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ORIGINAL RESEARCH

Not-so-Absolute Cosmic Simultaneity

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Abstract
Cosmic simultaneity is the proposal that we can reconcile absolute simultaneity with relativity by means of the cosmic time function definable in certain cosmological models. In this paper, I add a new criticism to the debate on cosmic simultaneity: once the relevant notion of absoluteness is clarified, a seemingly appealing approach to cosmic simultaneity, the metaphysical approach, proves to be inconsistent. My overall argument proceeds as follows. First, I argue for what I call the *Causal Connection Condition* (CCC): the fact that two events stand in a certain temporal relation is absolute only if it obtains independently of the occurrence of any causally disconnected event. I then show that, according to metaphysical cosmic simultaneity, whether two events are cosmically simultaneous depends on causally disconnected events. I conclude that metaphysical cosmic simultaneity is inconsistent.

1 Introduction

Ever since the advent of relativity, various proposals have sought to reconcile the theory with an absolute notion of simultaneity. One *prima facie* appealing approach involves the use of the *cosmic time* function, definable in certain highly symmetric cosmological models. This notion of absolute simultaneity, derived through cosmic time, has been labeled *cosmic simultaneity* (Swinburne, 2008; Read & Qureshi-Hurst, 2021, p. 8105; Read, 2023, p. 133), and I shall name its proponents *cosmic absolutists*. An often-quoted cosmic absolutist is the physicist James Jeans, who as early as 1936 stated that, on the basis of cosmic time, we have nothing less than "every justification" to assign an absolute meaning to terms like past, present, and future (Jeans, 1936, p. 22). However, scholars have pointed out a heterogeneous array

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of serious obstacles in taking the route of cosmic simultaneity.[1] In this paper, I follow this trend by highlighting a problem which has been overlooked in the literature. My claim is that, once the relevant notion of *absoluteness* is clarified, an appealing approach to cosmic simultaneity turns out to be inconsistent. When this is considered alongside the previously acknowledged problems, cosmic simultaneity turns out to be an unsuccessful proposal.

My overall argument proceeds as follows. In the next Section, I clarify the relevant notion of absoluteness at stake when it comes to defining an absolute present, usually by means of an absolute notion of simultaneity. What can one say about absolute simultaneity other than it is denied by a frame-dependent definition? What other kinds of relativizations would deny it? Little attention has been paid in the recent literature on these questions. Here, I analyze possible answers and ultimately argue for what I call the *Causal Connection Condition* (CCC): the fact that two events stand in a certain temporal relation (including simultaneity) can be considered absolute only if it obtains independently of the occurrence of any *causally disconnected event*. In Sect. 3, I distinguish between the epistemological and metaphysical approach to cosmic simultaneity. In Sect. 4, I suggest that some existing problems with cosmic simultaneity might be addressed by adopting a metaphysical approach. However, on the metaphysical approach, whether two events are cosmically simultaneous depends on causally disconnected events. I conclude that, given the CCC, metaphysical cosmic simultaneity is inconsistent.

As the reader may already suspect, the argument is quite general in its scope, since it is intended to be theoretically neutral in many respects. For instance, I do not presuppose a particular metaphysical account of spacetime, nor a particular theory of causality or facts independence. As far as I can see, none of this is required to my argument. If this is correct, then the argument is accessible from a wide range of positions, thereby posing a significant novel challenge to cosmic absolutists.

2 The Absoluteness of Absolute Simultaneity

According to the theory of relativity, no foliation of spacetime into spacelike simultaneity hypersurfaces is valid for all inertial frames: whether two spacetime points belong to the same simultaneity hypersurface depends on the frame of reference.[2] This is troublesome for A-theorists, who wish to assign a special metaphysical role to the absolute present (Deasy, 2017, p. 390). If the present is to be identified with a

[1] Recent critics of cosmic simultaneity include Bourne (2004, pp. 114–116; 2006, p. 199), Wüthrich (2010, 2013, p. 17), Smeenk (2013, p. 15), Callender (2017, pp. 75–78), and Callender and McCoy (2021, p. 4).

[2] I hereby follow Callender (2017, p. 42) in framing the discussed problem in terms of general relativity, or simply 'relativity', rather than special relativity, as is common. This is because the Minkowski spacetime of special relativity is just one physically possible model in general relativity (more precisely, a model representing a physical possibility). A generally relativistic spacetime (M, g) is a connected Lorentzian manifold equipped with a Lorentzian metric. A model (M, g, T) is a generally relativistic spacetime endowed with a smooth stress–energy tensor field that describes the distribution of matter/energy throughout the spacetime. Solutions of Einstein Field Equations (EFEs) are standardly taken to be physically possible models. Minkowski spacetime is one such solution for $T=0$.

certain collection of simultaneous spacetime points, and if which spacetime points belong to this collection depends on the frame of reference, then which spacetime points are present also depends on the frame of reference. So, the general problem goes, how can one assign a special metaphysical role to the present if what is present is not absolute? This problem led Hilary Putnam to argue for a four-dimensional view of temporal reality in his influential paper *Time and Physical Geometry* (Putnam, 1967). Since then, many authors have followed Putnam's lead in exploiting the tension between relativity and the idea of a special absolute present to argue against this or that A-theory.[3] Consider, for instance, presentism, the view that attributes *existence* to present things only.[4] If what is present (and therefore what exists) ends up depending on the reference frame, then the transitivity of co-existence fails, which seems absurd.[5] To maintain that the metaphysically privileged present is somehow absolute has thus been rightly recognized as an endeavor that stands in contrast with the secular teachings of relativity, and A-theorists positing an absolute present have commonly tried to recover an absolute simultaneity relation to determine what is absolutely present.[6] These A-theorists will be committed to:

> *Simultaneous-Present Absolutism* (**SPA**): There is a metaphysically privileged absolute present, and whatever is absolutely present is absolutely simultaneous with whatever else is absolutely present.

