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Facts, Events, Things and the Ontology of Physics

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The philosophical importance of notions like 'facts', 'events', and 'things' lies in the central role they play in ontology, the venerable branch of metaphysics which deals with the question of *what there is*. Depending on various philosophical options, *reality* is regarded as either constituted by *things*, or by *events*, or by *facts*, or by a pluralistic combination of these categories. But what, precisely, is the difference among them? And given a plausible occamist commitment to the elimination of superfluous entities, can we consider one ontological category to be more basic than the others, so as to be able to define, say, facts and things only in terms of events or, alternatively, construct facts out of things *and* events? To the extent that ontology is regarded as the search for the most fundamental building blocks of reality, questions like those above should not be tackled by neglecting empirical suggestions coming from physics. A mere *analytically oriented* discussion on the role that things, events and facts play in our ordinary language and conceptual schemes must be measured against what *empirical* science tells us about the ultimate constituents of the world around us. Though one can always reject inquiries of this kind by playing the instrumentalist note — according to which physics does not tell us anything above and beyond the realm of the observable — I take it that positing objects or facts as existing in a mind-independent way is philosophically not more audacious than believing in the reality of the theoretical entities postulated by a mature science. If one is embarked in the risky business of

ontology, one might as well provisionally accept the ontological suggestions of theoretical physics, revisable as they may be.

In this respect, it has often been claimed that the four-dimensional outlook imposed upon physics by relativity rules out an ontology of things in favor of an ontology of events. I will show that this position really amounts to a prejudice. Furthermore, it could be argued that quantum physics seems to make obsolete *both* the category of 'things' *and* that of 'events'. However, if one really wanted to adjudicate between an ontology of events and one of things by using physics, one should look at field theory, the fundamental theory of matter of our days. In that context, an ontology of objects does not look unreasonable, though in a highly revised form: the *fields themselves* (like the electromagnetic or the gravitational field) might well be regarded as *substances*, since they are capable of carrying energy and of undergoing changes in their properties at different spacetime locations. Events with which such changes may be identified may be included in the micro-ontology of physics only to the extent that causation can be identified with the fundamental interactions of quantum field theory. It is concluded that physics cannot help us to adjudicate between events and things, and that, even if one could show that relativity or physics in general only needs an ontology of events, this should not be taken to mean that desks trees and persons should not be regarded as real.

§ 1 The relation between concrete facts, things and events: an hypothesis

Let me begin with some terminological point. Given that whatever constitutes non-abstract reality is in space and time (spacetime), I shall regard each of our three ontological notions as *particulars*, that is, as items locatable or located in space and time. Numbers, classes, event-types, general properties, relations and propositions may well be real. However, if they are taken

to exist in an abstract, platonic world, then they cannot exist in spacetime, simply because they are *causally inert* entities. I propose to regard 'abstract' and 'causally inert' as synonymous or at least as co-extensional terms, while 'concretely real' should be treated as being co-referential with 'causally active'. Therefore, in what follows, and unless specified otherwise, I will use 'fact' or 'state of affairs' to refer to 'singular facts', that is, to items that can be identified also by giving their spatiotemporal coordinates. For example, the fact that

(1) 'AS Roma has played a soccer match on Sunday 23.11.1997'

is spatially located wherever the Olympic Stadium is in Rome, and its temporal extension coincides with the duration of the match on that particular day. Obviously, (1) can be considered to be a cause of other facts, for instance of the following, other concrete fact

(2) 'There is traffic in the area around the Olympic Stadium in Rome in the afternoon of 23.11.97.'

In this example, (2) is an effect of (1). To the extent that they can function as concrete *relata* of the causal relation, facts can also be regarded as causally active.[1]

Analogously, I will not consider *types* of events as concerts or matches, but particular, located concerts and particular, located matches. Using a term of the art, the events I will be referring to are known as *token events*. The soccer match referred to above is one such event, so that the particular state of affairs referred to by (1) is constituted by the event 'soccer match played on 23.11.1997 at the Olympic Stadium by AS Roma'. The term 'AS Roma' refers to a soccer team, a collective entity (not to an abstract set!), constituted by eleven concrete players and a coach, each of which belongs to the category of *substances*, *objects* or *things*. (I shall use these three terms interchangeably).

[1] For the defense of this position, see D.H. Mellor, *The Facts of Causation*, Routledge, London, 1995.

What is the order of dependence linking facts, events and things? Rather than developing a full-blown argument, here I will just lay my cards on the table by discussing the example above. The concrete fact referred to in (1) is just a complex event, constituted by the actions of eleven men playing against another team according to certain rules, in a particular place at a particular time. In this, and I suspect in any other case, the concrete fact is therefore constituted by a token event, which, however, in its turn requires the existence of things (men, a stadium, a referee, etc.). From this simple example — others could be given illustrating the same point — the thesis that I would like to put forward should already be clear: *events and things can and should coexist* — in the sense that they are neither mutually exclusive ontologically nor independently definable logically — but *concrete facts are constituted out of events and things*. In a word, since to define facts we need events, and to define events (like actions) we need persons or things, the relations things have with 'their' events (properties or occurrences) *suffice* to yield concrete states of affairs, which we also need to postulate to interpret our sentences. Given this claim, that here I will not further defend, on what basis do we distinguish particular events and things, on the one hand, from concrete state of affairs on the other?

