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Should we represent the present in Minkowski spacetime?[1]

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ABSTRACT:

In recent times, there have been notable attempts to introduce an objective present in Minkowski spacetime, a structure that, however, should also be capable to explain some aspects of our experience of time. I claim that the "interactive present" introduced by Arthur and Savitt for such purposes is inadequate, since it turns out to be neither a physically relevant property nor a good *explanans* of our temporal experience. In its conclusive part, and after having proposed a more adequate model for the time of our experience, I draw some general morals about the relationship between physical time and experiential time.

KEY WORDS: present, Minkowski spacetime, spacetime physics, temporal experience

In recent times there have been interesting attempts to introduce a *mind-independent* present in Minkowski spacetime, a structure that has *also* be regarded as capable of explaining some aspects of our subjective experience of time, in particular the fact that we

share a "now" but not a "here".[2] Considering that Minkowski spacetime is the arena for *three* out of the four interactions postulated by contemporary physics (electromagnetic, weak and strong), this claim, if correct, would be quite remarkable. Against the prevailing opinion of physicists and philosophers like Einstein, Russell, Grünbaum, Davies, Rovelli and many others, we would have in fact discovered that it is possible to find a now (even a "transient one") in any contemporary physical theory whose spatiotemporal arena has the structure of Minkowski spacetime. At the same time, we would have gone some way toward a rapprochement of "the manifest image"[3] of time − allegedly characterized by a spatially extended, transient now − with the physical image, traditionally dominated by the picture of a block universe in which the present is absent because regarded as purely mind-dependent.

The main thesis of this paper is that in Minkowski spacetime the so-called "Alexandroff" or interactive present", introduced by Arthur and Savitt[4] for the above reasons, is neither a physically relevant property nor a good *explanans* of our temporal experience.

Therefore, it should be dropped. On the one hand, being defined as the set of events that can be in *mutual* causal communication with a given segment of a worldline, the Alexandroff's present is definitely objective and mind-independent, but not so relevant from the viewpoint of physics.[5]

On the other hand, regarded from the subjective, first-person perspective, or even as the set of events typically picked out by the indexical "being present, the "Alexandroff's present" turns out to be unfaithful to our experience, because it does not include all the events that experientially we regard as present, while including events that we do *not* regard as present. While Arthur explicitly denies that the interactive present can serve the purpose of describing the subjective present, both he and Savitt countenance the possibility of using it to *explain* or accommodate *some* key features of the subjective present. I will instead argue that, by incorrectly *describing* what we regard as present, the Alexandroff present is not a good explainer, since it is inferior to other available alternatives.

The paper is structured as follows. In the first section, I will present Savitt's two main motivations for having a present in Minkowski spacetime, and the corresponding two senses in which physics might be said to be in need of an objective now. In the second section, I will introduce the main features of the so-called "Alexandroff's present" (henceforth "Alex", for short), and the alleged link between the agreed-upon temporally extended character of the present of our experience (specious present) and its supposed "interactive nature". In the third section I will discuss what I refer to as "Alex's *dilemma*" between its marginal role in physics and its unfaithfulness to our experience. In the fourth section I will illustrate the former horn of the dilemma, by presenting some possible uses of Alex in mathematical physics: I will conclude that they are not sufficient to argue that Alex has an important role in physical theories. In the fifth, I will illustrate the latter horn of the dilemma, by defending an alternative, better explanation of the spatial extendedness of our experienced nows, based on empirical data concerning our psychophysical threshold for regarding two light signals as temporally successive.

§1 Savitt's two motivations for having a present in Minkowski spacetime

The first, and possibly more important, motivation consists in showing that the task necessary to close "Shimony's circle" between the objective aspect of time and its felt, subjective aspect, can, at least in principle, be completed:

> The program [of closing the circle] envisages the identification of the knowing subject (or, more generally, the experiencing subject) with a natural system that interacts with other natural systems. In other words, the program regards the first person and an appropriate third person as the same entity.[6]

I am very sympathetic toward this project,[7] as it is one of the inspiring Muses of the philosophy of time, and possibly of the philosophy of science in general. For this reason, I think that Savitt's quite ambitious slogan "*Philosophy of time should aim at an integrated picture of the experiencing subject with its felt time in*

an experienced universe with its spatiotemporal structure"[8] should be endorsed.

However, Savitt's second motivation for introducing an objective now in Minkowski spacetime is, I take it, in potential *conflict* with his ambition of "closing Shimony's circle". Such a second motivation consists in his attempt to show that Einstein's often quoted "worry" that physics cannot grasp "the Now" is in some sense unfounded.[9] In his autobiography, Carnap tells us about Einstein's views about the Now in its relation to science:

> «Once Einstein said that the problem of the now worried him seriously. He explained that the experience of the Now means something special for man…That this experience cannot be grasped by science seemed to him a matter of painful but inevitable resignation» (Carnap 1963, 37, my emphasis).

Parallel to Savitt's two motivations, there are *two* senses in which one could think that physics *needs* an objective now. According to the first sense, current physics is to be regarded as *incomplete* because it has not yet captured an allegedly objective property *being now*, a property that − unlike "being massive" or

"being charged" − has so far escaped all physical theories. While such a first sense might be regarded as *too* strong, I take it that it is the *only* sense in which one would be entitled to conclude that "there is a viable alternative" to Einstein's worry (see note 9).