What is the concept of absoluteness at stake in SPA? In the debate on the tension between A-theoretic positions and relativity, the question has rarely been posed. Of course, virtually every author would quickly concede that relativizing simultaneity or presentness to the frame of reference denies SPA. However, surely there are many other kinds of relativizations that would have the same effect. As an example, consider two flares on different stars in the Milky Way. Suppose that, according to some strict notion of simultaneity, whether these two events are simultaneous depends on not only the frame of reference, but also on whether some mental state obtains (e.g., on whether I *believe* that the two flares are simultaneous). Or, alternatively, on whether the concentration of N2 in Earth's atmosphere has ever fallen below a certain value. One could generate endless examples of relativizations which are not reducible to frame-relativization, and in any of such cases the sim-present absolutists (those who endorse SPA) will not be happy to make the fact that the two flares are part of the absolute, metaphysically privileged present depend on such things. On the other hand, SPA cannot amount to the claim that presentness and temporal relations obtain independently of *anything else*. For instance, facts about temporal relations will certainly depend on facts about the existence or occurrence of temporal relata, or

[3] Among others, one finds Stein (1970), Savitt (1994, 2000), Sider (2001, pp. 42–52), Saunders (2002, pp. 279–280), Wüthrich (2013), Callender (2017, p. 80) and Baron and Le Bihan (2023).

[4] More precisely, the presentist claim is that *always*, only present things exist (Crisp, 2003, p. 215; 2004, p. 19; Deasy, 2017, p. 380; Ingram & Tallant, 2023, p. 2).

[5] The point was famously stressed by Gödel: "The concept of existence […] cannot be relativized without destroying its meaning completely" (Gödel, 1949a, p. 559).

[6] For a brief discussion of the prospects of A-theoretic proposals disconnecting presentness from simultaneity, see the end of Sect. 4.

they may depend on the occurrence of *certain* causal relations, and so on. It seems, therefore, that an analysis of the concept of absoluteness at stake is needed.

Although such an analysis is difficult to encounter, one attempt can perhaps be discerned in the work of Craig Bourne, who considered necessary to clarify absoluteness in order to make his (presentist) proposal for an absolute notion of simultaneity (Bourne, 2006, p. 175):

> It is not good enough to say boldly that we just do have some sort of understanding of the notion of absolute simultaneity; that, after all, was what Einstein was dissatisfied with. The question is, then, what does it take to understand it? There are two components: how to understand *simultaneity*; and how to understand *absoluteness*. […] [Regarding the latter] we do understand what it is for ourselves to be *absolutely present* and for present-tense propositions to be absolutely true, for it is not possible for us to be anything but correct about whether we are present, if we are presentists: if we exist, we are present.

There are two key takeaways from this passage. First, both absolute presentness and absolute simultaneity are absolute in the same sense, since the condition for absoluteness is taken from Bourne to be the same in both cases. This clarifies that the notion of absoluteness that Bourne is interested in is the one of interest to the sim-present absolutist. Second, at least one condition for absoluteness is *modal*.

To understand this, it is useful to take a step back and consider the problem from which Bourne started his discussion, which he labels the *Present Problem* (Bourne, 2006, p. 23): "Although we know by immediate acquaintance which time is our own, how can we know that our time is *present*?". Here '*present*' is again the theoretically charged expression indicating the metaphysically privileged time. The problem arises when considering that, although we know which time is our own, namely *this* time, if other times exist then *this* time may not be the metaphysically privileged time. Bourne's proposed solution is presentism: on the assumption that the only time is the *present*, it is necessary that, if I say "*I am present*", I am correct (Bourne, 2006, p. 24).

Why? The most plausible answer seems to be that, given I necessarily exist when I state "*I am present*", and given that, on presentism, if I exist, I am present, it is simply impossible for me not to be present. But for the inference to work, one must also assume the necessity of presentism, for otherwise I could live in a world where presentism is false and be wrong in stating that I am present. In fact, often presentists contend that their view is not only true, but *necessarily* true (Ingram & Tallant, 2023, p. 2). Assuming that the modality at stake here should be *at least* metaphysical modality, Bourne's account of absolute presentness can therefore be reconstructed as the claim that absolute presentness entails (at least metaphysically) necessary presentness. Similarly, according to the passage quoted above, to say that something is absolutely simultaneous with something else, should entail that it is (at least metaphysically) necessarily so.

