THREE PROBLEMS IN THE RELATIVISTIC CONCEPTION OF SPACE AND TIME*

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1. *Events*

The purpose of this note is to set up three problems that arise in the epistemological foundation of Einstein's theory of Relativity.

From the very beginning, it was clear that Einstein's Reality is the set of all events. In his famous paper of 1905, Einstein reduces the concept of "time coordinate" to that of "simultaneity of two events", and then, in deriving the equations connecting two coordinate systems, he follows a line of thought coherent with the conception of Reality as a set of events. This point of view became more explicit —of course— with Minkowski's idea of a space-time continuum, but it is doubtless that it was clearly assumed in the previous Einstein's paper. In later works Einstein establishes explicitly this ontological principle. For example, he writes in "The meaning of Relativity":

"What has physical reality is neither the point in space nor the instant in time in which something occurs, but the event itself."

Now, the question arises naturally: What is an event? There are essentially two ways to give an answer: I shall call them, respectively, the *axiomatic-operational method* and the *analytical method.*

2. *The axiomatic-operational method*

This is, in practice, the method adopted by working physicists, without treating it, nevertheless, with the attention it deserves.

In fact, the physicist does not disturb himself with the question of the ontological status of the concept of event. He knows that it

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is impossible to give rigorous definitions for *all* the terms entering in a scientific theory, so he accepts that he must start from some kind of undefined basical entities: for the theory of Relativity, these undefined basical entities are the events. In this sense, physical theory proceeds as a branch of mathematics: one establishes certain relations between the undefined events, and then derives some logical consequences of such relations. This is the pure axiomatic method. But the ontological problem presents itself when the physicist wishes to confront his theory with experience. At this moment he doesn't establish explicitly any *definition* of physical (real) event, but he simply *takes* certain entities which he calls *events* and confronts his theory will such entities. But we know that this method entails a sort of (unconfessed) definition, i.e., a partial definition by extension: one defines a set simply by listing the objects belonging to it. I said "a *partial* definition" because, in taking certain "events" to check up his theory, the physicist doesn't make a *complet* list of events but a partial one, according with the needs of his concrete problem.

We arrive thus at the following situation: the physicist has, on the one hand, an axiomatic system which studies an "abstract" set called *set of events;* and on the other hand, a set of real events which is defined progressively and by ad-hoc practical devices. In testing the law A, the physicist uses the word "event" to designate certain entities $a_1,\ldots,a_n$. Then, in testing the law B, he incorporates the *new* real events $b_1,\ldots,b_k$, and so on. After this, if the theory holds good for every entity that has been called *event* by physicists, we say that this theory *explains* all known experiences. If there is a thing called *event* by physicists that doesn't verifies the theory, we say that this theory explains *certain* events but not all known events.

This method looks satisfactory and in fact it satisfies the rather poor standard of ontological rigor imposed to themselves by working scientits in general. But, from an epistemological standpoint, it seems that within the frame of the method just outlined, what is real is the mathematical theory, while empirical Reality has only a crude conventional status. This method do not solve the epistemological problem of Reality, but only ignores it. We are thus led to the second method.

3. *The analytical method and the three problems.*

The analytical method consists in trying to construct a definition or a characterization of the concept of real (physical) event in a rather absolute way, i.e., a way that establishes the event as previous to the theory. If we wish to regard the real World as the

set of all real events it is natural to ask for a characterization of events independently of any further theory. In appearance, the events referred to in Relativity are described by expressions like this: "The arrival of the hand (supposed unique) of a clock to the clock-number 1." From the point of view of Einsteinian Relativity, it is this arrival what has objective meaning and real existence. But in this connection ther are three epistemological problems that arise from the beginning of the theory. I shall call them the *accuracy*, the *semantical* and the *atomistic* problems.

A) *The accuracy problem.*

Suppose that we have two measuring instruments X and Y, each consisting essentially in a graded dial and a moving hand. Suppose also that instruments X and Y are so connected that the arrival of each hand to the respective number 1 are simultaneous events. From Einstein's point of view, simultaneity of neighboring events has a intuitive and direct sense which is not objected by the theory of Relativity. Suppose now that we repeat the experience but we perform the observations with more accuracy, so we conclude that in fact the arrival of the X-hand to the X-number 1 is not simultaneous with the arrival of the Y-hand to the Y-number 1, but with the arrival of the Y-hand to the Y-number 1,1. Further measurements may provide new situations, establishing successively that the arrival of the X-hand to the X-number 1 is simultaneous with the arrival of the Y-hand to the Y-number 1,11, or to the Y-number 1,111 and so on. This fluid situation shows that in fact we do not know what we call *the arrival of the X-hand to the X-number 1*, because in the first case we *believe* that this *event* is simultaneous with a certain Y-event, and then we *believe* that it is simultaneous with another Y-event. Strictly speaking, from an *operational* point of view we perform different operations in each case, so it seems that the above mentioned X-event depends on the operations performed to realize its observation. In this way, the true X-event in itself appears as a metaphysically postulated entity. There is not an a priori absolute operational method permiting to establish the Y-event *really* simultaneous with the given X-event, each method being perfectible in the sense of its accuracy.

