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TROUBLE ON THE HORIZON FOR PRESENTISM

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1. Introduction

It is well known that presentism—the view, roughly, according to which only present entities exist—is in tension with our best physics—especially special and general relativity.[1] A natural move for the presentist with a naturalistic bent is then to propose a way to accommodate presentism within those well-confirmed theories. *Surface presentism* offers a straightforward way to achieve this.[2] It states that although we should take general relativity to be an accurate description of the physics of our world, we may nonetheless restrict the domain of concrete existence to a single three-dimensional hypersurface: intuitively, a 'slice' of four-dimensional spacetime. This generally requires specifying a preferred frame of reference to anchor the present. But presentists are quick to point out that a frame of reference may be metaphysically privileged without being physically privileged. Which is to say, a frame of reference may define the scope of ontology without it being physically detectable by any experiment. Relativity certainly doesn't preclude the existence of preferred frames in this sense; we are just generally discouraged from positing them for reasons of parsimony. Surface presentists, however, maintain that the reasons for adopting

1. More carefully, presentism is the view that only present concrete entities exist; past and future concrete entities do not exist. We set aside here the controversy over how presentism should be formulated. See, for discussion, Crisp (2004); Meyer (2005).
2. The phrase 'surface presentism' comes from Hinchliff (2000, p. 584). Hinchliff uses the phrase to refer to a view on which the physics is reverted to a neo-Lorentzian physics. That's not how we use the term here. The surface presentist adds absolute simultaneity relations but does not take this to alter the physics. The physics itself is compatible with the presence of such relations; there is just no physical reason to have them. There are also solutions to general relativity that have 'fixed foliations', whereby the entire 4D manifold is decomposed into a series of slices. The surface presentist, as we understand them, adds extra structure to the metaphysics beyond what is suggested by the physics, but not in a way that requires a return to Lorentz's physics.

presentism overwhelm such parsimony considerations.[3]

In this paper, we present an argument against surface presentism based on the existence of black holes. The argument is such that if one accepts the existence of black holes, then one has reason to believe that surface presentism is false.[4] The argument merely requires the existence of black holes broadly understood and not the more questionable existence of physical singularities at their centre—or, more rigorously, of singular spacetimes.[5] Black holes in this sense are a generic prediction of general relativity in the classical domain, namely where general relativity is extremely well confirmed. We thus assume that the existence of black holes is empirically confirmed via the role they play in one of our best theories.

Using black holes to argue against presentism is not new. Romero and Pérez (2014) have argued that there are regions in the event horizon of a black hole where an observer on the inside and an observer on the outside will be co-present according to one of their frames but will disagree about what other events are co-present (see Sengers, 2017 for a reply). The argument then works similarly to the classical Rietdijk-Putnam argument in favour of four-dimensionalism. This argument supposedly demonstrates an inconsistency between presentism and relativity on the grounds that presentism requires a network of relations of absolute simultaneity to define an objective present and there is no such network in special relativity (Rietdijk, 1966; Putnam, 1967).[6] This style of argument, however, is generally ineffective against the surface presentist who is willing to simply posit a preferred frame of reference—both in response to the Rietdijk-Putnam argument and, presumably, in response to any version of that argument based on the presence of black holes.

We therefore propose a novel argument based on black holes designed to trap the surface presentist. The argument focuses on the notion of an event horizon. We argue that there is no way to locate an event horizon within the austere ontology afforded by surface presentism, and so the existence of black holes constitutes a strong reason to doubt surface presentism.

We begin with a brief statement of the argument, including a discussion of black holes and event horizons. We then consider a number of responses available to the presentist and show that none of them succeed. On balance, then, we recommend rejecting surface presentism.

This is by no means the end of presentism: there are, potentially, other forms of presentism that don't face the same difficulty. Surface presentism is, however, a natural extension of presentism into a relativistic setting. The failure of this view therefore constitutes a blow against the broader presentist program.

2. The Argument

2.1 Total and Mereological Surface Presentism

As noted, surface presentists maintain that all that ever exists is a single three-dimensional region, but which region that is changes.

There are three ways to implement the basic idea behind surface

3. Versions of surface presentism have been suggested by a number of philosophers. The view is developed in detail by Bourne (2006); Hinchliff (2000). For discussion, see Balashov and Janssen (2003); Crisp (2008); Savitt (2000); Wüthrich (2013); Zimmerman (2011).
4. In fact, the argument targets any view in metaphysics according to which there are no future entities—such as the *growing block theory*.
5. See, e.g., Lam (2007).
6. The Romero and Pérez (2014) argument, as they present it, is a bit stronger than the Rietdijk-Putnam argument. Romero and Pérez argue that there is no way to slice spacetime into hypersurfaces along the horizon of a Schwarzschild black hole: a black hole in a Schwarzschild geometry. As Sengers (2017, §3.3) argues, however, this can't be quite right, since it is generally possible to find a global slicing of spacetime around a black hole in a Schwarzschild geometry by re-describing the metric using Kruskal-Szekeres coordinates.

presentism. First, one might adopt a broadly mereological form of surface presentism. On this picture, there exists a single 3D region, and that region is part of a four-dimensional spacetime—the full 4D manifold described by general relativity. The 4D manifold exists in virtue of having an existing part—the present 3D region—but it does not exist in its entirety. Its non-present parts do not exist. Call this view *mereological surface presentism*. Second, one might deny that 4D spacetime exists. Only a single 3D region exists, and that region is not part of a 4D object. Call this view *total surface presentism*.

Mereological surface presentism and total surface presentism both involve accepting a form of moderate anti-realism toward general relativity. While, in both cases, general relativity provides an accurate description of the physics, the mathematical representation of the world as a 4D manifold equipped with a metric tensor field described by the field equations is not to be taken literally. Rather, it is a mere mathematical convenience for representing reality. What exists, according to the surface presentist, is not to be naively read off of the mathematical core of general relativity.

Mereological surface presentism and total surface presentism differ in terms of how deep their anti-realist take on general relativity is. The mereological surface presentist wants to take the 4D representation ontologically seriously to some extent, but in a way that coheres with presentism. The total surface presentist, by contrast, treats the 4D representation as part of the theory, but not an accurate description of the world. But, other than that, both sorts of surface presentism take general relativity at face value. Indeed, in order to keep their view as naturalistic as possible, the surface presentist should minimise the revisions made to general relativity. They should make sure that the modifications they make do not damage the theory in a way that renders it either internally inconsistent or at odds with the available empirical data that support the theory.