There is no need to take this reconstruction of Bourne's account of absoluteness too seriously. Its purpose, here, is merely that of a starting point for discussing the relevant notion of absoluteness. Should the sim-present absolutist accept that an event

e_1 is *absolutely* simultaneous with an event e_2, only if the relation holds in all (at least metaphysically) possible worlds? I suspect not. Suppose that, in a world W_1 where absolute simultaneity holds, a trumpeter just played an excellent jazz song; each note generated by absolutely simultaneous finger movements on the valves. Suppose, now, that there is a second world W_2, identical to W_1, except that a mouse, by jumping out at some spacetime point connected with the performance, frightens the trumpeter, disrupting the otherwise absolutely simultaneous finger movements. If the sim-present absolutist concedes that these two worlds are indeed physically possible worlds, as it seems they should, then to say that an event e_1 is absolutely simultaneous with e_2 does not entail that the relation holds in all physically possible worlds (let alone in all metaphysically possible ones). In W_1 the finger movements are *absolutely* simultaneous, while in W_2 they are not.

In order to shed more light on the absoluteness notion of interest to the sim-present absolutist, let me now consider a third world, W_3, very similar to W_1 and W_2. Likewise with both worlds, absolute simultaneity can hold between events. Likewise with both worlds, there is a trumpeter playing. Likewise with W_2, at some spacetime point there is a mouse jumping. In W_3, however, the mouse lives on a distant star system. It is an alien mouse, and none of its actions are causally relevant to the trumpeter's performance. Suppose, moreover, that in W3 as well, depending solely on the fact that the alien mouse jumped on a distant star system, the trumpeter finger movements have not been (absolutely) simultaneous. One must be careful here. The alien mouse's actions are supposed to be causally disconnected from the jazz player's finger movements: no one was scared, and the song was still excellent. And yet, depending solely on the alien mouse jumping, the finger movements just were not simultaneous.

Can the sim-present absolutist maintain that W_3 is (at least metaphysically) possible? That is, can the sim-present absolutist maintain that, had in W_3 the alien mouse not jumped on a distant star system, the trumpeter's finger movements would have been *absolutely* simultaneous? I suspect not. It is perfectly acceptable for the sim-present absolutist to say that, in W_2, depending on the fact that the earthly mouse jumped out, the trumpeter's finger movements were not *absolutely* simultaneous. The earthly mouse's actions had a causal influence on the trumpeter's performance, and causation is commonly linked with counterfactuals involving temporal relations. However, in W_3 absolute simultaneity depends on causally disconnected events. As a consequence, the sim-present absolutist would have to accept, with the possibility of W_3, that whether some events are part of the absolute present can depend on causally disconnected events, such as a faraway alien mouse jumping.

To see why this should worry the sim-present absolutist, suppose, *ad absurdum*, that they were to allow absolute temporal relations to depend on causally disconnected events. For example, whether two events are absolutely simultaneous might depend on the causally disconnected event 'establishment of a new convention'. This would not by itself render simultaneity conventional. Indeed, for a relation to be conventional it should be somehow *determined* by the convention itself rather than by the establishment of it (Rescorla forthcoming, p. 3). Yet, certainly part of the reason why a relation being held conventionally is uncontroversially considered *non-absolute* is that, if a new convention were established, the relation may not hold. Thus, if the sim-present absolutist allows some absolute temporal relations to depend on

the event 'establishment of a new convention', this would place the relations at least uncomfortably close to being conventional. It seems therefore that the sim-present absolutist has two options. First, they might attempt to establish, by means of some complicated argument, from which kind of causally disconnected events absolute relations can depend on. Or, which seems the *convenient* option, they might adopt an intransigent position, disallowing absolute relations from depending on *any* type of events causally disconnected from the relata.

On the basis of what said above, I propose that the sim-present absolutist should accept the following condition for the absoluteness of temporal relations:

> *Causal Connection Condition* (**CCC**): The fact that two distinct events are in a certain temporal relation (e.g. simultaneity) is *absolute* only if it obtains independently from the fact that any distinct *causally disconnected* event e_x occurs.

Here, 'event' is used in its metaphysically loose sense, encompassing both instantaneous events, represented in relativity by spacetime points, and extended events, represented by worldlines.

Aside from the above general arguments for the CCC, one might wonder what is the CCC's status within available metaphysical accounts of temporal relations. Of course, the matter is broad and cannot be completely covered in this context. However, one thing one might say is that the CCC is consistent with a popular metaphysical account of spatio-temporal distance such as Lewis's. Lewis distinguishes between internal and external relations, where internal relations supervene on the intrinsic nature of each relatum taken separately, while external relations supervene on the intrinsic nature of the relata taken together as a composite (Lewis, 1986, p. 62). When it comes to spatio-temporal relations such as simultaneity, Lewis considers them to be *external* relations. While the duplicates of two simultaneous events may not be in the same temporal relation in different possible worlds, their being simultaneous in one world, for Lewis, entirely depends on the *nature* of the two events as a *composite*, and therefore on nothing causally disconnected from the composite.

