An Empirical Argument for Presentism

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Abstract

According to orthodoxy, our best physical theories strongly support Eternalism over Presentism. Our goal is to argue against this consensus, by arguing that a certain overlooked aspect of our best physical theories strongly supports Presentism over Eternalism.

1. Introduction

We all think that some things are present. Presentists go on to say that *everything* is present: nowhere in reality will you find any dinosaurs or Martian outposts. Eternalists disagree. According to Eternalists, the present is just one part of a four-dimensional reality that includes both past and future things.

A very influential objection to Presentism is empirical: insofar as Presentism entails that there is an absolute relation of simultaneity, Presentism seems to be in conflict with relativistic physics. Our goal is to argue against the orthodox view that our best physical theories strongly support Eternalism. However, we won't be directly responding to the objection from relativity. Many have already responded to the objection from relativity, and we don't have anything to add beyond their responses.[1] Instead, we will argue that there is a *different* aspect of our best physical theories, which so far has been overlooked, that strongly supports Presentism.

We'll begin by introducing the relevant aspect of physics that we will be focusing on, namely, that our universe is Markovian (section 2). We'll then argue that, while Eternalism does not give us any reason to expect that our universe should be Markovian, certain versions of Presentism imply that our universe *must* be Markovian (sections 3 and 4). We then argue that this constitutes strong evidence for Presentism, and we conclude by assessing the balance of empirical considerations for and against Presentism (section 5).

[1] See, for example, Markosian (2004), Zimmerman (2011) and Emery (2019).

2. Markovian Laws

Clearly the past can place causal constraints on the future. For example, the fact that yesterday someone placed a book on a table might be one of the causes of the fact that I will soon pick the book up. But some of the causes of my picking up the book are not in the past. The fact that the book is on the table *now* is also a cause. In fact, there is something special about the present cause. It doesn't matter how the book ended up on the table; given the present state of the book, the past causal history of the book is irrelevant to whether I will soon pick it up. In other words, present causes "screen off" past causes. A Markovian causal process is one where past causes are always screened off by present causes in this way. Markovianism is, roughly, the claim that every causal process in the universe is Markovian.

It needn't be like that. We can imagine that yesterday a wizard cast a spell that causally necessitated that a magic sword will come into existence tomorrow. However, (we can further imagine that) the spell left no lingering causal traces in the present, so that the entire intrinsic state of the present fails to causally necessitate that a magic sword will come into existence tomorrow. Instead, the wizard's spell *directly* caused something to happen tomorrow, without the help of any intermediary present causes. This is a paradigm example of a Non-Markovian process.

Let's state Markovianism more precisely. For any time t, let H_t be the proposition that exactly describes the intrinsic state of the history of the universe up to and including time t, and let T be the proposition that exactly describes the intrinsic state of t. Finally, let $t+$ refer to the history of the universe strictly after t. In a deterministic setting, Markovianism can be formulated as follows:

> **Markovian Determination**: For every time t, if it is nomically necessary for $t+$ to have some intrinsic property P given H_t, then it is nomically necessary for $t+$ to instantiate P given T.

While our initial example concerning the book on the table is compatible with **Markovian Determination**, our second example concerning the wizard's spell is not. If t is the present time, then is nomically necessary for there to be a magic sword tomorrow given H_t, but it is not nomically necessary for there to be a magic sword tomorrow only given T. More generally, **Markovian Determination** implies that every time must nomically necessitate what was nomically necessitated by its past. Intuitively, the past cannot "directly" affect the future in a way that bypasses the present.

Markovianism can also hold in indeterministic settings. Suppose, for example, that the wizard's spell yesterday only ensured that the objective chance that there will be a magic sword tomorrow

is 50%. Such a case is intuitively Non-Markovian, even though it is compatible with **Markovian Determination**. So, a different principle is required for stochastic causal influences.

For every stochastic law of nature L, we can associate an objective chance function Ch_L that is meant to encode the objective chances of certain propositions given by L. For any proposition Q, we can distinguish *the historical t-chance of Q given L*, which is the chance of Q given L and H_t, or $Ch_L(Q \mid H_t)$, from the *present t-chance of Q given L*, which is the chance of Q given L and T, or $Ch_L(Q \mid T)$. We can now formulate the following principle:

> **Markovian Chance:** For every time *t*, the present *t*-chance that *t*+ will instantiate some intrinsic property P given L is equal to the historical *t*-chance that *t*+ will instantiate P given L. In other words, $Ch_L(t+ \text{ will instantiate P} \mid T) = Ch_L(t+ \text{ will instantiate P} \mid H_t)$.