Mereological surface presentism faces an obvious challenge. The mereological surface presentist maintains that the 4D manifold exists and it has parts that don't exist (namely, non-present parts). Parthood, however, is generally thought to obey the following constraint: x is part of y only if x and y both exist.[7] The existence of a 4D manifold with non-present parts would thus seem to call those parts into existence.

Total surface presentism appears to do better. By rejecting the existence of a 4D manifold, there is no fear that parthood relations will call the future into existence. The price, of course, is that a stronger form of anti-realism about general relativity is required. For this, the presentist can call upon some form of scientific instrumentalism or anti-realism to scaffold her position. Alternatively, she may find it useful to endorse a dynamical approach to relativity (à la Brown 2005). According to this approach, the explanatory role usually ascribed to the geometry of spacetime is relocated to the dynamical laws determining the behaviour of matter. This seems to at least leave room for some degree of ontological anti-realism toward a 4D spacetime.

We are willing to grant to the presentist, at least initially, that some form of anti-realism about 4D spacetime is available (in a sense to be qualified later on, see §2.3). What we aim to show is that total surface presentism suffers from the same kind of problem that afflicts mereological surface presentism. This motivates discussion of a third view that lies somewhere between surface and mereological presentism.

On this view, the entire 4D manifold exists (as per mereological surface presentism) but it does not exist as a concrete object (as per total surface presentism). Rather, it is an abstract object that has an existing concrete part: a single 3D slice, but which slice that is changes as parts of the manifold shift from being abstract to being concrete and then back again. We consider this version of ersatz presentism in §3.4. We show that while it avoids the initial problem with total and mereological surface presentism, it faces difficulties of its own.

7. It is for this reason that presentism is thought to be at odds with perdurantism (see Benovsky 2009; Tallant 2018), though see Brogaard (2000) for a potential way forward.

2.2 *Event Horizons and Dependence*

For now, we will focus primarily on total surface presentism. Unless otherwise explicitly stated, that is what we will mean by 'surface presentism'. As noted in §1, the problem facing surface presentism concerns black holes. Black holes are regions from which nothing escapes (not even light or other massless particles).[8] The event horizon is the name of the boundary between the region from which nothing escapes and the rest of the universe. The black hole is the broad entity that includes both the singularity—or whatever exists in its place—and the region surrounding it.

Our argument against surface presentism focuses on the event horizons of black holes. In a standard textbook on general relativity, an event horizon can be defined as follows. A spacetime is represented in general relativity with two mathematical objects: $\langle \mathcal{M}, g \rangle$, where $\mathcal{M}$ is a differentiable manifold of points and g is a metric tensor field giving information about metric structure. A black hole region $\mathcal{B}$ is then defined in contrast to the rest of the manifold $\mathcal{M}$ as follows:

$$\mathcal{B} = \mathcal{M} - J^{-}\left(\mathcal{I}^{+}\right).^{9} \tag{1}$$

$\mathcal{I}^{+}$ refers to the future null infinity—infinity in the future timelike directions—and $J^{-}(\mathcal{I}^{+})$ to the causal past of this null infinity. Hence, the black hole region is defined indirectly via the entire manifold, which is infinite in the timelike direction. The *event horizon* is then defined as a *boundary* $\mathcal{E}$ of the region $\mathcal{B}$. But what kind of boundaries are event horizons, exactly?

Well, consider a standard spatial boundary: the boundary around a football field. Generally speaking, the current location of the boundary depends entirely on the fact that there is a specific region of space with certain properties, i.e., the region is now covered with grass, currently serves a specific purpose (namely it is a field of play), and so on. Importantly, the past and future of the spatial region is generally irrelevant to the specification of the field's boundary.

Event horizons are spatial boundaries, but they are quite unlike ordinary spatial boundaries. Whereas the location of a boundary around a football field can be specified in terms of current facts concerning a specific spatial region, the current properties of a spatial region are insufficient to determine the location of an event horizon. Rather, specifying an event horizon requires looking at the future properties of a spatial region. Specifically, whether there is an event horizon located in the present depends on whether there is a spatial region now such that, at every moment in the future, there is no path out of that region (this is the importance of looking to future null infinity in the above definition). As Curiel puts it:[10]

> Where I locate the horizon today depends on what I throw in it tomorrow—which future-directed possible paths of particles and light rays can escape to infinity starting today depends on where the horizon will be tomorrow, and so that information must already be accounted for today. (Curiel, 2019, p. 29)

Ashtekar and Galloway make a similar point, writing:

> The notion [of an event horizon] is teleological because one can locate an event horizon only after having access to the spacetime geometry to the infinite future. (Ashtekar and Galloway, 2005, p. 2)

8. Black holes are often regarded in the context of general relativity as including a singularity at their centre, but this is not a necessary condition of black holes. For instance, as a referee notes, Wald (1984, p. 300) defines black holes without reference to singularities in terms of the non-vanishing complement of the causal past of future null infinity of a strongly asymptotically predictable spacetime. Additionally, a theory of quantum gravity might give a description that does not require the existence of a singular spacetime. At any rate, our discussion is entirely orthogonal to what is happening at the centre of black holes (and can proceed with Wald's definition).
9. Our presentation follows Jaramillo (2013).
10. See also Curiel (2020, §3.1).

This way of putting things has an epistemic flavour: we cannot know where the event horizon is now without epistemic access to the future. But underlying this epistemic point is a metaphysical one: we need epistemic access to the future to work out where an event horizon is now, because we need to know what properties a particular spatial region might possess running into the future, because it is those properties that determine the presence of an event horizon now.

An analogy will help to clarify the nature of event horizons. Consider a world with two kinds of highways: normal highways and special highways. Both highways are endless. However, a normal highway is one that features many exits. A special highway is one that has no exits. When you enter a special highway you are doomed to die there. Now suppose that you pull onto a highway. What kind of highway are you on? Well, that depends on the road ahead. If the road ahead is a special highway, then there will be no exit. If the road ahead is a normal highway, then there will be exits. Importantly, the local, intrinsic features of the two kinds of highways might well be (presently) the same. What makes a highway special depends entirely on spatial facts located beyond the current section of the highway.

This is how we should think about event horizons: they are spatial boundaries onto very specific kinds of regions. Two regions can otherwise agree on their local, intrinsic features, and yet only one region may ground an event horizon in virtue of the future of that region. If the future of that region is one in which objects that enter the region escape into other areas of space, then there is no event horizon. If, however, the future of the region is one in which everything that enters the region is 'captured' and never leaves, then there is an event horizon.

