that motion" [5].

The second argument is the existence of a measure of space and time, which seems to be independent of the bodies filling up space: „Also that time is not merely the order of things succeding each other is evident because the quantity of time may be greater or less, and yet that order

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[3] Z. Augustynek, *Własności czasu* (The Properties of Time), Warszawa, 1970, pp. 20–21 (in Polish).

[4] *The Polemics with Clarke,* Leibniz's 3rd letter, No. 4. All texts are quoted from: G. W. Leibniz, *Philosophical Papers and Letters,* edited by L. E. Loemker, D. Reidel Publishing Company, Dordrecht, Holland, 1969.

[5] *Clarke's Third Reply,* No. 4.

continues the same. The order of things succeeding each other in time is not time itself, for they may succeed each other faster or slower in the same order of succession but not in the same time" [6].

The proposition of this passage is clear. Time possesses metric properties — one can define a temporal distance between events. Thus one cannot reduce time to a bare order of things. The same difficulty applies to space. In a nutshell, for Clarke "space and time are quantities, which situation and order are not" [7].

It looks as though Leibniz never grasped the full force of these two arguments of Clarke.

These arguments truly undermine the whole conception propounded by Leibniz. Naturally, this does not necessarily mean that his conception is totally unsound. An example will help to illustrate the point: the experiments of Fresnel and Young proved fatal for the corpuscular theory of light and were accepted as final by the scientific opinion of that time. Notwithstanding, in a different form and in a different setting, corpuscular theory was revived. Similarly with Leibniz's space: while abstaining from deciding about its "ultimate" truth, one may say that Leibniz is powerless against the two impelling arguments of Clarke since to maintain the assertion that space is but the order of coexisting things one has to point out the things whose existence causes inertia and those that are responsible for quantities of space and time. One cannot show such things even now!

THE APPEAL OF LEIBNIZ'S CONCEPTION OF SPACE

As has just been said, Clarke's two dynamic arguments are just as fatal for Leibniz's conception of space today as they were 300 years ago, because, as shall be shown in the course of the paper, the emergence of the special and the general theory of relativity did not weaken their impact. Nonetheless, Leibniz's conception which, according to scientific procedures, should be considered as false, is often considered more attractive, "truer" in some sense, than Newton's. Many distinguished scientists, Einstein among them, have, after all, maintained that what is falsehood for philosophy cannot be truth for science [8].

The paradox of this situation is that the philosophically unappealing,

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[6] *Clarke's Fourth Reply,* No. 41.

[7] *Clarke's Third Reply,* No. 4.

[8] Einstein's dislike for the so-called Copenhagen interpretation of quantum mechanics is another expression of the same attitude of mind, when in the name of some *a priori* notion of reality, one does not accept the most indisputable "facts".

one would want to say "false", conception of space as a thing reappears like a *deus ex machina* at every attempt to create a physical theory, i.e., a mathematical model of reality; simultaneously, the philosophically attractive idea of Leibniz invariably proves impossible to fit into a mathematical model.

A good illustration of this rule is characteristically furnished by nothing else but the history of the origin of the general theory of relativity. While working on this theory, Einstein had been influenced by Mach's philosophy, mainly by the criticism of the concept of inertia.

Mach is often viewed as the precursor of neopositivism which in this case is quite odd because Mach's idea which so influenced Einstein is the very example of putting a certain *a priori* notion of reality before the most indisputable experience. Analysing the Newtonian concept of inertia, Mach finds it philosophically unsound; one cannot speak of inertia with respect to pure space, there must exist some physical factor, some thing opposing acceleration. For such a thing Mach proposes to take the gravitation (or other kind of pull) of heavenly bodies: a body becomes accelerated not with respect to space, but to the "centre of mass of the heavenly bodies". The set of ideas, stemming from the criticism of Newton's conception of inertia, and linking the phenomenon of inertia with a physical factor which is unknown but indispensable to fulfil the demands of philosophy, is known as Mach's principle [9].

Einstein, setting out to build a new theory of gravitation, assumed the realization of Mach's postulate as one of his targets. In order to realize how far Einstein was influenced by the ideas diametrically opposed to those of Newton it seems appropriate here to cite his (i.e. Einstein's) following statement: "We now come to our views on space. An important thing here is to take notice of the relation of experience to our concepts... By means of simple changes in their position, we can put two bodies together. Theorems on congruences, which are fundamental to geometry, are linked with laws governing such changes of position. To grasp a concept of space, the following remarks seem essential: We can form new bodies putting bodies *B*, *C*, ... next to *A*: we then say that we have extended body *A*. Extending sufficiently any body *A*, we can make it to reach any other body *X*. The set of all such extensions of body *A* we shall call the 'space' of body *A*. It is accordingly a true assertion, that all bodies exist in the space of a (freely chosen) body *A*. In this manner, we do not allow ourselves to speak of 'space' — abstractly — but of the space relatively to a body *A*" [10].