In practice the situation is as follows: when we believe that the arrival of the X-hand to the X-number 1 is simultaneous with the arrival of the Y-hand to the Y-number 1, we construct a certain physical theory which will be called T_1. When we believe (or accept) that the above mentioned X-event is simultaneous with the arrival of the Y-hand to the Y-number 1,1, we construct another physical theory T_2. In this manner we have a sequence of different

theories T_1, T_2, T_3... etc. This situation is generally accepted in physics, but it is not acceptable if we establish the concept of event as the primary and objective basis of Reality. It is not acceptable that the *nature* of the ultimate and objective constituents of Reality may depend on the method of observation. In any case, it would be better to consider the successive operational observations as having objective meaning, and to banish the event itself.

If this conclusion seems to contradict the usual behavior of scientists, it is due to the fact that in ordinary working physics (as in ordinary common sense) we never consider events as ultimate constituents of Reality, but we assign this status to *objects*. Thus, in ordinary physics we say that the X-hand and the X-number 1 have objective meaning, and that the arrival of the first to the second is a relation between them. From this point of view the objection disappears, because it is not a contradiction to accept that we know perfectly the two objects but we do not know exactly the relations between them; in particular, it becomes acceptable to give a *relative* meaning to the arrival of the X-hand to the X-number 1. In this way, objects are absolute and events are relative, but in the theory of Relativity the situation is exactly the opposite one: events are absolute and objects are relative. Then, it is not acceptable, within the frame of Relativity theory, to confess that an event is not exactly definable.

B) *The semantical problem.*

In this theory there is a problem similar to that of elementary or atomistic facts which arises in certain semantical epistemologies such as Wittgenstein's, Carnap's and Russell's. It is also near to the problem of events in applied Probability theory. The problem is this: let us call X_1 the event consisting in the arrival of the X-hand to the X-number 1, and Y_1 the analogous event for instrument Y. If the World is defined as the set of all events, we accept that X_1 and Y_1 belong to the World. But, does the pair $[X_1, Y_1]$ belong to the World? From an intuitive standpoint, the simultaneity of those arrivals constitute also an event; is it a physical (or objective) event? From the intuitive standpoint the arrival of a set of electrons to a certain piece of a circuit is an event; is it a physical (or objective) event? It seems that the answer of Relativity theory to both questions is No. Because these supposed events are in fact decomposable in several elementary events: in the last example, such elementary events would be the arrivals of each electron to that piece of a circuit. It is well known that a satisfactory definition of elementary or atomistic event is a hard problem, and the solution of this problem seems to be of funda-

mental importance for the epistemology of Relativity, because in this theory the World is just the set of such events. Another example of the same kind is the following: if we accept that the arrival of the X-hand to the X-number 1 is an event, must we accept that the arrival of the X-hand to an odd X-number is an event? In Probability theory these two descriptions correspond to *different* events: the second is a *class* of events similar to the first. This leads also to the necessity of a sharp concept of elementary event; modern physics has not yet clarified the general concept of elementary particle, thus it is hopeless to find a satisfactory, objective and absolute definition of elementary event.

Here we encounter one form of the classical problem of universals, namely the following: do sets possess objective reality? If the answer is *yes*, then sets are to be taken as points of the space-time-continuum, i.e., as elements of the World. If the answer is *no*, then sets are to be banished from the physical World.

C) *The atomistic problem.*

We have seen that the definition of the World as the set of all events leads directly to the problem of defining atomic events. In this connection a new difficulty arises: if we accept that there is a thing such as the arrival of the X-hand to the X-number 1, we must ask for the ontological status of both the X-hand and the X-number 1. If only events have objective existence, then the so-called X-hand must be conceived as a collection of events, this is, in fact, the idea which permits a correct interpretation of the Lorentz-Einstein contraction. Then, the macro-events such as the arrival of the X-hand to the X-number 1 must be replaced by collections of micro-events such as collisions of electrons, etc. But collisions of electrons are not observable in themselves and have a rather theoretical character. We arrive thus to the conclusion that the objective constituents of the World (i.e., the events) have a theoretical character and have not at all objectivity in the usual sense.