The second sense in which physics might need a now is quite *weaker*, as it amounts to claiming that a physically objective now − possibly corresponding to some objective spatiotemporal structure − is needed *either* to explain some key features of our subjective experience or manifest image, *or* in the practical application of physical theories by human beings, *or* to give a semantic interpretation of our use of "now" as an indexical.

Incidentally, these two senses relative to a possible role of "the Now" in physics remind one of the current debates on the role of causation in physical theories. While Frisch[10] defends a more substantive role for causation in physics (analogously to the first, stronger sense in which physics might need a now), Norton grants the pragmatic importance of causation, but argues that it is definitely absent from fundamental physical theories[11] (in tune

with the above illustrated weaker sense in which physics might need a now).

I will now argue that it is only this second, weaker sense that one could have in mind when one claims that "physics needs a now". While Arthur and Savitt explicitly agree with the point that the now could *not* figure in future, yet to be discovered, *physical laws*,[12] they do not grasp its consequence *vis à vis* their ambitious project of introducing a now (in some sense) in physics. If any important physical property is sooner or later captured by laws, if "now" is an indexical, and indexicals cannot appear in laws, then I think one must conclude that Einstein's and others' claim is correct: there cannot be any Now in physical theories, since pragmatic uses or explanatory purposes do not suffice to overthrow Einstein's worry. Einstein and all the other scientists/philosophers quoted above would not deny that in the application of physics we may have to resort to a now, so that Arthur's and Savitt's polemical point is overstated. I submit that there is no real disagreement between them and the philosophers/physicists whom they criticize.

In order to be clearer about the import of my remark, let me put it this way. As hinted above, there is a strong and deep analogy between the issue of ascertaining the status of the now and that of clarifying the status of causation in physics. Well, on the basis of this analogy, I think it is fair to say that *vis à vis* the status of the now, Arthur and Savitt really side with Norton against Frisch, so that for them the sense in which physics needs a now cannot but be quite weak, but they seem to write as if they were on Frisch's side, that is, as if there were significant sense in which physics needs a now.

Going beyond Arthur's and Savitt's real intentions, one could try to defend the possibility of a strong sense in which physics may need a now by claiming that some property might not figure in laws, and yet be objective and physically relevant. However, the objectivity or mind-independence of a property or a relation is only a *necessary* but not also a *sufficient* condition for the property in question to be of physical interest. And with some qualifications to be discussed in section 4, Alex, regarded as the set of events that are in mutual causal communication with a segment of

timelike curve, seems to be one of these objective but physically irrelevant properties.

It seems then safe to conclude that the *only* reason to introduce an objective present in Minkowski spacetime ought to be linked to the above mentioned *second* sense, the sense that I think Arthur and Savitt are really after. Let me stress one more time, however, that this sense leaves Einstein's claim unscathed, at least as long as we are not prepared to regard physics as incomplete simply because it has not yielded so far a solution to the body-mind problem, by giving a third person, physical description of our temporal experience.

In the rest of the paper I will argue that even in the second, weaker sense, Alex is an arbitrary choice, since other spatiotemporally extended structures, or other non-geometrical explanations, can do the job in a more satisfactory way.

§2 Alex's features in relation to the extended character of our experience

It is now time to look at the features of "Alex" in some more detail, since they are crucial in order to assess its suitability for explaining our experience of time, or for accounting for some pragmatic uses of the "present" in cosmology, as when we claim that, for example, "galaxies in our universe formed a certain number of billions year *ago*", or "the *present* age of expansion of the universe".[13]

The Alexandroff's present *relative* to a segment of any timelike curve delimited by points *a* and *b* is the intersection of the future light-cone whose vertex is the beginning event *a* with the past light cone whose vertex is the end event *b* (it is assumed, as customary, a temporal orientation). The Alexandroff's present *relative to the segment a-b of a worldline* − call such a set Alex [*a*,*b*] − is then by definition the set of points in the above mentioned intersection. The (relational) objectivity of Alex [a,b] depends on the invariance of the relation of causal connectibility within the special theory of relativity. In fact, it turns out that any event in the set Alex [a,b] *is both a possible effect and a possible*

cause of events on the segment of the worldline, and for this reason it could be regarded as the set of events with which my body or any other physical system modelled by a worldline can in principle *interact* during the time-like interval a,b. Notice for example that in fig. 1 below, point *c*, which is outside Alex [a,b] but inside event's *b* past light cone, can be a possible cause of many events on the segment, but is not in *mutual* causal contact with all of it, since it cannot, in its turn, be caused by events belonging to the segment.[14] The notion of mutual causal connection can be put more precisely in this way: Alex's present relative to *a*,*b* is the set of all points *z* such that *there exist two points x* and *y*, belonging to the segment *a*, *b* for which we have *both* $C_P xz$ *and* $C_P zy$, where C_P is the relation of *past causal connectibility*.[15]

One more point worth noting is that the length of the timelike interval under consideration may vary from context to context, and this is certainly an advantage of this conception: as we know from ordinary discourse, "now" can pick out my present perception, the

present historical moment, or even the “present stage” of cosmic expansion.