Now, the dependence of boundaries on the regions they bound is a stock example of ontological dependence (see Correia, 2008 and Koslicki, 2013). The fact that a boundary of a certain type is located *here* depends, ontologically, on the properties of a specific region. It is therefore natural to suppose that the kind of dependence at issue for event horizons is ontological as well. What's odd about event horizons is that the dependence extends across time. This difference can be

captured by more precisely stating the dependence conditions of the two boundary types considered thus far:

Ordinary Boundaries
The location of a spatial boundary of type B at time t depends ontologically on the properties possessed by a spatial region at t.

Event Horizons
The location of an event horizon at a time t_1 depends ontologically on the properties possessed by a spatial region at t_1 and at each time $t_2 ... t_\infty > t_1$.

In the first case, the location of a boundary depends only on the current nature of a spatial region. In the second case, the location of an event horizon depends on the current and future nature of a spatial region. The ontological basis for the event horizon is thus not entirely present; it is partly future as well.

2.3 The Argument Stated

Given that an event horizon, now, depends ontologically on the future, an argument against surface presentism can be formulated as follows:

1. If surface presentism is true, then future spatial regions do not exist.
2. Some event horizons presently exist.
3. The present location of an event horizon depends ontologically on the future properties of a spatial region inhabited by a black hole.
4. If [2] and [3], then a future spatial region inhabited by a black hole exists.

   Therefore,
5. Surface presentism is false.

The first premise is just a corollary of surface presentism. If surface presentism is true, then all that ever exists is a single, present 3D region. No past or future regions exist.

The second premise follows from an empirical assumption: that the existence of event horizons is indirectly supported by the available

evidence. In saying this, we are working with an expanded notion of empirical confirmation. For us, empirical confirmation is not just a matter of direct observation as, for instance, when one directly observes a light change from red to green. Empirical confirmation can be indirect in this sense: the existence of some x is indirectly confirmed when x is a posit of a theory T and the empirical predictions of T are confirmed by the available observational data. In this situation, we may not have any direct empirical evidence for x in the form of observations of x itself. Nonetheless, x enjoys empirical support because T does.

General relativity is empirically confirmed by the evidence and fits the empirical data in the classical, i.e., non-quantum, domain amazingly well. In the context of general relativity, black holes with event horizons are needed to explain a range of physical phenomena. Accordingly, general relativity posits the existence of these entities.[11] In this way, the existence of event horizons is indirectly confirmed via the confirmation of general relativity. Admittedly, our reliance on indirect confirmation makes the argument a bit less forceful than if it relied on direct observational data. This is a point we will return to later on, when we discuss whether the surface presentist can rewrite general relativity without event horizons. For now, it is enough to note that a great many posits in science enjoy indirect empirical confirmation, and so event horizons are not unusual in this respect.

The third premise follows from the nature of event horizons as boundaries of black hole–inhabited regions. The fourth premise is based on the following sub-argument:

1. x ontologically depends on y.
2. If x ontologically depends on y, then x and y both exist.

Therefore,

3. x and y both exist.

The sub-argument relies on the following two ideas. First, that ontological dependence is a relation between entities. Second, all relations are existence entailing, in this sense: for any relation R, if Rxy then x and y both exist. The argument against surface presentism is thus a version of the more general problem of cross-time relations for presentism (though, as we discuss later on, it is not the standard version). This is the problem of explaining how there can be any relations between present and non-present entities if presentism is true, given that all relations are existence entailing.[12] The claim that all relations are existence entailing is considered by some to be a truism (e.g., Crisp, 2005), presumably on the grounds that the following inference pattern is valid in classical logic:

1. Rab.

Therefore,

2. $\exists x \exists y Rxy$.

Strictly speaking, the above sub-argument does not provide full support for the fourth premise in our argument against surface presentism. What we need, in addition, is the idea that property possession entails existence, in this sense: if a has property P, then a exists. We need this further inference to secure the existence of spatial regions in the future (in addition to the properties they possess, which form the ontological basis for event horizons). Since both the inference from Pa to $\exists x Px$ and from Rab to $\exists x \exists y Rxy$ are instances of a general inference from n-ary predication to existence, we will pass over this complication in what follows and focus only on the ontological dependence of event horizons on the future properties of spatial regions.

There are many responses to the argument available to the presentist. Note, however, that the argument is similar to the challenge facing

11. To be more precise, general relativity does not universally imply the existence of black holes as the equations admit of some models with black holes, unlike others. But the models consistent with the empirical information gathered thus far about the distribution of matter in the actual world all describe the existence of a great quantity of black holes. So, in this sense, black holes are a generic prediction of the relevant subclass of models of general relativity (relevant in being consistent with our knowledge of the actual world).

12. For a discussion of the problem, see Bigelow (1996); Bourne (2006); Crisp (2005); De Clercq (2006); Markosian (2004); McDaniel (2010); Tallant (2018).

mereological surface presentism discussed previously (the challenge concerning the parthood relation). In both cases, a relation between existing and non-existing entities is required to make surface presentism work.

3. Presentist Responses

As we see it, there are four immediate lines of reply to the argument outlined above available to the presentist. Here, in brief, are the options (to be developed below):

1. Deny that the present location of an event horizon ontologically depends on the future.
2. Accept that the present location of an event horizon ontologically depends on the future but deny that ontological dependence in this case is a relation between the present and the future.
3. Accept that the present location of an event horizon ontologically depends on the future and that ontological dependence is a relation between the present and the future, but deny that ontological dependence relations are existence entailing.
4. Accept that the present location of an event horizon ontologically depends on the future and that ontological dependence is a relation between the present and the future *and* that ontological dependence relations are existence entailing, but deny that any of this implies the falsity of surface presentism.

In addition to these four replies, there is a fifth option open to the presentist:

5. There are no event horizons located in the present.

This fifth option requires a foray into the physics of black holes, and so we will deal with it in the next section. In this section, we will focus just on the first four options introduced above. As we shall argue in a moment, each response fails. That these responses fail serves to make at least a *prima facie* case for the conflict between event horizons and surface presentism.

Before we begin, it is important to head off an objection. We have said that we are willing to grant to the surface presentist a certain degree of anti-realism toward 4D spacetime in general relativity. But then why shouldn't we just grant the surface presentist the same latitude when it comes to black holes? One might argue that black holes, like 4D spacetime, can be treated as nothing more than artefacts of the mathematics of relativity and not something we should take ontologically seriously.

The objection presents us with an opportunity to clarify both the latitude we are willing to extend to the surface presentist and the argument against surface presentism presented above. The surface presentist wants to keep her naturalistic credentials intact, and so she aims to accept general relativity. She thereby needs it to be the case that 4D spacetime is ontologically dispensable from general relativity, either in whole or in part. Which is to say, it must be possible to 'take back' an ontological commitment to the full 4D manifold without doing violence to the theory.