According to this analysis, one could be tempted to take the CCC as a metaphysical necessity, especially since there may be reasons independent of Lewis's account to consider the CCC a metaphysically necessary principle. Consider presentism. As noted, proponents of the view commonly take it to be *necessarily* true: necessarily, what exists is present. Moreover, one might think that the *existence* of something is *essentially* independent of causally disconnected things. Taken together, the two theses entail that *necessarily*, if something is absolutely present (and absolutely simultaneous with other present things), it is so independently of causally disconnected things (where the modality is again metaphysical). Why believe that existence is essentially independent of causally disconnected things? Suppose for the sake of argument that the nonexistence of something, call it X, depends on the existence of a causally disconnected thing, call it Y. This would make X having or lacking its intrinsic properties dependent on the existence of Y. This, however, contradicts the common characterization of intrinsic properties as those properties that an object has, or lacks, independently of the properties (or existence) of any other object (Lewis, 1983, p. 197; Le Poidevin, 2010, p. 174; Marshall & Weatherson, 2023). One can

object to this common characterization by arguing, for instance, that X must have its intrinsic properties in virtue of *causally connected* objects, especially those that had a causal role in determining the very existence of X. However, this move is not available when it comes to causally disconnected things such as Y.

The above reasoning shows that, within certain metaphysical views about time, existence, and properties, one can find reasons to strengthen the case for the CCC and to clarify its status as a metaphysical necessity. Of course, presentists may have different accounts of properties or existence in mind. More generally, the sim-present absolutist can reject the CCC, together with the above-mentioned metaphysical accounts of time or intrinsic properties, and opt for an absolute simultaneity notion depending on global features of the universe. Whether the resulting view would be plausible depends on the specific metaphysical assumptions endorsed by such sim-present absolutist, but doubt can be cast already at this general level of discourse. Many A-theorists postulating absolute presentness, indeed, will agree that whether an event is absolutely present should not depend on causally disconnected events, but rather that it is instead somehow an *internal* matter.

However, since SPA is a very general position, I do not think that one can provide an argument showing that *any* sim-present absolutist is compelled to the CCC. Nonetheless, it remains the case that the CCC is highly intuitively plausible. Notice that the principle is rather weak, since it is a necessary but not sufficient condition for the absoluteness of a certain temporal relation. Let me stress, for instance, that a frame-relative notion of simultaneity is standardly regarded as non-absolute for reasons independent of the CCC. Moreover, the CCC has the merit of addressing the question raised in the introduction: which other types of relativizations might challenge the absoluteness required by the sim-present absolutist other than frame-dependence? Since one such proposal, as argued, is needed, missing a better one, one should give CCC a chance to see how it plays out. In fact, CCC is a crucial assumption of my overall argument against metaphysical cosmic simultaneity. Let me therefore introduce cosmic simultaneity proposals in the context of relativistic physics.

3 Epistemological and Metaphysical Cosmic Simultaneity

In many relativistic spacetimes, one cannot even specify a *global* time order, in the sense that one cannot order all spacetime points by a relation of chronological precedence that is transitive and irreflexive, let alone establish a global time order that is also absolute (Earman, 2002, p. 4). However, fortunately for absolutists, some spacetimes do admit a global time order. The current standard view is that the ones that do this most nicely are the so-called globally hyperbolic spacetimes.[7] Such spacetimes allow more than just defining a transitive and irreflexive precedence relation between all spacetime points. According to Geroch's splitting theorem, one can also define a continuous *global time function* that maps all spacetime points onto the real line preserving the precedence relation. Moreover, the manifold can be seen as diffeomor-

[7] For details on why these spacetimes are best at satisfying certain conditions regarding causality see Minguzzi and Sánchez (2008).

phic to the product of a 3-D spacelike Cauchy hypersurface and the real line, where *Cauchy* hypersurfaces are intersected by each and every timelike curve exactly once (Geroch, 1970).

Of course, however, the possibility of defining a global time order and a global time function is of limited interest to the absolutist, for the decomposition of a globally hyperbolic spacetime into space and time still depends on the reference frame. Some have therefore looked at the subset of globally hyperbolic solutions in which one can specify a *unique* global time order and a *unique* global time function (Callender, 2017, pp. 72–73). When such solutions are cosmological, the unique global time function is named *cosmic time*.

The term 'unique' is crucial here. It indicates that, on the particular foliation that allows the specification of the cosmic time, the spacelike hypersurfaces have a specific physical property, such that this foliation is *physically distinguished* from all other possible foliations in a (provably) unique way. Still, of course, different foliations remain a possibility. Prominent examples of such solutions are FLRW (Friedmann-Lemaître-Robertson-Walker) solutions. The restriction to non-empty FLRW spacetimes is standardly achieved by the assumption of two simplifying principles: the *Weyl Principle* (WP) and the *Cosmological Principle* (CP). WP states that the worldlines of galaxies (or clusters of galaxies, or even clusters of clusters) form a 3-bundle of non-intersecting timelike geodesics orthogonal to a series of spacelike hypersurfaces. CP states that the spatial distribution of matter over such hypersurfaces is homogeneous and isotropic on sufficiently large scales (Narlikar, 2002, p. 107).[8] WP is a precondition to CP (Rugh & Zinkernagel, 2011, p. 412; Macchia, 2011, p. 317; Callender, 2017, p. 73). Given WP, one can define a global comoving frame via the definition of fundamental reference frames in which *fundamental observers* (freely falling fictitious entities each having the average speed and mass of matter in given large-scale regions) are at rest. Given CP, one can prove that the foliation of the spacetime relative to such comoving frame is the *unique* foliation that preserves homogeneous and isotropic spacelike hypersurfaces. The proper time intervals measured by fundamental observers provide cosmic temporal distances (Smeenk, 2013, p. 204).