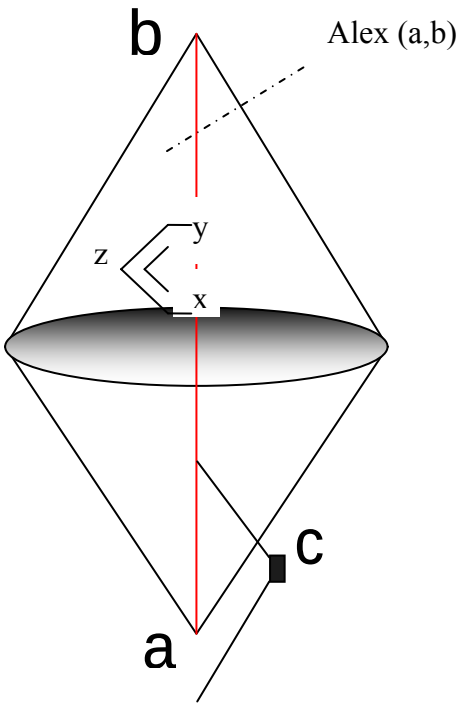

FIG. 1

Imagine that the segment a,b represents, with due idealizations, my pointlike body *looking* at this room “right now”. If you are unhappy with a segment, imagine a long and thin cylinder, a worldtube. Why should my experience be represented as temporally extended along the segment a-

b, so as to form what is known as a *specious present?* There are two possible arguments in favour of such a hypothesis. One comes from phenomenological evidence stemming already from James, Husserl and other psychologists and phenomenologists, linked to studies related, say, to our perception of music or language. The wealth of evidence coming from this corner and militating against a point-like present is quite strong.

A second, more speculative and physicalist argument, has been put forth by Stein. On Stein's hypothesis, the temporal extendedness of the present of our experience is due to the conditions that he regards as necessary for a *conscious experience* to occur. These conditions require coordination, i.e., *several mutual interactions of the parts of the brains with themselves and of such parts with their external environment*. Notoriously, in relativistic physics, interactions take time, and it is this *empirical hypothesis* that could explain, among other things, why our experience of the

present is not knife-edged, as James put it, but "specious", or temporally extended.

In a word, the idea of a spatiotemporally extended present like Alex's − a set of events that is in mutual possible causal interaction with our bodies and brains experiencing something − in Stein's opinion would be a consequence of the fact that the stability of the various parts of our brains and of the external physical objects around us needs several coordinations, which are realized by mutual physical influence.[16]

Agreed: one immediate advantage of choosing Alex as a model of our experienced present is that it allows *a* plausible explanation of the reason why we all share the same now,[17] as well as of our "natural" intuition − belonging to "the manifest image of time − that the now, or the present moment, *appears* to us as being cosmically extended: Alex is temporally thin and spatially fat.[18] This "illusion", notoriously, was unmasked by Einstein in order to lay the foundations of the special theory of relativity. To this purpose, he had to show that any perception ascertaining the

simultaneity of two events is always strictly local, so that the attribution of a relation of simultaneity to two *distant* events necessarily entails some conventional, or operational element.

Considering the fact that our experience of time is always local, it is also natural to claim that *if* we want to represent our experience of time in Minkowski spacetime, we must rely (on segments of worldlines measured by) *proper* time, and not on *coordinate* time. Dieks has pointed out, correctly in my opinion, that we don't need global nows to accommodate our *local* experience, since different spatial hyperplanes intersecting the same point or the same short timelike segment (an idealized representation of our body) *lead to the same experience*.[19]

However, notice that Alex's spatial extendedness, while sufficient to explain the corresponding aspect of our experienced now, is by far *not* sufficient to consider Alex as a good *explanans*. Different extended regions of spacetime might also succeed in explaining this aspect of our experience, and Savitt must somehow show that Alex is the best explanation we can give, a difficult task

that he tries to undertake without success, I think, and that I will discuss in the last section.

Summarizing my presentation of Arthur and Savitt's view of Alex, I agree with them on the following two points: (1) the present of our experience *looks* extended; (2) the notion of time on which to base the representation of the experienced present in Minkowski spacetime is *proper* time rather than *coordinate* time.

§3 Alex caught between its uselessness in physics and its unfaithfulness to our experience

The dilemma that I want to present in this section is a consequence of a tension between Savitt's two motivations for introducing Alex in Minkowski spacetime, which for brevity I will refer to as "Shimony's circle" and "Einstein's worry". In a word, I will now argue that

(i) the undisputable objectivity of Alex − needed by Savitt and Arthur to subvert (at least partially) Einstein's opinion against the describability of the now within physics − makes it unsuitable to account for the subjective present;

(ii) conversely, any success in representing the subjective present with a geometric structure of Minkowski spacetime would make a solution to Einstein's worry highly implausible. Let me broach these two points in turn.

(i)

Alex, as recognized explicitly by Arthur (and, I think, implicitly recognized also by Savitt), is *not* the subjective present, or "the set of all those events of which we are consciously aware at the moment of considering them".[20]

One of the reasons for this claim is put forward by Arthur himself: the set of events that we can actually be conscious of during an interval of time is always a *subset* of the set of those events that are in *actual* mutual communication with our bodies during that interval. This is not simply due to our selective attention − filtering out from our awareness many events that are in our relative Alex − but also to the fact that Alex is the set of *possible* and not of *actual* causes and effects affecting our bodies during a specious present. Therefore, many events in Alex will not be

registered by our consciousness, and Alex cannot coincide with the events represented in our subjective present.