A plausible reply is that only the linguistic expression of a state of affairs *can be true or false*, while the linguistic counterpart of events and things (their *names*) obviously can't. 'The sinking of the Titanic' is the *name* of an *event*, but, as such, it is not susceptible of being true or false, since it is a mere nominalization of the verb 'to sink', referred to an *object*, the ship named 'Titanic'. The event in question can become part of a fact (like the one corresponding to 'the Titanic sank' or 'The sinking of the Titanic really occurred') only by becoming the subject of a sentence. In this case, it functions very much like a name of an object, as in

(3) '*The sinking of the Titanic* was slow, tragic and unexpected',

which, incidentally, shows that events, like things, *can* have properties and attributes.

I need not commit myself to some correspondence theory of truth to claim that there exist an extralinguistic element that true sentences describe, picked out by the reference of names of things. To be a bit more specific about the nature of such an extralinguistic stuff, I follow Quine in subscribing to the remark that «the familiar material objects may not be all that is real, but they are admirable examples [...] Our conceptual firsts are middle-sized, middle-distanced objects».[2] At this stage of the discussion, and until some scientific theory forces us to conclude otherwise, it is appropriate to agree with common sense in regarding the objects of our unaided perceptions as a paradigm of what is real. In fact, one could say with no great inaccuracy that while the world of common sense is somewhat exclusive in admitting only an ontology of things, events are considered to be the proper object of physical inquiry. How do we distinguish between events and things?

[2] W. O. Quine, *Word and Object*, The Mit Press, 1960, pp. 3-4.

§ 2 Enduring and perduring entities: temporal parts, identity and change

Interestingly, the conceptual difference between objects and events is usually given in terms of their different way of *persisting through time*. While *objects endure* by being wholly present at different moments of time, *events perdure* by having spatio-temporal stages or temporal parts, no one of which is fully present at more than one time.[3] A player of the team AS Roma is fully present at any moment of the match, while any event of the match, and the match itself, is obviously not fully present, say, during the first half, because the second half must still be played when the first is going on. In a word, the essential difference between events and things is usually thought to depend on the fact that *events, unlike things, possess temporal parts*. For this reason, it is also added that things can retain their *identity through time*, while the different temporal stages of a temporally extended event, if they can be distinguished at all, are not necessarily linked by a common identity, though they are parts of a larger whole. The first half of a match is not the same entity (events) as the second part, but the player Tom during the first half *is identical* with Tom during the second, despite minor changes in his physiology (he may get more tired and sweaty as the game goes on). Such a distinguishing property also makes possible to attribute to objects, but not to events, *change*. In the ordinary sense, it is said that the very same object changes if and only if it instantiates two incompatible properties at different times and the difference of properties has contiguous effects.[4] In order to see whether such distinctions between events and things are really justified, it will be appropriate to trace them back to their linguistic and epistemic origin.

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[3] For this distinction, see D. Lewis, *On the Plurality of Worlds*, 1986, Blackwell, Oxford, p. 202. The essence of this distinction was given by D.H. Mellor, *Real Time*, Cambridge University Press, 1981, ch. 8, and by C.D. Broad before him in *An Examination of McTaggart's Philosophy*, Cambridge University Press, 1933, p. 138. See also P. Simons, *Parts. A Study in Ontology*, Oxford University Press, 1987, p.117.

[4] This definition of change is due to D.H. Mellor, *Real Time*, quoted, p.114.

One of the first positions that has been defended in the history of western thought sided with common sense in claiming that reality is exclusively constituted by material objects or, more technically, *primary substances*. According to Aristotle, such substances are what is real in the primary sense, union (*synolon*) of content and form. Being the referent of proper and common names in propositions and sentences, substances are susceptible of being determined by attributes, quantities and qualities, what in ordinary language we call *predicates* .

With some imprecision, we could say that the *prima facie* difference between things and events is mirrored by the syntactical, linguistic difference between subject and predicates. A concrete fact occurring at a certain time, *qua* a conjunction of a subject with a predicate, is then a conjunction of a substance with an event occurring to it, as, for instance, in 'Socrates is turning pale while he holds the cup containing hemlock' where 'Socrates' is the name of the substance, and 'turning white' and 'holding the cup containing hemlock' are two events occurring to him. If this is true, the reason for a distinction between an object and an event is to be found in *the subject-predicate structure of many Indo-European languages*, and corresponds to the difference existing between a material thing and its properties. Such a difference, however, has an *ontological raison d'être* only to the extent that an object may be said to possess some kind of 'thisness', *in the sense that it must be something over and above the complex of its external properties and internal occurrences*, a problem that has been debated in the history of metaphysics since the Middle Ages.

The ascription of thisness to objects (also known as *haecceity*) may seem an absurd piece of speculation, until we realize that it was justified by the need of explaining somehow an object's constancy of identity through time, despite changes in its properties. If an object is just the totality of its properties, and one of them changes in the time interval going from *t* to *t'*, how can we say that we are looking at the same object at times *t* and *t"*? Stripping away thisness from objects

could of course be accomplished by criticizing the notion of substance, but the empiricist philosophers who performed the deed had to invoke the intervention of the mind as an *Ersatz*, that was supposed to make up for the explanatory loss. For instance, Hume recognized the permanence of an object's identity through time as an important property, but he explained it by means of the «gentle force» of habit, supplied by the mind in order to hold together the various, separate ideas conjoined with, and related to, an object. Also Kant — who was obviously not an empicirist but more than Hume wanted to stress the creative and constitutive power of the human mind — referred to the *subjective* category of *substance as applying to the temporal, transcendental scheme of 'permanence in time'*.[5] In a word, since the property of 'having a permanent identity through time' was for both Hume and Kant supplied by the mind, the constancy itself could not be an objective property of things, and *things could be regarded just as collections of properties*.