Our goal is to argue that 4D spacetime cannot be so easily dispensed with. For while the surface presentist rejects the existence of the 4D manifold, she leaves the full theoretical structure of general relativity in place (on pain of reformulating the theory itself). Because the structure of the theory remains intact, however, it will continue to have all of the same predictions. Since black holes bounded by event horizons are a generic prediction of general relativity, the theory will continue to predict the existence of such entities despite the shift in ontology. What we show, then, is that by giving up the 4D manifold, one thereby introduces a deep conflict into general relativity: at a theoretical level, the theory predicts the existence of black holes, but at an ontological level, it is incapable of supporting them. This is a troubling state of affairs: the predictions of a theory should not conflict with its ontology in this way.

The latitude we extend to the surface presentist is thus provisional and granted only for the sake of argument. There is thus no real question of allowing the presentist to reject the existence of black holes as

well, since their existence is predicted by general relativity and so giving them up would amount to disconfirming the theory (which would be just as bad from a naturalistic perspective). A more serious option for the presentist might be to accept the existence of black holes but deny that they are bounded by event horizons. Whether this is a viable way forward for the presentist is an issue we return to in the final section.

3.1 No Ontological Dependence

As noted, the first response available to the presentist is to deny that event horizons depend ontologically on the future. Indeed, the presentist might argue that there are independent reasons to suppose that ontological dependence is not a cross-time notion, and so whatever the connection might be between present event horizons and the future, it cannot be a relation of ontological dependence.

One way to develop this line of thought is to maintain that ontological dependence is a purely *spatial* notion. There can be no ontological dependence over time. While once popular, this line of thought has come under fire recently. Baron, Miller, and Tallant (2020) and Wilson (2020) offer a range of cases in which ontological dependence extends across time. In general terms, it no longer seems reasonable to assume, without argument, that ontological dependence cannot extend across time.

Even if the presentist can motivate the idea that the connection between event horizons and the future is not ontological dependence they are still tasked with explaining how event horizons depend on the future. What the presentist needs is a replacement for ontological dependence. One possibility might be to rely on *nomic* rather than *ontological* dependence. There being an event horizon in the present is determined by facts concerning a future black hole region, combined with the laws of nature (in this case, the laws specified by general relativity).

So long as the presentist can provide the relevant facts about the future—in this case, the facts about the properties of a future spatial region—they are in a position to accommodate the location of event horizons in the present, or so the thought goes. While it is generally a challenge for the presentist to provide facts about non-present times, this is a challenge that they are used to managing and a number of strategies exist.[13] Perhaps indeed the presentist can supply such facts about the future.

The question, though, is whether this picture does justice to the nature of event horizons. The answer, we submit, is 'no'. The answer has little to do with event horizons *per se*, resting instead on a more general point about the relationship between boundaries and the bounded. To see this, consider the boundary around a football field once again. If the boundary around the football field depends on the field, then *necessarily*, if the field exists, then the boundary around it exists. If the dependence of the boundary on the field is nomic dependence and not ontological dependence, however, then the relevant notion of necessity is nomic and not metaphysical necessity. The type of dependence sets the grade of necessity with which the existence of one entity guarantees the existence of the other.

Nomic necessity is usually thought to be a restricted necessity, in this sense: if y's dependence on x is *only* a nomic necessity, then it should not hold for all metaphysically possible worlds (unless the laws are metaphysically necessary, a complication we set aside). In particular, there should be some way of changing the actual laws of nature that would lead to a failure in the relevant dependence and thus to the existence of x without y. If there is no such way, then the necessity—and thus the dependence—is metaphysical and not nomic after all. Thus, in the case of a football field, it should be metaphysically possible for the field to exist without its boundary if the dependence at issue is a mere nomic necessity. But this does not seem to be metaphysically possible. If the field exists, then it guarantees—with the strength of

13. See, for instance, Bigelow (1996); Bourne (2006); Crisp (2007); Ingram (2016); Kierland and Monton (2007); Markosian (2004); Tallant (2009a,b); Tallant and Ingram (2015). For a useful overview of strategies and the problems they face, see Caplan and Sanson (2011).

metaphysical necessity—the existence of its boundary.

Nomic necessity is thus the wrong grade of necessity to capture the relationship between the boundary and the bounded, and so nomic dependence is the wrong kind of dependence. The modal strength of the relationship at issue is stronger than any physical laws can make it. This applies equally well to event horizons. The existence of a black hole necessitates the existence of its boundary. The strength of this necessary connection, however, is stronger than physical necessity, since there is no way to alter the laws to break the dependence at issue. That is, there is no metaphysically possible alteration one could make to the actual laws that would allow for the existence of a black hole without its boundary.

Is there some other notion that can express the connection between event horizons and spatial regions? Perhaps. But even if some other notion can be found, the peculiar intimacy of the relationship must still be accounted for, and, ultimately, it is the intimacy of the relationship that poses a problem for surface presentism. Whether we model the relationship as ontological dependence or via some other concept, a problem remains. For whatever that dependence might be, it is difficult to see how the dependent entity might exist without its metaphysical basis.

3.2 *No Cross-time Relations*

The second response available to the presentist involves conceding that the location of an event horizon ontologically depends on the future, while denying that ontological dependence is a relation. Or, at the very least, that cross-time ontological dependence is a relation. The presentist who pursues this second line of response diagnoses the general problem posed by event horizons as an instance of another, familiar problem for presentism: the problem of cross-time relations.

As previously noted, the problem of cross-time relations arises for presentism in light of the fact that there seem to be relations between the present and the past. For instance, present events are caused by past ones, and so there seem to be cross-time causal relations. Similarly, present people can admire past people, be taller than past people, and refer to past people, which seems to suggest the presence of cross-time admiration, taller-than, and reference relations, respectively. All relations, however, are existence entailing, in this sense: a is related to b via relation R iff a and b both exist (since, again, $Rab \vdash \exists x \exists y Rxy$ is a theorem of classical first-order predicate logic). So it seems that if presentism is true, there can be no cross-time relations of admiration, causation, taller than or reference.

The problem with event horizons is similar insofar as the problem seems to revolve around a cross-time relation. Seeing the parallel between the problem posed by event horizons and the problem of cross-time relations is potentially advantageous for the surface presentist. For she can simply roll the two problems together and argue that the standard solution to the more general problem of cross-time relations applies here as well.