For analogous reasons, however, the set of events in Alex is not picked out by our everyday uses of "now", when the latter is regarded (as it ought to, in Arthur's, Savitt's and my opinion) as an indexical. While the context dependence of such uses is well accounted for by the variable length of the timelike curve whose extremes are a,b, and while it must be admitted that our uses of the indexical "now" need not necessarily pick out the set of events that we subjectively regard as present, the intentions of the speakers are certainly relevant to fix the events picked out by the indexicals we use. However, by no stretch of imagination could we claim that by uttering "now" we typically intend to refer to all the events with which we are in possible and mutual causal communication (namely, to Alex). On Savitt's and Arthur's part, this could be stipulated only with a remarkable degree of arbitrariness, since in our usage of now, the idea of intending to refer to events *simultaneous* to our speech act seems much more prominent.

However, if Alex is neither (nor is it intended to be) the subjective present, nor is the set of events that we typically intend to pick out when we use the temporal indexical "now", why should we be believe that − simply in virtue of its spatial fatness − it is needed or relevant to explain our experience"?

As an additional argument against the adoption of Alex as an *explanans* of our temporal experience, notice that when we look, say, at the starry sky, we believe that it is part of our present experience. However, the events corresponding to the emission of light from a supernova occurred various year before our perception, and are therefore certainly not in out *momentary* specious present, which typically lasts more than half a second but less than a few seconds. Notice that *knowing* that the emission of light from the supernova is before our perception does not make us change the way we perceive the events in question: our illusion of presentness of the supernova is as stubborn as Müller-Lyer's famous illusion of the arrows appearing of different length despite our knowing that the segments of the two arrows are equally long.

It then follows that the events on the supernova responsible for our perception of it are outside the Alex's present representing our specious present, and yet they are pre-theoretically regarded by us as being present.

It seems that we can conclude that *if* Alex does not describe our subjective present correctly, *a fortiori* it cannot explain it, at least if we accept the thesis that the explanation in question requires the existence of a *supervenience* relation between our subjective, mental events associated to our experience of the now and Alex, regarded as subvenient basis of physical events. The example of the supernova shows that, by taking for granted the intentionality and the externalistic character of our mental states, an experience of the present must include events that are *not* contained in Alex (the base of supervenience). So a difference in what we regard as present (we look at a star that is much farther away than the previous supernova), by including in any case events outside Alex, is not reflected in a change of the subvenient base; since this means that our subjective experience does not supervene on Alex, we must accept the view that the explanation of our temporal experience

does not supervene on Alex. But then, how can Alex's explanation of some aspects of our subjective present be regarded as reliable?

It could be replied that whenever we are looking at closer stars, say, the Sun, we could *stretch* the segment [a,b] that represents our present into a much longer temporal intervals (16 minutes), so as to include the original electromagnetic emission from our star. Such an "elastic" procedure could possibly be iterated even when we look at the nocturnal sky with a powerful telescope. Wouldn't this be a way to rescue Alex from the charge of being "unfaithful" to our experienced present because of lack of supervenience? After all, we have already noticed how the length of the present is pragmatically dependent on the events we are referring to.

Suppose we accept this elasticity as a necessary consequence of the variability of the contexts of utterance of the temporal indexical. This "stretchy Alex" however, would be parasitic on a different model of the experienced present, a model that is altogether different from the original "Alex", and that includes events lying *on* the past light cone. The amount of the stretch, or the length of the elastic, *would in fact come to depend on the events*

we are looking at, and therefore on our regarding as present the set of events on the past light cone centered in our bodies. This would be tantamount to regard Alex's as dependent on another type of "present", one that would admittedly be much closer to our experience, but that would identify the present with the events on the past light cone. If the length of Alex becomes supervenient on the distance of the events which we are interacting with, one must accept that Alex is less accurate a representation of our present experience than the past light cone.

Arthur, who considered the possibility of representing the present of our experience with the set of events lying on the past light cone, complains that such a move would be equivalent to eliminating «any distinction between past and present».[21] This is doubtlessly correct. Arthur should have realized, however, that the elimination he complains about is *the* essential feature and by-product of our experience of the present. In fact, we are completely unaware of the time lag due to the speed of light, and unconsciously attribute light an infinite speed: the approximation, for all practical purposes of our earthbound life, is extremely good

since objects that are close "enough", as noted by Butterfield, typically don't change much after light bounces off them and reaches our retinas.[22]

I think that what we are facing here is a deep, acute conflict between the descriptive needs of physics and those of the psychology/phenomenology of the experience of time. On the one hand, if we adopt Einstein's standard convention of simultaneity in terms of "inertial-worldline-orthogonality", from the viewpoint of physics the events of the emission of the electromagnetic radiation from the stars or the Sun must be regarded as being in the causal past of our perceiving bodies. On the other hand, if we regard the emission of radiation from celestial objects and our act of perceiving it as *simultaneous* with our perceptions, we are much more faithful to our experience, but we eliminate any difference between past and present.

We could of course adopt a criterion of simultaneity that is *different* from the one that is customarily adopted, and yet closer to our experience of time: according to this different method, we could regard as simultaneous with our perception any event on the

past light cone. However, as already noted by Einstein, this method of fixing simultaneity would be quite impractical for physical needs, because it would make simultaneity depend on the particular spatiotemporal position occupied by the clock:

> We might, of course, content ourselves with time values determined by an observer stationed together with the watch at the origin of the co-ordinates, and co-ordinating the corresponding positions of the hands with light signals, given out by every event to be timed, and reaching him through empty space. But this co-ordination has the disadvantage that it is not independent of the standpoint of the observer with the watch or clock, as we know from experience."[23]

The impracticality of the method of simultaneity discussed in this quotation shows that even if we decided to modify Einstein standard criterion of simultaneity, the descriptive needs of physics and those of psychology would diverge.