Considering our progress in understanding the structure of solid matter since the time of Hume and Kant, I think that we are now in the position to explain the constancy of identity of objects as a by-product of the stability of their atomic and molecular configurations. Objects like desks, trees or persons are characterized by a set of relations of their parts such that most of them have a temporal duration which tends to resist changes from the environment. Therefore, in approving Hume's and Kant's idea that an object or a substance is just a collection of properties in a relatively stable mutual arrangements, one need not also endorse their view that the property of permanent identity is mind-dependent. If a physicalistic or chemical explanation of the typical constancy of an object's reciprocal configuration of its parts is available, as I think it is, why invoke the mind? Notice that I am not saying that we can give a complete description of a chair in pure physicalist language, something which at the current stage of physics cannot be attained, but

[5] The reference is obviously to Kant's 'Transcendental Deduction' of the *Critique of Pure Reason*.

rather that the stability of the physical and spatial relations, say of the molecules of a certain piece of crystal can in principle explain the constancy of its external appearance. Likewise for a piece of chalk and a chair.

The permanence in time of such a collection of properties can be better understood by reflecting on how we learn to *recognize* things as being the same in different moments of time. In our everyday experience, and especially when we learn to use language — that is, when we learn to use *the same word* for approximately similar sensory stimuli — we must be able to recognize objects and persons as being identical, despite some change occurred in them at previous moments of time. Such an acquired capacity is by no means trivial. Piagets's experiments on the children's ability to recognize objects after they have passed behind a screen that blocks them from sight for a short time are well-known. Only at a certain age are such objects judged as being the same, even if the velocity with which they enter the region of space located behind the screen is different in intensity and direction from the velocity with which they reappear. Of course, the child can recognize the object as the same, only if, say, its color and shape are constant while something else (velocity) changes. In other words, these experiments show in what sense the properties — dispositional as they may be — which are responsible for the color and shape of objects, must be regarded as stable in time independently of our mind: such a stability is presupposed by every successful, concrete application of the ability. Likewise, we are capable of recognizing our desks, our apartments, our friends — paradigmatic examples of objects — as being the same after some time, even if they undergo remarkable changes in their external appearances, just because the mutual arrangement of certain of their properties is stable. To summarize, in order to attribute an enduring identity to an object, we need not to believe that it is something over and above the collection of its properties, that is, something over and above the set of events that can be attributed to it.

In order to specify in more details the nature of the relation between an object and 'its' events, it is useful to refer to a well-known definition of events. By further clarifying this relation, we will also be in a better position to evaluate the doctrine that objects cannot have temporal parts and are therefore wholly present at any instant of their existence. Consider a property instantiated by an object at a certain moment of time: for instance, the being red of a certain traffic light at time *t*, or Tom's falling on a snow track at *t'*. Following Kim, I call such temporally indexed properties, instantiated by the two substances in question (the traffic light and the person) at some time, simply *events*.[6] An event is the being red of the traffic light at a particular time and Tom's fall at another time. At the time of the fall, Tom is wholly present, meaning that he, as an object, does not have temporally extended parts; his fall, on the contrary, has temporal parts, each of which is not wholly present when it exists.

An essential point of the debate on things and events, which is often neglected, is that the last sentence applies only to *a certain way of looking* at Tom as a person: if we are interested in regarding Tom as the owner of all the properties he has just at the time of the fall, then we may conclude that Tom is wholly present at any of the times of the fall. However, if, as shown above, the object Tom *is nothing over and above* the properties he has historically considered (included the relational ones, like being a brother or a son), then we *can* regard Tom also as an 'historical', temporally extended entity, and therefore just as a complex event, characterized by having temporal parts, whose sum gives his whole life. If (i) if Tom is the sum of his properties at certain times as argued above and (ii) properties instantiated by Tom at times are, following Kim, simply events, it follows that (iii) Tom is the sum of 'his' events. Consequently, the main difference between Tom as a thing and Tom as a complex, historical totality of properties and occurrences

[6] See J. Kim, "Events as property exemplification", in *Action Theory*, Brand M. and Walton D. (eds.), Reidel, Dordrecht, 1976, pp. 198-215. According to Kim, an event is a triple, constituted by a substance a property and a time.

that define him, is only a difference in description, occasioned by the different *purposes* and *interests* we may have in choosing one description over the other. In a word, *the thing-language and the event-language offer two different descriptions of the same entity, two senses having the same reference, Tom*.[7]

In this sense, I propose to consider the difference between events and things as one that mainly depends on our varying pragmatical interests, with no ontological import.8 Rather than providing more arguments for (i), here it matters simply to remark that there are entities for which an historical description using an event-language is more appropriate than for other entities. In considering entities whose history matters, like peoples, nations, cities, biological species, planets, stars like our sun, or even the observable universe itself, the choice of considering them as a collection of events (properties at times) that can be temporally ordered by 'before' and 'after' appears natural. In describing a stone or a tree or a desk as an object rather than as a collection of events, we simply (and implicitly) dismiss its historical nature as less important, though an historical consideration of a stone or of our desk is always possible and in some case important. For instance, the desk may be an antique, or the stone may have archeological or geological interest: in these cases, an historical consideration, dividing the stone or the desk's temporal carrier in different stages may be appropriate.