Aside from standard FLRW solutions, there are other cosmological solutions that can be used in cosmic simultaneity proposals, i.e., solutions in which one can prove the existence of a unique time function such that hypersurfaces are uniquely distinguished. One set of interest is the set of Constant Mean Curvature (CMC) solutions, of which FLRW models are special cases. CMCs are roughly defined as those solutions in which there exists a time function such that the spacetime is foliated by Cauchy hypersurfaces with a mean curvature value constant on each hypersurface, but increasing with time (Andersson et al., 2012). When this time function is provably unique, the relative foliation is uniquely physically distinguished by all other possible foliations by having a constant mean curvature.

One can generalize by saying that cosmic time is, for each solution within the specified subsets of solutions, the time function which uniquely preserves some phys-

[8] A homogeneous and isotropic spacelike hypersurface is such that, at any point/event that belongs to the hypersurface, there are no preferred spatial directions in which the universe looks different.

ical properties of spacelike hypersurfaces. However, according to the formalism, all possible foliations are equally valid. Without additional assumptions, one can only conclude that certain spacetimes can be foliated by uniquely physically distinguished hypersurfaces. These foliations may be theoretically desirable as far as they simplify calculations. However, this is not enough to recover absolute simultaneity. The cosmic absolutist must add something further. They must add that the foliations are also *privileged*:

Privileged Foliation (**PF**): A foliation of a certain cosmological solution of EFEs is privileged if, and only if, each spacelike hypersurface within the foliation (hereafter 'privileged spacelike hypersurface') has some physical properties (e.g., homogeneity and isotropy), and this is not the case for all other possible foliations, *and* the simultaneity relations between spacetime points as defined on that foliation represents an absolute relation between events.[9]

From this, it follows:

> *Cosmic Simultaneity* (**CS**): Given a privileged spacelike hypersurface Σt, for every distinct pair of events e_1 and e_2, respectively represented by the spacetime points p_1 and p_2, if $p_1 \in \Sigma t$ and $p_2 \in \Sigma t$, then e_1 is absolutely simultaneous with e_2 and vice versa.

At this point, the crucial question arises: how should the cosmic absolutist justify their claim that simultaneity relations, as defined on the privileged foliation, are absolute?

It looks like the physical properties that render a foliation privileged should be somehow *relevant for determining* whether two events are absolutely simultaneous. But what does 'relevant for determining' mean here? One possible interpretation is epistemological: the fact that two events are absolutely simultaneous is discoverable only if some physical properties are uniquely held by spacelike hypersurfaces in a certain foliation of the universe, but this is not a necessary condition for the obtaining of absolute simultaneity itself. In this sense, privileged foliations are *epistemologically privileged*. Another, stronger, interpretation of 'determining' is metaphysical: some kind of metaphysical link holds between the physical properties at stake and absolute simultaneity. In this interpretation, for some events e_1 and e_2 to be absolutely simultaneous, it is *necessary* that the spacetime points representing them belong to a privileged hypersurface. In other words, on the metaphysical interpretation, CS is reinforced as a stronger claim:

> *Cosmic Simultaneity* + (**CS+**): For every distinct pair of events e_1 and e_2, respectively represented by distinct spacetime points p_1 and p_2 within a certain cosmological model, e_1 is absolutely simultaneous with e_2 and vice versa if, and only if, there exist a privileged spacelike hypersurface Σt such that $p_1 \in \Sigma t$ and $p_2 \in \Sigma t$.

[9] Although hypersurfaces related to the cosmic time function are often labeled 'privileged' by physicists, the term sounds to my ears metaphysically charged (e.g., is there a *privileged* moment of time?), so that I shall use it as a distinctive philosophical term, as opposed to 'physically distinguished'. For an analogous distinction in terms of *special* foliations and *absolute* foliations see Forrest (2008, p. 251).

An "epistemological" defense of CS has been notably made by Swinburne (1983, p. 73; 2008). On the basis of his non-operational account of the meaning of simultaneity, Swinburne suggests that absolute simultaneity is still possible, although in principle *undiscoverable*, within many solutions of EFEs.[10] However, he maintains that we can discover whether two events are absolutely simultaneous only in a universe correctly represented by a spacetime foliable into spacelike hypersurfaces that are (at least approximatively) homogeneous and isotropic, i.e., in a (at least approximatively) FLRW universe (Swinburne, 2008, p. 258; Read & Qureshi-Hurst, 2021, p. 8107). Swinburne also provides a precise account of how homogeneity and especially isotropy are relevant to the possibility of discovering absolute simultaneity: it is because they provide a *unique* possible method for testing the absolute simultaneity of two events through the synchronization of clocks in all fundamental frames. Given this, according to Swinburne cosmic time in FLRW universes provides (Swinburne, 2008, p. 257):

> […] a unique simplest and so probably correct standard of simultaneity not merely on the cosmic scale, but also on the local scale (by selecting a unique frame of reference, that of the fundamental frame associated with the local galaxy relative to which local measurement should be made).