The *second* argument against the possibility of stretching indefinitely Alex according to needs is this: if the extension/duration of the now were totally context-dependent, i.e., dependent on what we observe, its *physical* meaning would seem to become proportionally weaker. Alex would still be objective, but characterized by a length that is somehow mind-or observer

dependent!! So once again our attempt to solve Einstein's worry fails to the benefit of trying to solve the issue raised by "Shimony's circle".

These conclusions are generalizable to structures other than Alex and the past light cone above. Once we accept (for physical reasons) Einstein's standard criterion of simultaneity, it follows that even if we *could* successfully model the psychological present by using some other structure, like the past light-cone discussed above, we would end up with something which introduces some deep discrepancies with the constraints of the physical description of the world. And the simplest hypothesis that explains this gap is this: our natural folk-physical belief about what is present is illusory, since it *falsely* assumes the presentness (*simultaneity* with our perception) of whatever falls into our visual fields, supernova explosions included.

Einstein has expressed the illusory nature of our experience of time quite clearly:

> "The illusion which prevailed prior to the enunciation of the theory of relativity − that, from the point of view of experience the meaning of simultaneity in relation to

> spatially distant events and, consequently, that the meaning of physical time is a priori clear − this illusion had its origin in the fact that in our everyday experience we can neglect the time of propagation of light. We are accustomed on this account to fail to differentiate between "simultaneously seen" and "simultaneously happening"; and, as a result, the difference between time and local time is blurred." [24]

To summarize what I tried to show in this section in a single sentence: there are events in Alex that are not in our experience of the present, and events that are in our experience of the present that are not in Alex. And while in Savitt's and Arthur's intentions Alex is doubtlessly no more than *a first step* in explaining our subjective temporal experience − so that they would agree that much more needs to be done − I claim that the above discussion suffices to show that it is a step in a wrong direction.

I think that these considerations are sufficient to conclude this section with these two remarks:

1) In virtue of its objectivity, Alex cannot fulfil the aim of closing Shimony's circle. The question of bridging the gap between the time of physics and the time of the manifest image is still up for grabs, and must be studied by other means, namely

neurophysiology and psychology,[25] and not by combining some arbitrary physical structure physics with some features of our experience.

2) Attempts to close Shimony circle by adding structures to Minkowski spacetime are destined to be unsuitable for the descriptive purpose of physics, and therefore to prove Einstein's worry unfounded.

Against Savitt, I think I can conclude that the two motivations above cannot be had at the same time, and one of them must give way. In the next two sections, we will see that, as a matter of fact, the situation is even worse: Alex can serve *neither* purpose. The physical irrelevance of the interactive present on one hand (§4), and further arguments in favour of the unfaithfulness of the interactive present on the other (§5), will complete my objections to the introduction of Alex in a physical theory whose spatiotemporal arena is Minkowski's.

§4 The physical irrelevance of Alex

It would be unfair to claim that the Alex' present has *no role* whatsoever in physical theories. For instance, the condition of "strong causality" in a Riemannian manifold is provably equivalent to the fact that the Alexandroff topology coincides with the manifold topology, or to the fact that the Alexandroff topology is Hausdorff.[26] The basis of this topology is given by the intersection of the set of future directed timelike curves originating from p with the set of past directed timelike curves originating from q, with p earlier than q: $\{I^+(p) \cap I^-(q) : p, q \in M\}$.

Readers will recognize Alex's present relative to the segment [p, q] of the timelike curve, except that the Alex also contains lightlike geodesics, and is therefore $\{J^+(p) \cap J^-(q) : p, q \in M\}$, where $J^+(p)$ is the set of future directed causal curves originating from p and $J^-(q)$ is the set of past directed causal curves originating from q.

We need to distinguish an important fact separating Minkowski spacetime from general relativistic spacetimes, and investing the possibility of deriving metrical facts from topological/causal facts alone. While in Minkowski spacetime the manifold topology coincides with the Alexandroff topology, in order to obtain the desired equivalence in general relativity, we need to impose the further condition of *strong causality*, which is equivalent to the fact that the manifold has *no* "almost-closed causal curves", or no curves that come arbitrarily close to intersecting themselves. This means that "for every point p in the manifold M and for every neighbourhood O of p, there is another neighbourhood V of p contained in O such that no causal curve intersects V more than once".[27]

In Minkowski spacetime it can be shown (following Robb) that the postulation of a "beforeness" relation, plus some axioms that such a relation satisfy, is sufficient to fix the fact that an event is in the interior of a past or of a future light cone.[28] This means that all the topological properties of regions of Minkowski spacetime can

be recovered just by looking at the relation of causal connectibility, and the topology of spacetime can be the Alexandroff topology.

In a word, the main foundational interest of the Alexandroff topology lies in the possibility of determining metrical facts from topological facts involving the interiors of the light cones of Minkowski spacetime. The possibility of quasi-closed curves in general relativistic models, however, divorces the manifold topology from the Alexandroff topology, because in spacetime with almost closed causal curves not all causal automorphisms can also be homeomorphisms (i.e., topology preserving mappings).