To make this claim more plausible, I need to defend the view that also temporally extended entities retain their identity through time and can, therefore, change. Notice first of all that events, like objects, may have a certain temporal duration: the *t* in Kim's definition need not be a pointlike instant. Consequently, the state of being red, instantiated by the traffic light, may last a minute, and Tom's fall may last some seconds and may be slow at the beginning and rapid at the

[7] The expression thing-language and event-language are due to H. Reichenbach. See note 13.
8 For a similar opinion motivated by different arguments, see B. Van Fraassen, *Quantum mechanics*, Oxford University Press, 1995, p. 454.

end. Likewise, we can imagine that the red light may be faint at the beginning and intense at the end, and that this change is continuos, without any clear subdivision. A particular concert may have distinct movements, all belonging to the same event, that can be differently characterized, and a war may have different stages, differently described. If for our descriptive interest it becomes appropriate to subdivide the history of a famous philosopher or of a star in various temporal stages, then we can say also of persons and stars that they have temporal parts, none of which are wholly present at one time. Heidegger *qua* existential philosopher was not wholly present after 'die Wende', though Heidegger as a person was. Conversely, what's wrong with saying that events themselves change, in a way that a concert (an event) is first slow and then *allegretto*, a fall is first funny and then fatal, a war first bloody and then cold?

Moreover, the feature that typically characterizes things — their being wholly present at any time of their temporal existence — applies also to events, *whenever they are pointlike or not temporally extended*. Though the temporal thickness of events can be more familiar from everyday life and the absence of temporal extension can be the result of an idealization, there is no reason why pointlike events should not be considered to be events. And these events are certainly wholly present when they occur, since they have no temporal parts, a remark that shows that the possession of parts is not a necessary feature of events: in relativistic physics, for instance, events are usually considered to be temporally and spatially non-extended.

Likewise, in our perceptual experience, we can always find parts of perceived events which are short enough as to *appear* to be wholly present at *t*. In fact, if the *t* in question is below the sensory threshold which is necessary to perceive two events as being two or as being temporally ordered, the event in question will be perceived as wholly present, even if in physical time it has temporal parts. Since, however, we are now considering the psychological aspect of the event (say the quality of a certain note), we must admit that the short duration of that note makes it

perceptually indivisible, which means that the note in question is wholly present at the time of its perception, something that provides another example showing that also events, in certain circumstances, can be devoid of temporal parts, and be wholly present when they occur.

It could be replied that objects are in *every* circumstances wholly present at a certain instants of their temporal carrier and this could be regarded as an important difference with events. However, such a reply holds water only if objects can *never* be treated as temporally ordered (historical) entities having temporal stages, but this is far from being true. If we consider a person as an historical series of events, we cannot say that a woman is wholly present also when she a girl, at a certain stage of her life, since many of her properties which she will instantiate only later on in life are not present then, and conversely. A mountain like Everest may be regarded as being a typical instance of an entity being wholly present at any instant of its temporal carrier, just because its changes are much slower than those of a person, i.e., its configuration is much more stable. But this does not mean that the Everest, in certain contexts, cannot be treated as something which does *not* instantiate its complete collection of properties at any one time. Suppose that the greenhouse effect becomes so serious that the raise in the temperature is sufficient to melt all the snow on the top of Everest. Before the gigantic melt, the Everest's later property of 'having no snow' was not present. And if 'being covered by snow' is meant as an important property of mount Everest at earlier stages of its carrier, the fact that mount Everest being was wholly present at the time in which the snow will melt can be questioned. *Qua* historical entity, the mount Everest is not wholly present at any moment of its carrier, exactly as the second world war isn't wholly present in 1940, but is wholly present in the interval *t* stretching from 1939 to 1945.

Finally, the usual argument against the idea that events themselves change is also dubious, and goes as follows. Suppose that one wanted to claim that an event *E* changes from being *P* at *t*

to being *P'* at *t'*. Since *E* has temporal parts, one can always redescribe the change in *E* in such a way that it is only the first part *e* of *E* that can be attributed the property *P* at *t*. Another, later part *e'* of the same event *E* has another property *P'* at a later time *t'*. Since *e* □ *e'*, there is no change in the event *E* = *e*+ *e'* (despite the fact that *P*□*P'*), because we are really dealing with *two* events, such that *e* is *P* and *e'* is *P'*.

To begin with, this argument does not apply to situations in which the division in temporal parts of the event is arbitrary or conventional, because the 'change' in the property *P* may be continuous, as in the case of the redness of the traffic light, which may become more intense with the passage of time. How are we to divide *E* (the being red of the traffic light during a certain time) in precise temporal parts, in such a way that the property *P* exemplified by it (the becoming more intense of the light) can be 'distributed' or attributed to the different parts? If the division in parts is continued indefinitely, it will get to unextended events, which cannot change by definition, but this is obviously not what is intended by the argument above. An instantaneous temporal slice of an object cannot change either — because the notion of change can be applied only to entities whose existence (identity) lasts for some finite time — but this fact is not considered to be evidence in favor of the claim that object, as opposed to slices of them, cannot change. Therefore, if it does not work for things, it cannot be applied to events either.

Secondly, the fact that a continuous change of a quality of an event should always be attributed to the object of which the event is a property and not to the event itself, cannot be taken as a successful rebut. Note that it is because of a change in the quality 'redness', attributed to the *traffic light* (an object) at a certain time, that we can attribute the change also to the traffic light. However, there is no evident absurdity saying that the intensity of the color (a feature of the event) changes. Moreover, both *e* and *e'* have a common relational property, that of 'being part of the same event *E*', ad it is in virtue of this identifying property that we can attribute a change

to *E*, as when we currently say that the nature of a single war has changed, that a school year has changed from easy to difficult, that the life of Mr. *X* (an event) has become impossible, and so on. Once again, these remarks are not to deny that there exists some difference between events and things at the descriptive level; rather, it is just to deny that such a difference is clearly specifiable in all circumstances independently of our descriptive purposes and that events determine or circumscribe a set of entities that are ontologically different or autonomous with respect to things or objects.