The standard solution to the problem of cross-time relations involves accepting that there are no cross-time relations, while maintaining that the phenomena that seem to require such relations—phenomena like causation, admiration, and so on—can nonetheless be recovered in a way that is compatible with presentism.[14] This generally involves showing how an apparently relational phenomenon can be analysed in terms of some more fundamental, non-relational facts.

Take causation for instance. One presentist strategy for handling causation involves adopting a Humean regularity theory of causation, according to which causation is analysed in terms of constant conjunctions between events (see Bourne, 2006; McDaniel, 2010). So long as presentists can accommodate the fact that x and y tend to occur in close temporal proximity, they can account for the fact that x causes y even if one of x or y does not exist. The fact that x and y tend to occur together is not a relational fact but just a long conjunction of facts about the past,

14. For an excellent and wide-ranging implementation of this strategy, see Bourne (2006).

present, and future. Assuming that the presentist can supply facts of this kind, she can also allow for causation of a Humean stripe.

A similar approach is available for the other relations mentioned. Admiration is analysed not as a relation, but as a mental state which is fully determined by the current physical state of the world. Thus, Sara admires Joan of Arc, because she occupies a certain brain state. No relation to the past is necessary. Similarly, Sara is taller than Gandhi simply because it is a fact now that Sara is 180cm and it is a fact that Gandhi was 162.6cm when he was alive. These facts fully determine that Sara is taller than Gandhi, without the need to posit a cross-time relation between them.[15]

The surface presentist might thus try a similar line. Ontological dependence between the present and the future is real, but it is to be analysed in non-relational terms, terms that are acceptable to the presentist. The surface presentist who takes this way out must supply a range of facts about the present and a range of facts about the future that can then provide the basis for a connection of ontological dependence.

It is far from clear, however, that the surface presentist can draw on the standard solution to the problem of cross-time relations as a way to address the difficulty posed by event horizons. The reduction of causal relations to conjunctions of facts works, in part, because causation is generally taken to be contingent. Accordingly, contingent conjunctions of facts about the past, present, and future can serve as an appropriate reductive base for causation. Ontological dependence, however, is *not* a contingent notion. It is generally taken to imply necessitation between the dependent object and the dependee.[16] No amount of purely contingent facts about the past, present, or future will be an adequate reductive base for this necessary connection.

Of course, the presentist can simply appeal to *modal facts* about the past and present. She can thus seek to recover ontological dependence from constant conjunctions spread across a modal space. Thus, she can point to the fact that pairs of facts about the present and the future occur together in every possible world: namely, facts about present event horizons and facts about future black hole regions.

The trouble with this suggestion, however, is that while ontological dependence generally implies necessitation, necessitation doesn't imply ontological dependence (cf. Fine, 1995). So merely finding the right modal constant conjunction is still not enough for ontological dependence. Even this expanded base of facts is not good enough for reductive purposes.

Perhaps there is another way to spell out the reductive base that will work. We cannot rule it out. But note that the project is now much larger than simply rendering surface presentism viable. The project has become the rather ambitious one of providing a reductive base for ontological dependence in general, without the need for any relations.[17]

Even if such a project could be completed, it is far from obvious that surface presentism is out of strife. For it seems that ontological dependence is an existence entailing notion, even if it is not a relation. Which is to say that x ontologically depends on y only if x and y both exist. While the idea that ontological dependence is existence entailing may not have the same truistic feel as the claim that all relations are existence entailing, it seems plausible nonetheless.

To see why, consider what ontological dependence is supposed to be, at an intuitive level. Ontological dependence is supposed to be, in part, a way of capturing metaphysical structure. This shows up in the metaphors that are often used to describe ontological dependence relations: ontological dependence is a matter of providing *foundations*, it is a matter of *building one thing from another* (see, for instance, Bennett, 2011). The metaphor paints a picture of one thing 'resting atop' another. The metaphor is no doubt compelling because it captures an intuitive

15. See De Clercq (2006) for a variation on this strategy whereby 'taller than' is reduced to the greater than relation between certain height properties.

16. Of course, ontological dependence cannot be defined in terms of necessitation. But that is because necessitation is necessary but not sufficient for ontological dependence. See Correia (2008); Fine (1995) for discussion.

17. The presentist might look to the operator view on grounding for help here: see, e.g., Fine (2012).

feature of ontological dependence: namely, that it is like construction, in some sense. One way in which ontological dependence is like construction, it seems, is that the foundations and the founded must both exist.

If that's right, however, then cross-time ontological dependence is anathema to surface presentism, regardless of whether it involves a relation or whether it can be specified in terms of clusters of modal facts. We suspect that most presentists will actually be pretty sympathetic to this line of thought. Consider the kind of hoops that presentists are willing to jump through to make sense of truthmaking for claims about the past. Truthmaking, however, can be thought of as a form of ontological dependence. If cross-time ontological dependence is generally allowed, however, then we can just allow for present truths to ontologically depend on the past. While some presentists do allow that present truths hold because of the past, they generally don't accept that this is a case of ontological dependence.[18]

Put it this way: if cross-time ontological dependence is generally acceptable to presentism, that would be a big deal. We'd be happy enough to have brought this fact to light. We fear, however, that cross-time ontological dependence remains at odds with presentist metaphysics and thus that event horizons are trouble for this reason.

3.3 Relations Are Not Existence Entailing

To a certain extent, our discussion of the second response to the challenge posed by event horizons already foreshadows our view on the third response. As noted, the third response involves accepting that there is ontological dependence between the present and the future, and even accepting that ontological dependence is a relation. What the presentist denies, however, is that all relations are existence entailing. Ontological relations between the present and the past do exist but not their relata.

Arguably, this idea makes sense if we consider relations involving fictional objects (McKinnon and Bigelow, 2012, make this point). Relations between fictional and non-fictional objects seem to provide a powerful counterexample to the supposed truism that all relations are existence entailing. Sara admires Sherlock Holmes. She feels empowered because of Hermione's heroism. She is taller than Frodo. None of this seems to call Sherlock, Hermione, or Frodo into existence in any obvious way. True enough, there is a story to be told about why this might be the case. It is plausible enough, though, that the situation is to be read at a surface level. Sara stands in relations to fictional objects, and that's okay (metaphysically speaking).