However, it should be admitted that the illustrated role of the Alexandroff topology in foundational studies is a far cry from claiming that Alex is *relevant* for physics. In particular, there is no connection between the Alexandroff topology and temporal properties, despite the fact that *stably* causal spacetimes − for which the above relationship between manifold topology and Alexandroff topology a fortiori holds − do have a cosmic time.[29]

The latter concept is relevant for another issue: Arthur claims that it is in the *application* of physics, rather than with respect to

physical laws, that the now has a role. He correctly points out that it makes a great deal of difference with respect to available evidence whether it is supposed that the Big Bang occurred 14 or 26 *billions years ago*: "the relativity of the now to certain events (humans having theories) does not detract from its objectivity".[30] However, here the question is not the objectivity but the relevance of the now for physics. In the sentence just quoted, we can give the truth conditions of the above tensed expression by simply pointing out that, relatively to a certain class of events in spacetime, where we are tenselessly located at the moment in which we use a certain theory, the Big Bang has occurred 14 billions years before those events, rather than 26 billions before. But let us even grant a role to the tensed expression "billions of years ago" (we can accept that indexicals have essential meanings), and let us suppose that the "located" above is "located now". Why should this expression entail reference to the set of events that is in mutual causal interaction with the worldline that, initiating with the Big Bang, intersects now the areas of spacetime in which we now refer to that first event, is not clear at all!

Given the possibility of using a cosmic time, as it is customary in Frieman-Robertson-Walker's cosmological models (without thereby using cosmic time to refer to a *cosmic present*), we can interpret that tensed language (billions years ago) as referring, in the moment in which we use the theory, to the proper time of the "fundamental observer" associated with the mean motion of matter in our local cluster or supercluster of galaxies. Such a proper time can be extended, given certain assumptions, to the proper time of other "fundamental observers". Once again, this standard manoeuvre is fully compatible with denying the possibility of using cosmic time to defend a cosmically extended present. However, the point here is that our need of referring to the beginning of time and space cannot be said to provide evidence for the postulation of Alex. In virtue of the Cosmological Principle in fact, "the age of the Universe" is in fact something that holds for *all* possible regions of the universe now sharing the same values of pressure and density of cosmological dust, and not just for us users of the physical theory in a particular region along a particular worldline, as seems to be implied by local structures like Alex's.

§5 Another model of the present of our experience?

The point of this final section is to show that not only is Alex unsuitable to represent or explain some features of the present of our experience, but also that no other structure of Minkowski spacetime could do the job. This will allow me to conclude that we should not try to use such a spacetime to represent or explain or account for features of the present of our experience, in the weakest possible sense of explain or account. Given the facts (already argued for) that

(i) Alex has no important applications in *physical* theories;

(ii) it does not seem a plausible explanation of the extendedness of our subjective present,[31] and

(iii) these seem the two only reasons to introduce it,

I conclude that we should drop it.

With respect to (ii), we have already explained why Alex's interactive present, if used to explain our subjective present, should

at least describe it correctly. In this spirit, it seems reasonable to add to the previously discussed counterexample of heavenly bodies that Alex should also contain events that we regard as present simply because their temporal separation is so small as to be inferior to our capacity to tell them apart. There is a lot of experimental evidence in this field, which for our purpose we need to consider only synthetically, and which, however, is very relevant in order to explain the central feature of our experience of time.[32]

The main fact that I want to draw attention to is that Alex's present does *not* contain events that we nevertheless consider as simultaneous, in a sense of simultaneous that is close to Stein's notion of "contemporaneous" (see note 16). Owing to the minimal threshold that is necessary to distinguish *two* light signals as being temporally *successive*, we perceive as *simultaneous* events that are separated by less than a given threshold.

More in general, the threshold to tell two signals apart is different from person to person, and varies also from sensorial modality to sensorial modality. But in average, and for *visual stimula*, empirical research indicates that there is a threshold of

30ms for a person to be able to tell two flashes of light apart, let alone determine their temporal order, for which at least 45 ms are necessary. Multiplying the threshold time 30ms by the speed of light *c*, we get 30 x 10^{-3} x 300.000 km/h = 9000 km. A flash *a*, that originated 30 ms ago on the surface of a sphere whose radius is 9000 km, but simultaneous with event *b*, where I am located, registers on my retina only 30ms later, at event *d*.