§ 3 Events and things in contemporary spacetime theories

In discussing the impact of relativity theory on an ontology of enduring things, it is necessary to recall that the major philosophical novelty of the special theory of relativity, carrying over to the general theory, is that the notion of 'being present at a distance' or, alternatively, 'occurring at the same time', comes to depend on the arbitrary choice of an inertial frame. It is no longer *absolute* or frame-independent as it used to be in Newton's universe, where a privileged inertial frame was guaranteed by the existence of absolute space, and a preferred 'rigging' of the space was legitimated by absolute time. In the Einsteinian universe, all inertial frames are on a par, and no one is privileged. By invoking this experimentally confirmed conception of temporal relations, one could suggest the following argument. Suppose an ontology of objects is admissible also in a post-Einsteinian universe. If, in order to avoid solipsistic consequences, objects have to be able to coexist at a distance, then they have to be objectively co-present.[9] However, in relativity objects can be co-present only with respect to an arbitrarily chosen inertial frame in which

[9] This idea is illustrated and commented extensively in J. Balashov, "Enduring and perduring entities in Minkowski spacetime", manuscript to be presented at the PSA 98 colloquia. I thank the author for his willingness to send me the manuscript. Here I use his hint for a different analysis.

they are simultaneous. Since simultaneity at a distance is not an absolute notion, also the co-existence of objects becomes a frame-relative, non-objective notion. Provided that (i) the essential feature of endurantism as an ontology of objects is the alleged fact that they are wholly present, and (ii) more than one object must objectively exist at any one time to avoid solipsism, it would seem to follow that either endurantism is committed to solipsism, or to an implausible frame-dependent notion of reality, or it conflicts with relativity.

However, a weak point of this anti-endurantist argument is that it is not clear why the co-existence of objects being wholly present at any one time really requires the objectivity (invariance for all observers) of the notion of *simultaneity at a distance, or of co-presentness at a distance*. It must be admitted that, to the extent that endurantism requires *an ontology of tensed facts* in which only what is present (with respect to me-now) exists — and we bear a privileged relation of coexistence with Steve Weinberg but not with Albert Einstein — tensions and conflicts with relativity may arise. In a tenseless ontology, temporal slices of pairs of objects are in some sense co-real or tenselessly co-existent at any instant of time, even if one slice is earlier than the other. If only tenseless facts are real, the temporal distance between slices (events) usually does not imply that one of the two is real while the other isn't. Why should an endurantist commit herself to an ontology of tensed facts, so as to run into problems with relativity? After all, the debate over the nature of tenses (whether they are real or mind-dependent) seems relatively independent of the things-events controversy, since an ontology of things may or may not be committed to the reality of tensed facts. The supporter of endurantism is always free to choose an ontology in which the only mind-independent facts are tenseless temporal facts of the kind expressed by sentences like '*a* is earlier than *b*, '*a* is simultaneous with *b*', '*a* is later than *b*'.

However, it may be replied that a believer in an ontology of things is more naturally committed at least to a *tenseless* form of becoming — namely, to the idea that for all times *t*, the future

temporal stages of an object as of *t* do not exist, and only the past stages do. In this case, as we are about to see, the endurantist embracing such a becoming in a relativistic context would have to accept the view that spatially distant objects (or temporal slices thereof) do *not exist* as of a location *O* at time *t*. Can a *realist* commitment to the reality of objects be reconciled with an *antirealist* denial of objects collocated in the spacelike related region?

To see first of all why this antirealist claim follows, let (*O*, *t*) be the finite spatio-temporal region occupied by any object *O* at time *t*, at which, in agreement with the endurantist requirement, *O* is wholly present. The question is whether such presentness extends at a distance as the 'anti-solipsistic' argument above has it or not. Since a spatial part of an object is usually still an object, and the duration of *t* may be reduced at will, it is possible to consider the region (*O*, *t*) to be small enough as to be assimilated for all practical purposes to an approximately pointlike spatio-temporal region. On this hypothesis, a theorem proved by Stein can be applied,[10] with consequences that are far from threatening even to the endurantist wanting to embrace tenseless becoming.

The argument for this conclusion is in the form of a dilemma: tenseless becoming is either mind-dependent (i) or is real (ii). As a consequence of Stein's theorem — which *strictu sensu* is applicable to a dyadic, reflexive and transitive relation of definiteness holding between pairs of spacetime *points* of Minkowski spacetime — if (i) is the case, all points (all pointlike objects) are real as of any location (*O*, *t*). In the second case (ii), Stein proves that if— as required by objective tenseless becoming — for any point (pointlike objects in) (*O*, *t*)), at least some other point (object) is not real as of (*O*, *t*), *then* the objects that are spatially distant with respect to (*O*, *t*) simply don't coexist with (*O*, *t*), in the same sense in which the points (slices of the object) located in the future light-cone of (*O*, *t*) are not real as of (*O*, *t*).

[10] See H. Stein, "On relativity theory and the openness of the future, *Philosophy of Science,* 58, 1991, pp.147-167.