Thomasson's (1999) notion of historical dependence provides another way to resist the idea that all relations are existence entailing.[19] According to Thomasson, historical dependence occurs when "one entity requires another in order to come into existence initially, although it may be able to exist independently of that entity once it has been created" (Thomasson, 1999, p. 31). For Thomasson, 'independent existence' allows for the destruction of whatever it is that brought a given entity into existence. She makes this clear when she classifies, as a case of historical dependence, a situation in which sugar has been used to produce alcohol. The alcohol's existence depends on the sugar's existence, but the sugar itself is used up in the process of alcohol production (it is metabolised by yeast, which produces alcohol as a byproduct under anaerobic conditions). Historical dependence does not appear to be an existence entailing relation.[20]

What of the derivation from Rab to $\exists x \exists y Rxy$? Well, this is one of the peculiarities of classical logic, a peculiarity that has been remarked upon independently of anything to do with presentism. Priest (2001),

18. See, for instance, Tallant (2009a,b); Tallant and Ingram (2015). Tallant (2009a) takes this to be a kind of ontological cheating, whereby we have truthmaking without ontological dependence.

19. We are grateful to a referee for pointing this out.

20. This applies to both the rigid and generic notions of historical dependence that Thomasson outlines. Rigid historical dependence being the dependence on a particular individual, and generic being the dependence on something of a particular type.

for instance, takes theorems like this one to motivate a revision of classical logic into free logic. Free logic does not validate the inference from predication to existence. It thus allows for relations between existing and non-existing things and also for the more mundane fact that unicorns have horns (a fact that, like *Rab*, has an untoward existential consequence in classical logic).

However, we do not believe that the ontological dependence involved in the black hole case can be taken care of this way. Ontological dependence, unlike relations involving fictional characters, or historical dependence, is existence entailing. This is for essentially the reasons introduced above: ontological dependence is a structural notion and, as such, it demands the existence of foundation and founded like no other relation. This is particularly true for the intimate relationship between event horizons and black holes. Put it this way: if we were to discover that Sara ontologically depends on Sherlock Holmes, we would be hard pressed to deny that Holmes exists. And so it is, we submit, with event horizons and the future.

3.4 Ersatz Surface Presentism

This brings us to the fourth response. The fourth response is, in a sense, the most concessive. The surface presentist accepts that the location of event horizons ontologically depends on the future. She also accepts that ontological dependence is an existence entailing relation. What she denies is that this gives us any reason to suppose that surface presentism is false.

In order to make this kind of solution work, we must find a way to modify surface presentism so that the existence of the future can be accommodated, without undermining core presentist values. One view along these lines is *ersatz surface presentism* (mentioned briefly at the end of §2.1). Ersatz surface presentism is a view more akin to mereological surface presentism than to the total surface presentism we have been focused on thus far. In order to state ersatz surface presentism, it is useful to remind ourselves of the more traditional variety of ersatz presentism.

Whereas standard presentism is the view according to which only present entities exist and non-present entities do not exist, ersatz presentism is the view according to which only present entities are concrete. Non-present entities exist, but they are abstract (see Bourne, 2006; Crisp, 2007). Non-present entities take the form of ersatz times. An ersatz time is just a set of tenseless sentences, describing what occurs at that time (this is analogous to ersatz modal realism, according to which worlds are treated as sets of sentences). Ersatz times are linearly ordered via the E-relation: an ordering over abstract times that is analogous to the earlier-than relation over concrete times found in non-presentist metaphysics. The present moment corresponds to whichever abstract time is concretely realised.

Ersatz presentism is not typically framed in spatiotemporal terms. However, it is not difficult to extend the view in this direction, as Wüthrich (2012) has done. Whereas total surface presentism is the view according to which only a single 3D region exists (though which region that is changes), ersatz surface presentism is the view according to which only a single set of spacelike separated spacetime points is concrete (intuitively, a slice of a 4D spacetime manifold). The rest of the spacetime points that constitute the 4D manifold described by general relativity are abstract objects.

As with ersatz times, we can treat ersatz spacetime points as sets of tenseless sentences, describing what happens at a point. We can then add a metric relation over ersatz spacetime points that mimics the metric relation over concrete spacetime points that we find in non-presentist views. This ersatz metric connection will connect spacetime points in ways that are analogous to the standard spatiotemporal metric. So, for instance, while spacetime points won't be timelike connected, they will be E-timelike connected, where being E-timelike connected is a matter of standing in the right ersatz metric connection. *Mutatis mutandis* for the spacelike and lightlike connections.

Whereas both total surface presentism and mereological surface presentism involve a measure of anti-realism toward general relativity,

ersatz surface presentism is more naturally construed as a version of realism toward general relativity, though certainly not a standard form of realism. The ersatz surface presentist is in a position to say that the entire 4D manifold represented by general relativity exists; what they deny is that the entire manifold exists concretely. Only a part of it is concrete. In this way, they gain the benefits of mereological surface presentism, without the associated cost of trying to make sense of parthood between present objects that exist and non-present, non-existent objects.

Because the ersatz surface presentist believes in the existence (but not the concreteness) of the future, she is in a position to accept the presence of ontological dependence relations that include future entities. She can thus allow that present event horizons depend ontologically on future black holes, in virtue of the fact that there are future (abstract) spacetime points that constitute the regions at which black holes are located (and will be located in a concrete way with the passage of time).

Ersatz surface presentism is an intriguing view and one that deserves greater attention than we can offer here. What matters for present purposes is that the ersatz solution to the trouble posed by event horizons is not entirely convincing. According to the ersatz surface presentist, a present event horizon is ontologically dependent on the future properties of regions occupied by black holes. Now, future regions are abstract objects. Thus, on this view, the only candidates to form the ontological basis for present event horizons are abstract objects.

As far as we can see there is nothing metaphysically incoherent about the idea that concrete objects depend on abstract objects. Indeed, we can think of at least one precedent that allows for a metaphysical picture along these lines. Take Paul's (2002, 2012) bundle theory of objects. For Paul, concrete objects are composed by properties, which are bundled together by a relation of restricted composition. Whether these properties should be viewed as concrete or abstract is debatable. But, at the very least, it seems that this example illustrates how a concrete entity could depend on abstract entities (by being composed of them). So perhaps something like a Paul-inspired bundle theory of objects could be combined with ersatz surface presentism to produce a theory of roughly the right kind.

Where we see trouble is with the physics of black holes. On the current picture, an event horizon is a boundary on a black hole region which is partly abstract in nature (in virtue of having ersatz spacetime points as parts). We understand and have a reasonably good theory of black holes and their event horizons construed as physical, concrete objects. What we lack is a theory of black holes according to which they are, in part, abstract objects. Perhaps this makes no difference at all to the physics. But that would be surprising indeed. Abstract objects are generally thought to lack many of the properties that we might think are relevant from a physical perspective, including causal properties and various spatiotemporal properties. Of course, with regard to the latter, the ersatz surface presentist can always supply ersatz spacetime connections and properties. But these, too, are pale imitations of the kinds of connections that play a role in physics.