Dean Zimmerman reveals himself as an epistemological defender of cosmic simultaneity as well when he claims that, if the spacetime correctly representing our universe is not too hostile (i.e., if it allows for a cosmic time function), we may be able to *predict* the "flow of becoming" (Zimmerman, 2011, pp. 232–233).[11] This seems to entail that the physical properties of privileged hypersurfaces have the role of granting *epistemological* access to absolute temporal relations, which may nevertheless hold independently of whether we have access to them. Were the spacetime too hostile, absolute becoming would, nevertheless, flow. This position is stated even more explicitly in the work of William Lane Craig, who claims that "cosmic time contingently coincides with metaphysical time" and that, in virtue of such coincidence, it represents absolute temporal relations (Craig, 2001, p. 237). For Craig, the absence of cosmic time in some cosmological models does not mean that, were it the actual universe correctly represented by one such model, there would not be absolute temporal relations.

Those endorsing CS + are instead committed to the above claim. A "metaphysical" defense of CS + has been proposed by Crisp (2008), who argues that, if one wants to accommodate presentism, one should consider restricting physically possible relativistic models to CMC solutions admitting of a unique CMC foliation, which Crisp takes to be privileged. According to Crisp, only a unique CMC foliation of a CMC solution can be isomorphous to the absolute history of the real enduring 3-D Space

[10] Swinburne clarifies that considerations of simplicity count against the existence of an absolute simultaneity relation in Minkowski spacetime, but that such existence remains nonetheless a possibility (Swinburne, 2008, p. 254)

[11] However, he ultimately follows Monton (2006) in claiming that cosmic simultaneity may be truly available only in a theory of quantum gravity.

evolving over time (Crisp, 2008, p. 264). It is important to note that Crisp's suggested restriction to possible models is not enough to entail CS+. Even if it is physically necessary for spacetime to allow CMC foliations, absolute simultaneity may still apply to events that do not lie on CMC hypersurfaces. In other words, even if one takes CMC models as necessary, CMC foliations are not, thus allowing for the definition of a non-CMC global time function that could represent absolute temporal relations. However, for Crisp, it is just a matter *of definition* that absolutely simultaneous events belong to CMC hypersurfaces (Crisp, 2008; pp. 264–265). Given this, the fact that certain foliations have certain physical properties is relevant for *determining* absolute simultaneity in a stronger sense than Swinburne's: for an event, to belong to privileged hypersurface just *is* to be absolutely simultaneous with all events belonging to the same privileged hypersurface. Of course, this is rather unsatisfactory, as one remains wondering what is *metaphysically* special about privileged foliations and privileged hypersurfaces. Here, Crisp aligns with the common strategy of the defenders of cosmic simultaneity, insisting that such foliations are "natural" and somehow "non-arbitrary", supposedly in the sense that they enhance simplicity in the description of the motion of galaxies (Crisp, 2008, p. 275).[12] Of course, however, theoretical desirability is not a strong candidate to ground metaphysical privilege.

A metaphysical cosmic absolutist who offers a justification for viewing privileged foliations as metaphysically special that does not rely on the virtue of simplicity is Peter Forrest. On Forrest's view, the fact that we live in an approximatively FLRW universe is determined by laws together with the initial conditions of the universe (Forrest, 2008, p. 249). However, Forrest is a growing blocker, so that he thinks that temporal reality, represented by spacetime, is increasing over time. More precisely, he assumes that spacetime itself is *uniformly* growing in hypervolume (Forrest, 2008, p. 252). Moreover, he assumes that *the expansion* of the universe is increasing in rate. Given these two main assumptions, he argues that, even if absolute temporal relations were at some cosmic moment different from those defined by a homogeneous and isotropic foliation, the inflationary expansion of the universe would necessarily *reduce* this deviation in the direction of the future. Therefore, given an approximately FLRW spacetime increasingly expanding, *necessarily* absolute temporal relations will end up coinciding with those defined by a homogeneous and isotropic foliation.

The latter examples should make clear the two different approaches towards cosmic simultaneity, metaphysical and epistemological, are independent of whether one proposes a lawlike restriction of the physically possible models. Given that cosmic time is definable only on certain spacetimes, one can ask whether absolute simultaneity holds only contingently. On the other hand, given a certain spacetime on which cosmic time can be defined, one can ask whether absolute simultaneity *must* be defined on a certain foliation. Metaphysical defenders propose an affirmative answer to the latter question. In what follows, I shall now expose the main criticisms received so far by cosmic absolutists before adding a new one. I show that metaphysical cosmic absolutists are less exposed to existing criticisms. However, they are precisely the target of the one I propose.

[12] See also Craig (2001, pp. 216–217) and Saunders (2002, p. 290).