In the former case (i), in which becoming is absent, the relation of tenseless coexistence is secured, because all objects located in the region outside the light cone of the region (O, t)) are real with respect to it. If, in the latter case, becoming is real, the argument according to which things at a distance must coexist loses its force, because Stein has proved it incompatible with objective becoming as it must be implemented in the theory of relativity. In this theory, in fact, the present is reduced to a point, and the 'now' coincides with a 'here'.[11] If denying co-presentness at a distance is counterintuitive, we cannot expect that the ontology of enduring entities passes the text of relativity without some modification. According to both horns of the dilemma of becoming, an ontology of enduring things does not seem to be ruled out by relativity.

A different problem raised by relativity to endurantism has been posed by Reichenbach, following an argument given by Einstein. An inertial trajectory representing the history of a point-like particle (an enduring object) at rest in a given frame is usually drawn with a vertical line, or vertical worldline. Any straight line, tilted from -45^0 to $+45^0$ with respect to the vertical, represents the possible inertial trajectory of another particle, having, with respect to the particle at rest, a constant velocity.[12] Let me label with A the location of the particle at the origin of the rest frame, and with A_1, A_2... etc. the later stages of this very particle, supposing it remains at rest with respect to the given frame. The points A, A_1, A_2 are all situated on the vertical worldline representing the particle of rest in successive moments of its carrier. Let B_1, B_2 label the later stages of another particle passing through A but endowed with constant velocity V with respect to particle at rest. Likewise let C_1, C_2 be points located on another inertial worldline of a particle possessing a velocity $V'' \neq V$ with respect to the particle at rest, and also passing through A. The two

[11] *Ibid.*
[12] For the limitation of relativity, the velocity in question will have to be smaller than, or at most equal to, the velocity of light: the worldlines can be found only in the region within the light cone.

tilted straight lines, one including the points $A\ B_1\ B_2$ and the other the points $A\ C_1\ C_2$, represent two different inertial lines intersecting point A.

Given that the theory of relativity mandates the absence of a privileged frame of absolute rest, according to Einstein-Reichenbach there is no fact of the matter as to whether the particle in A is the same as the particle passing through $A_1\ A_1$ or the same as the particle going through $B_1\ B_2$ or through $C_1\ C_2$, where $A_1B_1C_1$ and $A_2B_2C_2$ are locations lying in an horizontal line. There is in fact an *infinite* number of points on the segment joining A_1 with B_1 with C_1 and in each of these locations we can imagine a particle coming from A with a different velocity. As Reichenbach puts it:«Nature does not supply a unique rule in this case. Einstein saw in this fact the collapse of the old concept of substance. This means only (and that is how it is formulated by Einstein) that *there are* material field in which this arbitrariness exists. Einstein thus wishes to characterize the metrical field that propagates gravitational forces. On the other hand, there are also material fields in which there is a natural striation; an example is atomic matter, the world-line bundles of which can by no means be considered as arbitrary».[13]

The essential, anti-endurantist point in the argument above is that physics can provide no objective rule for the re-identification of objects (particles) at different times, due to the relativistic demise of the previously objective relation 'being in the same place at different times'. However, note that the atomic 'material fields' to which Reichenbach refers are presumably those belonging to the some rigid body, for instance a measuring rod, an instrument which is essential to the foundations of the theory. Obviously, in the case of a rigid rod, somehow the wordlines of its components ('atoms', loosely speaking) must be correlated by dynamic forces, which keep the reciprocal distance and relations of such parts almost invariant. This stability helps us to identify rigid objects across time. Despite the correctness of Reichenbach's point about the 'metrical field

[13] H. Reichenbach, *The Philosophy of Space and Time*, Dover, 1958, transl. by M. Reichenbach, p.270-1.

propagating gravitational forces', 'atomic matters' of rigid bodies cannot be left out of relativity, since macroscopic rigid objects like rods and clocks must be presupposed to give an operational meaning to spatio-temporal measurements. The need to attribute completeness to the theory closes the circle virtuously: since the theory of relativity needs rods and clock to perform measurement, if it is complete, it must be able to represent them in its own terms, *i.e., it must admit things in its ontology*, represented as four-dimensional tubes in spacetime. This much must be presupposed, even if we somehow relax the absoluteness of the length of an object, by assuming that it can vary with transportation in different points of space: the stretching and squeezing rod is still the same.

Physics or, to that effect, relativity, cannot be blamed for not being able to yield a criterion of identity for free particles of fields regions at different times, since this is not its business. After all, we don't need physical rules to identify objects at different instants of time, and from the fact physics cannot yield such a rule, *it does not follow that objects have no persisting identity*. Analogously, even granting that relativistic physics (and theoretical physics in general) does not need the notion of being present, from this we cannot conclude that the notion of being present is illusory. As Van Fraassen once put it: «Physics as such has not interest in where *I* am *now,* but I do, and if I did not, I would not be in a position to apply science at all».[14] Once enduring objects are seen as sets of three dimensional entities ordered by a local time variable, or as the complex of their history, the fact that there is no preferred rigging of 3-dimensional space does not mean that enduring objects can't keep their identity through time, an identity which, as said above, is objectively guaranteed by the relative stability of their parts. The fact that relativity favors an ontology of events cannot be taken to mean that an ontology of objects is incompatible with it.

§ 4 Events and things in quantum mechanics and field theories

[14] B. Van Fraassen, *Quantum mechanics*, Clarendon Press, Oxford, 1995, p. 453.