Furthermore, one might worry that just as it's natural in Paul's picture to view properties as concrete rather than abstract (for the very reason that they are parts of the concrete world), it's likewise natural to accept that taking future properties of the black hole to constitute a present object gives evidence for the concreteness of these future properties and of the future objects that instantiate them.

In short, an ersatz surface presentist can only really make sense of ersatz event horizons: event horizons that ontologically depend on abstract objects. We lack a physics of these anaemic objects, as it is far from clear that the standard physics of event horizons and of black holes applies.

To be sure, this is not a decisive objection against ersatz surface presentism. The ersatz surface presentist may argue that the physics remains intact despite the structure of event horizons. In the absence of a demonstration along these lines, however, we have reason to doubt the ersatz surface presentists solution to the challenge posed by event horizons.

Before proceeding, it is worth noting that a similar problem to the

one raised for ersatz surface presentism will arise for a nearby view: *Lucretian surface presentism*. Lucretian presentists believe in fundamentally tensed properties possessed by present entities (cf. Bigelow, 1996). Thus, according to the Lucretian, Suzy was sick because she now has the tensed property of *having been sick*. Now, recall the existence conditions for event horizons, stated above:

> **Event Horizons**
> The location of an event horizon at a time t_1 depends ontologically on the properties possessed by a spatial region at t_1 and at each time $t_2 ... t_\infty > t_1$.

A Lucretian surface presentist might seek to replace the future properties specified in the conditions with reference only to tensed properties possessed by some current spatial region. Thus, she might offer the following alternative existence conditions for event horizons:

> **Tensed Event Horizons**
> The location of an event horizon at a time t depends on the existence of a spatial region r with tensed properties $p_1 ... p_n$ at t.

On this view, event horizons depend not on the future properties of a spatial region, but on the present tensed properties of that region. The trouble, as before, is that we don't have a good physical story about the nature of event horizons in terms of Lucretian properties. Our best understanding of black holes, drawn from general relativity, makes no use of such properties. The Lucretian move, then, is not the innocent move of trading one equally good ontological basis for another. Rather, the Lucretian is proposing a radical new ontology of event horizons, one that does not align with the current story from physics. Again, perhaps there is a way to make such an approach work. But note that the task is not merely a metaphysical one; it becomes the scientific task of vindicating the appeal to tensed properties in physics.

The challenge here is similar to a difficulty posed for presentism by McKinnon (2003). McKinnon argues that presentism has difficulty accommodating consciousness. Here's the argument, in brief: the neural correlates of consciousness are temporally extended. In order for a conscious experience to exist, then, a temporally extended neural state must exist. However, there are no such temporally extended states if presentism is true (because only a single moment ever exists), and so there are no conscious experiences. McKinnon considers a solution to the problem in terms of Lucretian properties. The idea being that present conscious experiences depend on instantaneous neural states plus a range of tensed properties about past neural states. McKinnon's worry with this picture is that it makes consciousness mysterious. For we have no account of how conscious experiences might arise from tensed properties.

So, too, in the case of black holes, we have no account of how event horizons might depend on tensed properties instantiated in the present. Indeed, the problem is worse than the difficulty posed by consciousness. At least in the case of consciousness there is a well-known explanatory gap between physical states and conscious mental states, a gap that the presentist can exploit to make the case that tensed properties play a role in consciousness. There is no such gap in the case of event horizons and black holes, and so there's even less scope to give an account of event horizons in terms of tensed properties or something else, like ersatz spacetime points (as previously discussed).

4. Event Horizons Revisited

This concludes our survey of the standard tools that presentists have for solving problems for their view. In each case, we have argued that the problem posed by event horizons is more pernicious than the kinds of problems that presentists usually face. As noted in §2, however, there is another kind of solution available to the presentist, and that is to take issue with the notion of an event horizon.

The argument against surface presentism relies on the idea that black holes possess event horizons. Event horizons, in turn, are defined as boundaries of spatial regions from which nothing escapes. But there is some dissatisfaction with the notion of an event horizon. For instance, physicist Sean Alan Hayward writes:

> Existing textbooks define a black hole by an event horizon. However, its teleological nature means that it is epistemologically unsound, empirically unverifiable, even theoretically impractical and not directly related to local physics. The last decade or so has seen increasing evidence that more local notions are more useful and have understandable associated physics. (Hayward, 2013, p. v)

Although we do not take a position on whether the standard definition is as problematic as suggested in this quote, it is interesting to see that a dissatisfaction with the standard definition of event horizons has led some physicists to appeal to alternative, more local notions. The most popular way to do so is to supplement the notion of an event horizon with another notion that doesn't involve reference to future times. Here's Curiel describing a picture along these lines involving 'apparent horizons':

> One popular such feature is a so-called apparent horizon, a structure that generically appears along with a classical event horizon, but whose existence and location can seemingly be determined locally, and which can also be defined in spacetimes in which an event horizon cannot, e.g., those that are bounded in space so there is no good notion of 'escape to infinity'. An apparent horizon is a two-dimensional surface (which we may for our purposes think of as a sphere) such that, loosely speaking, all light rays emanating outward from nearby points on its surface start out parallel to each other. This captures the idea that 'nothing, not even light, can escape' in a local fashion—outgoing light wants to remain tangent to the surface. Note, however, that there is no guarantee that something entering the region bounded by a suitable characterization of the future evolution of such a surface may not later be able to exit from it. (Curiel, 2019, p. 11)

As we see it, there are two ways to use apparent horizons. First, one might appeal to an apparent horizon for pragmatic reasons. The more local notion is better from a practical perspective because it involves only local physics, and so the epistemic demands are less onerous. One does not need to gather information about the entire future of a region in order to work with an apparent horizon. Second, one may treat apparent horizons as a potential replacement for event horizons. On this approach, apparent horizons are treated as an alternative way of characterising the boundaries of black holes.

If apparent horizons are treated as potential replacements for event horizons, then this opens up a way for the presentist to respond to our argument. For the presentist might maintain that the empirical evidence supporting the existence of black holes under-determines whether they have event horizons or merely apparent horizons. Since the available evidence is compatible with either option, it is not strictly true that the existence of event horizons is empirically confirmed. At best, it is empirically undecided between two options: black holes with event horizons and black holes with only apparent horizons. As apparent horizons can be defined with no reference to the future, the argument offered in §2 could be answered simply by rejecting its more empirical premise that the universe includes black holes bounded by event horizons.