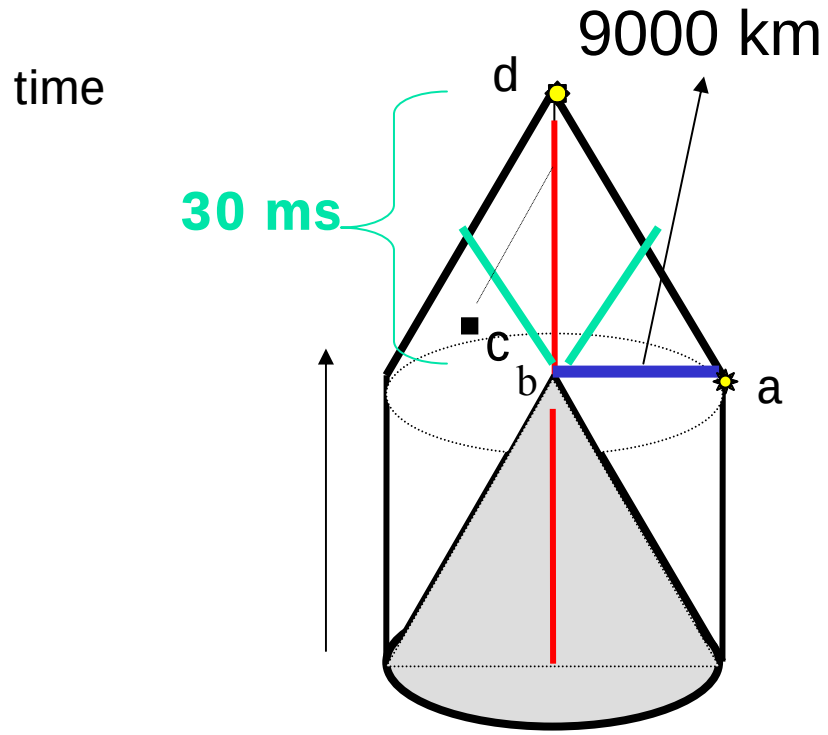

FIG.2

The flash *a* objectively precedes my reception of it at *d*, yet I perceive anything inside a sphere of a radius of 9000km, *a* included, as simultaneous with *b* and *d.*

Since light signals intersecting the vertical segment b-d are *physically* temporally separated but cannot be *perceived* as being temporally separated, they should be treated as part of the set of points that are subjectively regarded as present. Notice that events like *c*, supposing that are *on* the light cone, are *not* in Alex [b,d] but are perceived as simultaneous with *b* (at the center of the sphere) and with *a*, at its surface, and therefore *are* in the same present of the observer located in *b*. This counts as an another objection to the view that Alex can accommodate the present of our experience: Alex cannot explain the present of our experience since it does not contain events that we are bound to regard as present.

Should we then propose the grey area in the figure as a more faithful replacement of Alex and claim that the succession of the grey, conical regions along worldlines represents the passage of time?

I would be ready to maintain that the grey wedge or conical model is much less arbitrary than Arthur and Savitt's proposal, as it is based on well-confirmed psycho-physiological data, and that, therefore, it describes more precisely the extended character of our psychological present, in which perceived space, regarded as Leibniz's order of coexistence, is a construction of our brains. And yet, I am not sure that we should continue the game that Arthur and Savitt initiated by playing it with a different ball.

We have already noted how the fusion of the past with the present, of what is far away with what is occurring right here, explains why our experience of time "misrepresents" the physical, objective temporal separation of events. The misrepresentation, or better, the temporal fusion of timelike-related or light-like related events, is due to the fact that the time of occurrence of events is merged with the time of our perceiving them. To acknowledge that the present is extended means to acknowledge that the "past-there" is fused with the "present-here" because they are treated as simultaneous in virtue of the threshold needed to tell events apart. From an evolutionary viewpoint, this fusion does not represent any

terrible distortion of our environment, insofar as objects, as noted by Butterfield, do not change their properties too much during the time needed by light to inform us about them.

Notice that if we acknowledge that our experience of time is a fusion of events that from the viewpoint of physics are temporally separated, then it does not make much sense to try to represent with a geometrical/physical structure the set of events that *we* represent as being present, except by specifying that these events are part of a single experience of simultaneity.

Consequently, we *do* need to distinguish the "physical present" of events and the psychological present. The former, due to the relativity of simultaneity, and at least in Minkowski spacetime, must be represented as pointlike (each physical event is present, from its own "perspective", when and where it occurs), and it is only the latter that is extended, and can include many pointlike physical events, many of which are *temporally separated from the other*: violations of achronality are admissible only for the psychological present, but not for the physical present. If we want to bridge the gap between the time of physics and the time of our

experience, it is important to begin our work by recognizing their important differences.

[1] Thanks to Richard Arthur and Steven Savitt for extensive discussions and written exchanges over many of the topics discussed here. This has reduced, but possibly not completely eliminated, the number of misunderstandings on my part. Carl Hoefer has read a previous version of this paper and helped with critical comments and questions.

[2] Richard Arthur, "Minkowski spacetime and Dimensions of the Present", in: Dennis Dieks (Ed.), *The Ontology of Spacetime*, Elsevier Amsterdam, (2006), pp.129-155; Steven Savitt, "The Transient nows", in: Wayne C. Myrvold, Joy Christian (Eds.), *Quantum Reality, Relativistic Causality, and Closing the Epistemic Circle,* The Western Ontario Series in Philosophy of Science 74, Amsterdam: Springer 2009, pp. 339-352.

[3] This famous expression is in Wilfrid Sellars, "Philosophy and the Scientific Image of Man", chapter 1 in Wilfrid Sellars, *Science, Perception, and Reality*, New York: Humanities Press, 1963 pp. 40, where he contrasts the manifest image of the world with its scientific image.

[4] The interactive or Alexandroff present was originally suggested (in relation to the present) by Howard Stein, "On Relativity Theory and the Openness of the future", in: *Philosophy of Science* 58, 1991, pp. 147-167, and then elaborated upon by Wayne Myrvold, "Relativistic Quantum Becoming", in: *The British Journal for Philosophy of Science*, 54, 2003, pp. 475-500. These authors' claims, however, were somewhat less ambitious than Arthur's and Savitt's.

[5] Except, possibly, in recent attempts at building a mathematical setting in which causality can be studied independently of geometrical and differentiable structure Keye Martin, Prakash Panangaden, "Spacetime topology from causality", in: arXiv:gr-qc/0407093v1, 1993. Other applications can be found in algebraic approaches to quantum field theory. More on this below.