Interestingly, also Reichenbach recognized that the fact that relativity theory favors a language dealing with events ('an event language' as he put it[15]) over a thing-language, does not imply that objects are logical constructions out of momentary entities — as Russell and Carnap had it at one stage of their intellectual development — or that they don't exist. According to Reichenbach, it is apparently possible to translate any expression referring to things in one referring to events and vice versa,[16] and this intertranslatability claim, if correct, would make the thing-event debate look very different from, say, the tensed-tenseless time debate, in which no such translations from tensed to tenseless sentences is available.[17] This remark may also have the following ontological meaning: if, as previously suggested, objects are regarded as the paradigms of what is real, and it is legitimate to view them as the temporally ordered collection of their instantiated properties at certain times, then also properties at time, that is, events, must be considered to be real.

However, before concluding that physics cannot be decisive in ruling out an ontology of things *versus* one of events or *vice versa*, we should at least mention the possible metaphysical contributions of quantum mechanics. Considering that its revolutionary impact *vis à vis* classical physics is greater than that of relativity, one could suspect that quantum mechanics could jeopardize both an ontology of events and an ontology of things. Of course, an antirealistic interpretation of the quantum mechanical formalism is always possible, and has been endorsed by most physicists: if it were justified, claims about properties of non-measured entities whose state is not an eigenstate of an observable would simply be meaningless. But this instrumentalist reading of quantum mechanics would make it neutral toward our debate and would only reinforce my pre-

[15] H. Reichenbach, *The Direction of Time*, Berkeley, University of California Press, 1956, p. 224.
[16] *Ibid.*
[17] J. Faye, *The Reality of the Future*, Odense University Press, Odense, 1989.

vious claim that physics is compatible with both enduring and perduring entities, as they are conceived by ordinary language and commons sense. To put this claim under further scrutiny, allow me to be a bit more adventurous in supposing that quantum mechanics allows us to draw some ontological lessons, revisable as they may be.

The first claim that could be advanced against an ontology of events relies on Bohr's complementarity between a *spatio-temporal* description of phenomena and the *causal* principles of conservation, the first version of Bohr's complementarity principle.[18] To the extent that an ontology of events needs at the same time *both* the availability of an in-principle complete spatio-temporal description *and* the possibility of identifying events *via* their causes and effects as they are manifested by laws of conservation, such an ontology seems directly ruled out by quantum physics, *if the latter is indeed correctly characterized by Bohr's complementarity.* It is not by chance that in quantum mechanics one can talk legitimately about events only in referring to amplified effects of microscopic entities on macroscopic apparatuses. On the contrary, it is very difficult to classify the typical, non-measured temporal development of a quantum entity as an event, since it is non localized and may change discontinuously.

This relates to the second difficulty of an event ontology in quantum physics. As a consequence of the so-called 'quantum nonseparability', non-measured entities that, say, have been diffracted by a screen with two splits, may be spread all over spacetime, since before measurement they have a non-zero probability of being in a very large region of space (large not just compared to their wavelength). Analogously, in Bell-type experiments, particles which have been sent in two very distant regions of space can behave in an harmonious fashion even at a distance, in such a way that the measurement result on one particle on Earth is correlated to the result obtained with the twin particle on Andromeda.

[18] H. Folse, *The Philosophy of Niels Bohr: the Framework of Complementarity*, Amsterdam, North Holland, 1985.

In the case of Bell-type experiments, should we talk about *two* different events (processes), or about *one* single, spatially extended event? If we chose the latter alternative, the event would be non localized, and its parts would be disconnected in such a way that the localizability in different parts of space could not serve as a criterion of identity. It would be difficult to recognize such a spatially disconnected process as an event. If, as it is more plausible, the former alternative is chosen, once again we would have localizability of the entities only after measurement, since the entities themselves have in part a wavelike nature and therefore lack a definite location. As is well known, given Heisenberg's uncertainty principle, the availability of a precise knowledge of its momentum (energy), forces the particle to be spread out all in a vast region of spacetime. If, roughly speaking, before measuring the location of a quantum mechanical entity, the entity itself should be regarded (mostly) as a wave, then waves, given the pervasive phenomenon of *superposition* (the possibility of adding and subtracting their effects as in the ocean), cannot be ascribed an identity. Following Quine's slogan, one can ask how there can be an entity without identity. The lack of a precise spatio-temporal description of the event makes difficult any reference to events or processes.

The problem of identity through time also afflicts quantum entities seen as things or objects perduring in time, since quantum 'particles' or simply *quanta* like bosons or fermions are indistinguishable. If we have two of them (1 and 2), and two possible outcomes for each of them (H or T), we can't distinguish, with obvious notation, H_1T_2 from T_1H_2 (i.e., 'head with the first coin and tail with the second' from 'tail with the first coin and head with the second'), so that the quantum probability of obtaining H_1H_2, or T_1T_2 or HT (i.e., one-head and one tail) is always 1/3. Since we can't tell which particle is which by considering their properties, though we can certainly count them, we can say with Redhead and Teller that the particles don't possess primitive this-ness (*haecceity*), that is, their properties cannot be switched by the individuals in such a way

that their identity is kept: «We can amass quanta without [...] any ordering distinction in the way a stock of quanta is built up. Given an "amount" of quanta, there is no intelligibility to reordering or reassigning them while keeping fixed the property combinations that occurs.»[19]

The problem of the existence of object-like micro-entities (particles) in quantum mechanics is therefore twofold and is linked to their individuation, since, once again, we cannot have enduring entities without identity. The first problem regards the identity of a particle *at a single moment of time*: at any instant of time, any two bosons have properties that are completely exchangeable because of their indistinguishability. The second problem involves the individuation of a particle *at different times*: besides the problems raised by relativity and presented in the previous section (the relation 'being in the same place at different times' is relativistically not invariant), we must keep in mind that, unlike the classical case, in the case of *quanta* we cannot attribute precise spatio-temporal trajectories to each particle.