As touched on briefly in §2, however, there are two ways to think about empirical confirmation: as direct or as indirect. To reiterate, direct empirical confirmation involves gathering observational evidence for the existence of some entity. So, for instance, when we observe the presence of a kangaroo in a field, that counts as direct observation. Indirect empirical confirmation, by contrast, is via a theory. Thus, we have a theory T that posits some entity x. The existence of x is confirmed via the confirmation of T even if there is no observational evidence that directly supports x.

Given the distinction between direct and indirect confirmation there are two ways to formulate an under-determination problem for our argument. The first form of the problem focuses on direct empirical confirmation. Any observations we might make of black holes are compatible with event horizons and with apparent horizons. Thus,

there is an evidential symmetry between the two that undermines the empirical basis for our argument.

Of course, the observations in this case are different from the observations of kangaroos: we can't literally see a black hole. Rather, the observations at issue are, presumably, observations of the effects of black holes. Observations in this sense do indeed under-determine the choice between black holes with event horizons and black holes with apparent horizons. However, as discussed previously, we are taking the support for black holes to be indirect.

The crux of the matter, then, is that evidential symmetries in direct observation may be broken by confirmational asymmetries between theories. Here's a simple example. Suppose that we gather some observations in a particular area of forest. We find some scat, see some tree markings, find some burrows, and so on but never actually see an animal. We manage to identify two possible animals that fit the data, but we cannot decide between them based on the evidence at hand. Now, suppose we have a theory of the region that is confirmed over its rivals using a data set that is broader than the forest data (say data based on the geographical distribution of animals). Our theory implies that exactly one of our two types of animal could be in the area and thus responsible for the data gathered. Based on the confirmation of this broader theory, we are then in a position to break the evidential symmetry in our observations and come to a decision about which animal is endemic in the forest.

That's how we see things in the case of black holes. With respect to the specific observational data concerning black holes, there is an evidential symmetry between event horizons and apparent horizons. This symmetry gets broken at the theoretical level via the confirmation of general relativity, a theory that is supported by a larger data set than the observational data concerning black holes. The symmetry gets broken because general relativity posits the existence of black holes with event horizons rather than black holes that have apparent horizons only. In this way, general relativity is analogous to our imagined zoological theory that recognises only some furry creatures in a forest zone. The observational symmetry at issue, then, is not enough to undermine our argument against surface presentism, since our argument operates at the level of theories.

Can the presentist respond? One option might be to try and formulate an under-determination problem for indirect confirmation. To do this, the presentist would need to show that there is a confirmational symmetry between two theories. The first theory would be general relativity, which posits the existence of black holes with event horizons. The second theory—call it general relativity*—would posit the existence of black holes with apparent horizons and no event horizons. If the empirical evidence available under-determines the choice between general relativity and general relativity*, then the empirical basis for our argument could be undermined. The under-determination would thus apply not locally between two specific alternative claims about the properties of black holes, but between two theoretical frameworks considered as a whole.

Note that the shift from general relativity to general relativity* is non-trivial. It is not just a simple matter of 'swapping' event horizons for apparent horizons. While apparent horizons avoid reference to the future, they cannot fully replace event horizons. For it is possible for some entities—depending on the spacetime geometry—to escape some apparent horizons. This shows that, although useful, apparent horizons cannot obviously do the same explanatory work as the original notion of an event horizon (they cannot, for instance, be part of the explanation of why black holes don't emit light).[21] Even if we have apparent horizons, we still need a way to specify the point of no return: the boundary between a black hole region and the rest of spacetime, a boundary that nothing, not even light, can escape from once crossed.

21. We set aside in our discussion the fact that black holes do emit a faint amount of light in the form of Hawking radiation, according to their description in the framework of quantum field theory on curved spacetime. We can do so because this light has a different origin and does not invalidate the gravitational fact in general relativity that inbound light rays cannot escape black holes (for a philosophical presentation of Hawking radiation, see, e.g., Wallace, 2018).

The shift from general relativity to general relativity* thus incurs a burden to try and recover the explanatory power of the original theory in this new setting. The relevant question then becomes: Is there any promising alternative to general relativity that uses only apparent horizons and has the same explanatory power as the original theory? Or, at the very least, is there a sketch of how such a theory could go?

As matters stand, general relativity* is not really considered a live option in physics, so far as we know. This is because there is currently no reason to think that general relativity is anything but an extremely accurate theory of the non-quantum domain, which is the very domain that matters when assessing the existence of event horizons (setting aside a potential class of extremely small black holes). All attempts to detect deviations from the predictions of general relativity have thus far failed. The only reasons to seek a replacement for general relativity are linked to the problem of quantum gravity (namely, explaining the phenomena involving both quantum and gravitational aspects; two frameworks notoriously in tension). However, the alternative theory to general relativity that physicists are looking for will have to be extremely similar to general relativity in the classical domain in order to account for its successes. It is therefore natural to expect it to still predict the existence of event horizons. Thus, the possible replacement for general relativity that the physicists might come up with is unlikely to be a theory of general relativity*, in the sense at issue.

Even if an alternative to general relativity could be developed, the success of the under-determination argument would not be ensured. The fact that two theories fit the data equally well and have the same explanatory power does not entail that they are on a par, with the same scientific, empirical credentials. Other considerations are relevant to judge the confirmational status of a theory, such as the consistency of the theory with other overarching theories in physics, its historical success in allowing a leap forward in scientific progress,[22] the relative simplicity of the theory, the degree of unification displayed by the theory, and so on. There is more to confirmation than explanatory power and consistency with empirical evidence in a narrow sense.

In order to run an under-determination argument, then, the presentist has some work to do. We do not say that there is no response available to the presentist from apparent horizons. But consider the project at hand: one must either reformulate general relativity with apparent horizons and argue that it is as good as standard general relativity in all of the respects that matter for theory choice, or bet on the future replacement of general relativity by a theory that does not posit the existence of black holes with event horizons. That is not only a substantive project in philosophy; it is a substantial project in physics as well.

5. Conclusion

We have argued that surface presentism is at odds with the existence of black holes. In particular, present event horizons seem to ontologically depend on the future properties of black hole regions. We have argued that the surface presentist cannot accommodate this case of ontological dependence in the usual ways, by appealing to tools in the presentist's metaphysical toolbox. We thus conclude that surface presentism conflicts with empirical facts about our world that support the existence of black holes.

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22. The 'historical' theory that permits the leap can seem more empirically warranted than alternative potentially *ad hoc* theories formulated later on as alternatives.

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