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[9] More inclusive information about Mach's concepts can be found in: M. Heller, „Zasada Macha w kosmologii relatywistycznej" (Mach's Principle in Relativistic Cosmology), *Roczniki Filozoficzne,* 1970, 18 (3), pp. 27–52.

[10] A. Einstein, *Istota teorii względności* (The Meaning of Relativity), Warszawa, 1958, p. 9 (in Polish).

This reminds one strikingly of Leibniz's argumentation. "I will here show how men come to form to themselves the notion of space. They consider that many things exist at once, and they observe in them a certain order of co-existence, according to which the relation of one thing to another is more or less simple. This order is their situation or distance. When it happens that one of those co-existent things changes its relation to a multitude of others which do not change their relations among themselves, and that another thing, newly come, acquires the same relation to the others as the former; and this change we call a motion... . And that which comprehends all those places is called space. Which shows that in order to have an idea of place, and consequently of space, it is sufficient to consider these relations and the rules of their changes, without needing to fancy any absolute reality out of the things whose situation we consider" [11].

The fact that Einstein started constructing his new theory of gravitation with the conscious intention of eliminating Newton's suspect inertia with respect to pure space, and, what's more, that he thought for the while that he had managed to realize his aim, probably accounts for the common but, nonetheless, erroneous belief that space in the general theory of relativity is Leibnizian rather than Newtonian. This is not so; acceleration with respect to pure space, Clarke's supreme argument, has practically the same meaning in the general theory of relativity as it has in the classical mechanics. The famous problem about two identical spheres, one of which rotates and the other does not, is still valid. Can it be asserted for sure that one of them is rotating while the other is not, or can it be only assumed that one rotates with respect to the other? For Mach or Leibniz the second answer is unavoidable; in the Newtonian mechanics we know exactly which sphere rotates with respect to space. General Relativity confirms the verdict of Newtonian mechanics [12].

At the end of this chapter the authors must confess that they, too, find Leibniz's conception of space more natural and in some sense "truer" than Newtonian. The aim of the above argument was mainly to point out how very deeply the difficulties connected with any attempt to realize Leibniz's ideal in the form of a physical theory seem to go; absolute space is difficult to kill, so to speak, if it has been practically untouched by the general theory of relativity, in spite of the conscious efforts of the great founder of the theory.

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[11] *Fifth Letter of Leibniz,* No. 47.

[12] Philosophical preconceptions can sometimes blindfold the sense of reality. Up to this day there are physicists who maintain that in the two spheres problem one can tell only the relative motion of one sphere with respect to the other. This is absolute nonsense; if only bacause very small relativistic corrections cannot qualitatively change the results of Newtonian mechanics.

DOES THE WORD NEED CORRECTIONS?

This question repeatedly arises in the polemics. Leibniz put it already in the first letter: "Sir Isaac Newton and his followers have also a very odd opinion concerning the work of God. According to their doctrine, God Almighty wants to wind up his watch from time to time; otherwise it would cease to move. He had not, it seems, sufficient foresight to make it a perpetual motion. Nay, the machine of God's making is so imperfect according to these gentlemen that he is obliged to clean it now and then by an extraordinary concourse, and even to mend it as a clockmaker mends his work, who must consequently be so the more unskillful a workman, as he is oftener obliged to mend his work and to set it right" [13].

Leibniz explains his own position in his second letter: "I do not say the material world is a machine or watch that goes without God's interposition, and I have sufficiently insisted that the creation wants to be continually influenced by its creator. But I maintain it to be a watch that goes without wanting to be mended by him; otherwise we must say that God bethinks himself again. No, God has foreseen everything. He has provided a remedy for everything beforehand. There is in his works a harmony, a beauty, already pre-established" [14].

Clarke answered as follows: "The wisdom and foresight of God do not consist in providing originally remedies which shall of themselves cure the disorders of nature. ...The wisdom and foresight of God consist in contriving at once what his power and government is continually putting in actual execution" [15].