Since the latter difficulty has been in part already dealt with above, we can concentrate on the former. Entities that can be counted but not distinguished have certainly a very peculiar *status*, but the strategy to rescue their identity is, if not impossible, certainly quite dangerous, since it involves both anti-empiricist strategies and claims of non-locality. Distinguishability of any two particles can be reestablished if one is willing to introduce some kind of probabilistic correlations at a distance between the particles themselves:[20] one could still regard the outcomes H_1H_2 and T_1T_2 as positively probabilistically correlated, in such a way that the particles tend to go into the same state. Suppose the particles *are* distinguishable. Outcome or state H (or T) for one particle makes the state H (T) of the other more probable, so that H_1H_2 has probability 1/3 (like T_1T_2) , which is greater than the classical outcome 1/4. The *negative* correlation of the classical H_1T_2 and T_1H_2 would be expressed by the fact that rather than having 1/2 = 1/4+1/4 for the probability

[19] P. Teller, *An Interpretive Introduction to Quantum Field Theory*, Princeton University Press, 1995, p.29.

of 'one head and one tail', here we would have 1/3 < 1/2, where each of the two in-theory distinguishable outcomes would have probability 1/6. While it would still be empirically impossible to discern H_1T_2 from T_1H_2, we could nevertheless assume that they are in fact distinct: the difficulty signaled by Reichenbach about locality could perhaps be overcome, despite Van Fraassen,[21] as we now know that quantum mechanics is non-local, at least in the form of nonseparability. But should we think of a difference in theory between the two particles that is in practice impossible to detect?

If these are the difficulties that an endurantist or a perdurantist have to face, it would not be too far from the truth to claim that both a thing- and an event-ontology become problematic in quantum mechanics, possibly, as we will see, more the former than the latter. This is hardly surprising, since quantum mechanics presents problems with any ontological interpretation, the one resorting to facts included, since in the case of non-measured entities whose state is not in an eigenstate of an observable, one could assert that there is no definite state of affairs, corresponding to propositions possessing no definite truth value.

However, it would be mistaken to assume that an ontology of enduring entities is never presupposed by quantum mechanics, and I think it appropriate to say that any field theory, including relativistic quantum mechanics, must attribute reality to the field itself. Bigelow, Pargetter ad Ellis put this point in the following way: «Fields [...] carry energy; so their existence is required to preserve the law of conservation of mass-energy. Also, fields reduce the mystery of action at a distance, and explain the time delay in the distant effect produced by changes of properties of objects, since a finite time is required for the propagation of a field or a disturbance in the field [...]. [Fields] are, more particularly, the bearers of potential energy. Two separated oppositely charged particles have potential energy in the field created between them during their separation.

[20] See H. Reichenbach, *The Direction of Time*, quoted, p. 233-4.

If the reality of the fields were denied, we would still have to say that the charged particles were *disposed* to accelerate towards each other. The removal of the field would leave mere dispositions in its place. But is the *basis* of such a disposition, and where exactly *is* the energy? Hence the attractiveness of the reality of the fields — they explain the dispositions, and carry the energy».[22]

Such a long quotation is important not only to show that fields are currently taken as real by physicists, essentially for the same reason given by the authors above. In addition, the talk of dispositions as supervenient on fields leads us to believe that the field possesses most characteristic features of an enduring substance spread out in spacetime. The field's identity need not change in different regions of spacetime, though the values of the quantities in that region, its properties, may differ. Furthermore, *substantivalism* about spacetime cannot be ruled out so easily, if it is interpreted as claiming the reality of the gravitational field. Einstein himself equated the ether, devoid of mechanical properties, with space(time) when he claimed that there cannot exist space without gravitational potentials, since the latter «confer upon space its metrical qualities, without which it cannot be imagined at all. The existence of the gravitational field is inseparably bound with the existence of space.»[23]

If these reasons are sufficient to make room for an ontology admitting objects in order to be able to refer to the field itself, it is more difficult to interpret the changes in the field as events, given the problems raised above. Perhaps, it is only by relaxing the requirements of precise localizability and spatiotemporal continuity, satisfied by events in relativistic spacetime, that we can have some success in interpreting fundamental interactions in field theory as involving events. This success will also depend on the feasibility of an identification of causality with fun-

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[21] B. van Fraassen, *Quantum Mechanics*, quoted, p. 431-2.
[22] J. Bigelow, B. Ellis and R. Pargetter, "Forces", *Philosophy of Science*, 55, 1988, pp. 614-630.
[23] A. Einstein, "Ether and Relativity", An Address delivered on may 5th, 1920, in the University of Leiden.

damental interactions as they are given by quantum field theories.[24] In this case, an exchange of a quanta (say, a photon) mediating a causal interaction (say, between two electrons) could in some sense be regarded as an event. These remarks, however, are sketchy indeed and are meant only to point to future research programs: a more complete evaluation of the nature of this problem unfortunately will have to wait until we have a fusion between our best spacetime theory (general relativity) and quantum field theories.

[24] This interesting but speculative identification is put forward by A. Heathcote, "A Theory of Causality: Causality = Interaction (as defined by a suitable quantum field theory)", *Erkenntnis*, 31, 1989, pp. 77-108.