[6] Abner Shimomy, "Reality, causality, and closing the circle", in *Search for a Naturalistic World View*, Vol. I. Cambridge: Cambridge University Press, 1993, p.40.

[7] Arthur does *not* share this motivation with Savitt (personal communication).

[8] Ibid., p.340

[9] As evidence for the existence of this second motivation in Savitt's paper, consider that after quoting from Carnap/Einstein, Weyl, Davies and Rovelli, all trying to show that there cannot be a now in physical theories, he writes: «What I hope to do in this paper is show that there is a viable alternative picture to these views, a picture that includes, in some sense, a *now* and the passage of time» (ibid., p.340). With less emphasis, this motivation is shared also by Arthur, who writes: «Indeed it is false to say that physics does not take the "now" into account» (ibid., p. 151, n. 35).

[10] Mathias Frisch: "The most sacred tenet?' Causal reasoning in physics", in *British Journal for the Philosophy of Science* 60, 2009, pp. 459-474; Mathias, Frisch: "Causality and dispersion: A reply to John Norton", in *British Journal for the Philosophy of Science* 60, 2009, pp.487-495.

[11] John Norton: "Is there an independent principle of causality in physics?" *British Journal for the Philosophy of Science* 60, 2009, pp. 475-486.

[12] Arthur, ibid., p. 151-2, Savitt (personal communication).

[13] Arthur, ibid., p. 152.

[14] Event a and event c are not causally connectible, and the "first" event that could cause c is below a, or "earlier than a", see fig. 1.

[15] Myrvold, ibid. p. 480. Stein talked about Alex as the set of events *contemporaneous* with a given segment of a worldline, Stein, ibid, p. 159.

[16] Stein, ibid. p. 161.

[17] For a different explanation, see Jeremy Butterfield, "Seeing the Present", in *Mind*, 93, 1984, pp. 161-76 and Craig Callender, "The common now", in *Philosophical Issues,* 18, 2008, pp. 339-361.

[18] For this reason, Alex has also been used to explain the origin of the belief in presentism. «…presentists… are inclined to accord a kind of ontological privilege to that with which they can (then) interact. What they can interact with, at a particular near-momentary subregion R of their worldtube, is the contents of that region's Stein Present. But…such a Stein Present has very little temporal thickness and is very large in spatial extent. Such a region is easily mistaken for an instantaneous, global present.», in Ian Gibson and Oliver Pooley "Relativistic Persistence," in John Hawthorne (Ed.), *Philosophical Perspectives*, Vol. 20, *Metaphysics*. Oxford: Blackwell, 2006, p.169. For an attack on the significance of the presentism/eternalism debate in Minkowski spacetime, see Steven Savitt, "Presentism and eternalism in perspective", in D. Dieks (ed.), *The Ontology of Spacetime*, Elsevier, 2006, pp. 111-127, Yuval Dolev, "How to square a non-Localized present with special relativity", in D. Dieks (ed.), *The Ontology of Spacetime*, Elsevier, 2006, pp and 177-190, and Mauro Dorato, "The irrelevance of the presentist eternalist debate in Minkowski spacetime", in D. Dieks (ed.), *The Ontology of Spacetime*, Elsevier, 2006, pp. 93-109.

[19] Dennis Dieks, "Becoming, relativity, and locality" in D. Dieks (Ed.), *The Ontology of Spacetime,* 1, Amsterdam, Elsevier, 2006, pp.157-175.

[20] Arthur, ibid., p.151.

[21] Ibid., p. 151.

[22] Butterfield, ibid.

[23] Albert Einstein et. al., *The Principle of Relativity*, transl. by W. Perrerr and G.B. Jeffery, Dover Publication, New York, 1905/1952, p.39.

[24] Albert Einstein, "Physik und Realität", *Journal of The Franklin Institute* 221: 313-347, English translation in *Ideas and Opinion,* New York, Bonanza, 1936, p. 299.

[25] In any case, Savitt cannot be accused of trying to replace empirical research by philosophical reflection.

[26] Martin and Panangaden, ibid. The Alexandroff topology "is the coarsest topology in which all the interiors of light cones are open". See Lawrence Sklar, *Philosophy and Spacetime Physics*, University of California Press, Berkeley, 1985, p.81. More generally, an Alexandroff topological space is one in which the intersection of *any* family of open sets (also non finite) is still an open set.

[27] Robert Wald, *General Relativity*, Chicago University Press, Chicago, 1984, p.196. Strong causality is weaker than stable causality, which in turn is necessary and sufficient for the existence of a cosmic time function.

[28] Sklar, ibid, p.79. See also John Winnie, "The causal theory of spacetime", in J. Earman C. Glymour, and J. Stachel (Eds.), *Foundations of spacetime theories*, Minnesota University Press, Minneapolis, 1977, pp. 134-205.

[29] The use of closed Alex diamonds in algebraic quantum field theory as a basis to define an algebra of observables is also interesting but here it cannot be expanded upon.

[30] Ibid, p.152.

[31] For the sake of precision, neither Arthur (nor Savitt) presented Alex as a possible model of our subjective present, but argued that it could accommodate it.

[32] Some of this literature is covered in Callender (2008), who correctly invites philosophers of time that, like ourselves, are trying to bridge the experiential with the physical time, to devote more attention to experimental findings in neuropsychology.