One cannot help feeling admiration for the deep insight of both opponents, once the true object of the dispute is recognized. What is the matter under discussion in fact? The answer is given in the statement of Clarke: "the wisdom and foresight of God consists in contriving at once what his power and government is continually putting in actual execution". The sense of this sentence is clear: Clarke views the world as a solution of Cauchy's problem, laid down by God (the initial conditions determine the state of the world throughout time). What are then the disorders of nature mentioned earlier? Here one encounters something really surprising: Newton and Clarke seem to feel intuitively that the Cauchy problem is set locally and that — in general — one cannot warrant, or even hope for, the existence of a solution valid for all times. The authors realize, indeed, that this interpretation may seem ahistorical, but if it does not hold, then they are at a loss to explain what would be meant by "the disorders of nature" and what would Clarke have in mind

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13 *First Letter of Leibniz,* No. 4.

14 *Second Letter of Leibniz,* No. 8.

15 *Second Reply of Clarke,* No. 9.

when he writes: "The present frame of the solar system, according to the present laws of motion, will in time fall into confusion" [16].

That Leibniz understood quite well, but did not agree with, Newton's and Clarke's position, would be a further proof in favour of our interpretation. Leibniz writes: "God foresaw everything and prevented everything, from the start". One usually prevents extraordinary events, catastrophes, disasters, and the like.

Having thus unravelled Clarke's thought, one can at once grasp what Leibniz means by: "in the works of God there exists harmony, a pre-established beauty". This signifies that the world is a solution of a certain consistency problem, for example of a boundary problem including time as well.

To sum up the interpretation of this part of the polemics, as seen by the authors of the present article: Clarke sees the world dynamically, as the solution of a Cauchy problem, whereas Leibniz perceives it statically, as the solution of a consistency condition which includes time. Both notice that the Cauchy problem has by nature a local character; one can never be sure if two or more atoms are not going to collide; if such a thing happens, then Newton's laws of motion cannot anticipate the outcome. But — of course — reality cannot be discontinued for such a trivial reason; that is why Leibniz rejects the idea of determining the world from the initial conditions, while Clarke believes that in a moment of catastrophe the world is sustained in its existence by a simple act of God's will.

It is interesting that in our time difficulties have arisen in theoretical physics, which lively remind one of the problem of the "corrections" that Leibniz and Clarke were debating. The gist of the matter lies in the fact that Einstein's equations have on the whole no regular solutions; the cosmological solutions of Einstein's equations have always a time limit beyond which they cannot be extended.

What does this mean? The implications are twofold: either Einstein's theory is still incomplete, or else the world really has a time limit. If the matter were submitted to Leibniz's and Clarke's decision one might probably expect their answers to be roughly the following: Leibniz would say that the theory of relativity cannot be true since, both in principle and in fact, "God foresaw everything and prevents everything beforehand"; Clarke would be of the opinion that the theory of relativity, that marvellous generalization of Newton's principles, supplies one more argument to prove the thesis that in certain circumstances God must intervene to sustain the world in its existence [17].

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[16] *Second Reply of Clarke,* No. 8.

[17] It is clear that the general theory of relativity is incomplete since, for example, it does not take into account the quantum effects. The still unclear point is whether the introduction of new factors would remove the world's time

RECAPITULATION

Leibniz's idea to consider time and space as properties of things is very appealing. This finds expression in the trends in physics, to construct a Leibnizian or Machian theory. But from the moment one tries to implement Leibniz's concept by a physical theory, i.e., to represent it in a mathematical model of reality, one encounters very real difficulties. Clarke made us aware of it from the point of view of classical mechanics. The main problems, not yet overcome, are: 1° inertia, 2° measure of time and space.

In spite of popular misconceptions, neither the special nor the general theory of relativity did "abolish" absolute time and absolute space. In the general theory of relativity the presence of matter does modify, but does not fully determine, the structure of space-time. It is logically consistent and it makes sense in physics to speak of cases where space-time has a definite structure, but is not filled with matter.

According to modern practices, one has stopped asking whether space-time is absolute or not. Nowadays, one poses the question more precisely, namely one wonders if it is possible to construct a physical theory which would be a mathematical model of a totally relative space-time? It must be added that this question need not be answered by a simple yes or no. One can have models of space-time partly absolute, partly relative (i.e. modified by the presence of matter; the general theory of relativity is just such a model).

Leibniz's doctrine of space and time is very attractive. Yet, within the framework of the hitherto known mathematical methods, it does not seem to be realizable.

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limit. The very special nature of this limit causes that the physical mechanisms known up to now seem insufficient to remove it. It appears that in this problem most physicists share Leibniz's view-point, if only because calling God to rescue at each difficulty encountered by physics would be plain laziness.