4 Cosmic Simultaneity Fails to be Absolute

Cosmic simultaneity has been criticized on several grounds. First, there is what may be called the *coarse-graining problem*. Averaging procedures are crucial in order to define cosmic time. Take the cosmic time function preserving homogeneity and isotropy in the ΛCDM model for instance. According to the model, the universe is isotropic and homogeneous only when averaged on scales of approximately three hundred million light-years or more (Ryden, 2016, p. 11). However, averaging procedures entail information loss. Cosmic absolutists must therefore concede that information loss is crucial to *determine* absolute temporal relations (whether epistemically or metaphysically). Suppose, for instance, one wanted to determine whether two events in the Milky Way are *absolutely* simultaneous: the dull snap of a stone chipped by a *Homo sapiens* some 19,900 years ago, and the outburst of V838 Monocerotis (roughly 19900 light-years away). According to the cosmic absolutist, no information about the distribution of matter/energy within, or in the relative vicinity of, the spacetime regions where these two events occurred will enter this evaluation. Cosmic simultaneity between the stone's snap and the star's explosion is instead determined by averaging the state of motion of many galaxies, including our own, as well as by averaging the matter/energy density in a region much larger than our galaxy, where these two events occurred.[13]

Since absolute temporal relations are supposed to hold between *all* events, the coarse-graining problem reveals a weakness in cosmic simultaneity proposal (Bourne, 2004, p. 114; Callender, 2017, p. 75). However, since the problem has to do with epistemological considerations, it will be particularly relevant for an epistemological defender of cosmic simultaneity. For a metaphysical defender, indeed, it is open to argue that the physical properties making hypersurfaces privileged, even if defined by averaging procedures, are *real* and metaphysically relevant to determine absolute simultaneity. *How* they are relevant, will depend on the account; but once it is accepted their metaphysical role, the coarse-graining problem seems to lose part of its grip.

Second, there is a *phenomenological problem*. As Huw Price noticed, an important argument in favor of the reality of temporal passage is phenomenological: we have experience of the temporal passage, so there must be some genuine aspect of reality corresponding to such experience (Price, 1996, pp. 14–15). In fact, many sim-present absolutists who are realist about temporal passage seek to defend cosmic simultaneity precisely to ground this experience (Dieks, 2006, p. 166; Read & Qureshi-Hurst, 2021, p. 8112). However, they appeal to factors related to enormous scales, seemingly detached from any possible experience. Therefore, the problem: how can the

[13] One might object that when averaging the matter/energy density in a spatial region much larger than the Milky Way, the distribution of matter/energy within the Milky Way *could* be relevant because it could enter the averaging procedure. However, even if at some stage specifics of the Milky Way's density were to enter the procedure (perhaps in the case of an extremely accurate procedure), it is only the final coarse-grained density value that enters the evaluation of (say) homogeneity of the larger region in FLRW models, and that final value is compatible with a virtually infinite number of ways the Milky Way could be. Moreover, the distribution of matter in the immediate vicinity of a particular star or planet is so irrelevant to the final evaluation that it is not even a plausible candidate for a distinct input to a possible averaging procedure.

structure of our "local" temporal experiences be explained via its correspondence with structures at scales of which humans never had (and plausibly never will have) any direct experience? (Bourne, 2004, p. 114; 2006, p. 199; Wüthrich 2010, 2013, p. 17; Smeenk, 2013, p. 18; Read & Qureshi-Hurst, 2021, p. 8112).

One possible answer is to emphasize that our frame of reference approximately coincides with that of our galaxy (Dorato, 1995, p. 208). This is why, after all, we do observe an approximately isotropic universe. However, raising this point does not solve the phenomenological problem. First, even if we could access the frame of our galaxy—Earth's frame of reference only *approximately* coincides with that of the Milky Way—galaxies remain only *approximate* fundamental observers (Read & Qureshi-Hurst, 2021, p. 8114). Second, our experience of temporal passage is pervasive and, for most people, entirely independent of astronomical observations. It is therefore difficult to see how facts discoverable only through such observations could adequately ground our experience of temporal passage.

Statements of the third problem, the *modal problem*, trace back at least to Gödel's work (Gödel, 1949a, b). As seen, there are cosmological solutions of EFEs—such as Gödel's—in which a unique cosmic time cannot be defined. If one takes all such models to be physically possible, then absolute simultaneity cannot be recovered by means of cosmic time in all physically possible models. Therefore, absolute simultaneity becomes a contingent feature of the universe, depending on the overall distribution of matter/energy. Now, if one opts for an epistemological interpretation of cosmic simultaneity, it becomes an incredible coincidence that, among all possible universes where absolute simultaneity is inaccessible, we happen to live in one in which we can discover it.[14] As an alternative, one could follow Crisp's approach and change the physical theory by restricting the scope of physically possible models. However, this option remains highly problematic. Reasonably, one should not modify a highly successful physical theory only to accommodate a dubious metaphysical one which already has all the philosophical problems highlighted (Callender, 2017, pp. 77–78).[15] A third option, which seems to avoid both undesired consequences, is again to adopt a metaphysical approach to cosmic simultaneity. If the physical properties of hypersurfaces metaphysically determine absolute relations, then absolute temporal relations hold only in universes such as ours, where cosmic time can be defined, thus explaining away what on the epistemological interpretation was an incredible coincidence, i.e., that we happen to live in a universe where we can corroborate absolute temporal relations.

Note that the modal problem concerns particularly those cosmic absolutists who wish to vindicate an A-theoretic view of time such as presentism (Bourne, 2004, p.

[14] Conceded, of course, that we *do* live in such a universe. After all, some of the assumptions allowing the definition of cosmic time, such as the Cosmological Principle, may one day turn out to be empirically untenable (Callender & McCoy, 2021, p. 4).

[15] Of course, the situation is different if the metaphysical theory at stake has more virtues, enough that it can be taken seriously as providing a research program for physicists. One such case may be represented by *relationism about space and time* and by how it inspired the shape-dynamic theory of gravity (SD). SD is a theory of conformal 3-geometries where the four-dimensional diffeomorphism invariance of general relativity is replaced by three-dimensional diffeomorphism and three-dimensional conformal invariance. It is empirically equivalent to GR when the latter is restricted to CMC solutions (Barbour, 2012).

116; Callender, 2017, pp. 76–78); especially since, as said, they often take their view to be necessarily true, if true at all. This means that A-theorists defending SPA (simpresent absolutists) will tend to find the modal problem pressing. As seen, the same could be said for the phenomenological problem, while I claimed that the coarse-graining problem troubles especially *epistemological* defenders of cosmic simultaneity. Therefore, metaphysical cosmic absolutists who do not commit to an absolute present seem to be the cosmic absolutists who are best suited to resist the criticisms presented so far. However, I must now conclude my overall argument by pointing out a further problem, which, I claim, poses a peculiar difficulty to this category of cosmic absolutists.

Suppose CS+, i.e., that the fact that two distinct instantaneous events are absolutely simultaneous depends on whether the spacetime points representing these events belong to a privileged hypersurface. Then, whether these events are simultaneous depends on facts about causally disconnected events. For instance, if the relevant physical properties are homogeneity and isotropy, then the fact that these events are absolutely simultaneous depends on whether homogeneity and isotropy obtain, on average, over the entire universe-wide spacelike hypersurfaces of the privileged foliation. But, according to relativity, each spacetime point of a spacelike hypersurface in a given spacetime is causally disconnected from all other points belonging to the hypersurface. Therefore, it follows that, given CS+, absolute simultaneity obtains relative to causally disconnected events. However, if one accepts the principle CCC that followed from my analysis of absoluteness, a temporal relation that obtains relative to causally disconnected events cannot be absolute. One can see, therefore, that this critique aims at a fatal strike against metaphysical approaches to cosmic simultaneity, which have seemed to be the last refuge for cosmic absolutists. Of course, one can maintain that cosmically simultaneous events are absolutely simultaneous in a *restricted* sense, making absolute simultaneity possibly dependent on global features of the universe. However, according to the analysis in Sect. 2, the absoluteness required for SPA should include more than mere frame-independence, and it is plausible that it should include independence from global features.

However, I do not think that the failure of metaphysical cosmic simultaneity should be taken as a good enough reason to abandon the quest for relativistic absolute presentness. For instance, one can follow suggestions from Stein (1968, 1991), Sklar (1981, p. 138) and Dieks (1988, 2006) in adopting the view that the present is spatially limited to one event, therefore disconnecting presentness from simultaneity.[16] As an alternative, one can take the present to be represented by finitely extended regions of the spacetime manifold, as these are determined, for instance, by Lorentz-invariant light-cone structures (Savitt, 2020). On such *local* A-theoretic views, be the present(s) pointlike or finitely extended, there are *many* metaphysically privileged non-exclusive presents, and one can say that the fact that certain events make up *this* or *that* present is *absolute* at least in the sense of being frame-independent. Nevertheless, it remains an interesting open question whether this fact can be absolute in the

[16] However, such solipsistic views have reasonably been labeled "radical" and "implausible" (Bourne, 2006, p. 172).

sense required by this or that A-theoretic view. After all, localizing the present may be seen as just another way of relativizing it.[17]

5 Concluding Remarks

Whichever the adopted approach, cosmic absolutists face perhaps insuperable challenges. On the one hand, positing an absolute temporal relation that can be empirically corroborated only as a matter of mere coincidence (*if* it can be corroborated at all) is highly unsatisfactory. Moreover, it is hard to explain how physical properties of universe-wide hypersurfaces, defined by averaging procedures on enormous scales, could possibly grant epistemological access to relations regarding local events. To avoid these difficulties, one can posit a metaphysical link between the occurrence of certain events (i.e., between the properties of privileged hypersurfaces) and the obtaining of the required temporal relations. However, this approach ultimately makes these temporal relations dependent on causally disconnected events, rendering them, after all, not so absolute.[18]

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[17] For completeness, let me add that there seems to be one more option open to the A-theorist: instead of retaining absolute presentness by giving up on the uniqueness and globality of the spacetime structure representing the present, they can attempt to retain uniqueness and globality by giving up on the idea that simultaneity is ultimately relevant for establishing which events make up the absolute present. For a similar attempt see Müller (2020).

[18] There is still, perhaps, a viable answer for philosophers fond of cosmic time: to bite the bullet. Perhaps cosmic time does not allow one to recover a satisfactory notion of absolute simultaneity, but one can still stress that it allows for the definition of a *privileged* global order of events. However, if not absoluteness, what makes a foliation privileged? If the answer is simply that privileged foliations enhance simplicity in calculations, there remains little metaphysical content to their privilege.

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