Intuitively, this principle states that the chancy constraints that the entire history up to *t* imposes on the future are the same chancy constraints that *t* itself imposes on the future. In other words, the past of *t* does not impose any chancy constraints on the future that aren't already implicit in *t* itself. Again, this principle can easily be seen to rule out the case of the chancy wizard's spell. If *t* is the present time, then the historical *t*-chance of there being a magic sword tomorrow is 50%, yet the present *t*-chance of there being a magic sword tomorrow is not 50%.

Let us say that the world is *Markovian* just in case both **Markovian Determination** and **Markovian Chance** are true. We can now ask: is our world Markovian? Subject to certain qualifications, our best physical theories say that the answer is yes: specifying the present state of the universe suffices to determine (or determine the chances of) all future events. This is true in classical theories of particles and fields, quantum theories of particles and fields, and even relativistic versions of both classical and quantum theories. In all of these theories, in order to determine how the world will evolve in the future, it suffices to appeal to *present* facts concerning, for example, particle positions, masses, and velocities, or the values of various fields, or the wave function of the universe, etc. We'll now address two important objections to this claim.

The first objection has to do with relativistic physics. Both **Markovian Determination** and **Markovian Chance** quantify over "times", yet according to standard interpretations of Special Relativity and General Relativity, it is unclear what "times" are supposed to be, since there is no relation of absolute simultaneity. Our response is that we can reformulate **Markovian Determination** and **Markovian Chance** to be compatible with relativistic physics. In Special Relativity, we can claim that both principles are true with respect to every inertial reference frame, where every inertial reference frame corresponds to a way of "slicing" Minkowski Spacetime into times. In General Relativity, we can claim that both principles are true with respect to every global foliation of spacetime into "Cauchy surfaces", where "times" are meant

to refer to Cauchy surfaces. There is a worry here that there are some solutions to the equations of General Relativity that do not admit of *any* global foliation of spacetime into Cauchy surfaces. However, such solutions are widely regarded to be physically unrealistic. So long as we restrict our attention to so-called "globally hyperbolic" spacetimes, such a global foliation is always possible.[2] More advanced physical theories, such as Quantum Field Theory, also give us good independent reasons to restrict our attention to globally hyperbolic spacetimes. For example, as Earman et al. (2009) note, Quantum Field Theory on curved spacetime seems to presuppose that spacetime is globally hyperbolic. The standard procedure for constructing a natural algebra of observables over a curved spacetime "breaks down for non-globally hyperbolic spacetimes, and one can wonder whether it is even possible to construct a decent QFT when the spacetime is so causally ill-behaved" (116). We therefore conclude that the thesis of Markovianism can be well-posed in physically realistic relativistic theories.

The second objection is that whether or not **Markovian Determination** is satisfied in classical physics is sensitive to an ongoing metaphysical debate about how to interpret certain vector quantities. For example, in Newtonian physics, there is a debate about whether the instantaneous velocity of a particle at a time is an intrinsic or extrinsic property of that particle at that time. On the "at-at" view of velocity, velocity facts at a time are grounded in position facts at nearby, distinct times, implying that velocity is extrinsic. On an alternative view, there are irreducible intrinsic properties corresponding to instantaneous velocities that causally influence the future trajectory of a given particle.[3] It turns out that, according to the extrinsic view of velocity, **Markovian Determination** is violated in Newtonian physics. If velocity is extrinsic, the intrinsic state of the world at a time is wholly exhausted by specifying the number of particles there are, their masses, and their positions. Such an intrinsic state does not determine the future evolution of the universe, even though its past does determine the future evolution of the universe, violating **Markovian Determination**. However, if velocity is intrinsic, the intrinsic state of the world at a time must also include the intrinsic velocities of every particle, which *does* successfully determine the future evolution of the universe.[4]

Our first (and more important) response to this objection is that it does not extend to our more advanced quantum theories. The fundamental dynamical law of quantum mechanics is Schrödinger's Equation, which only requires the intrinsic state of the wave function of the universe at a single time (with no temporal derivatives) in order to determine the future evolution of the universe.[5] The reason why quantum physics differs from classical physics in this way is

[2] See Callender (2017) for an accessible introduction to (non-)globally hyperbolic spacetimes.

[3] For a classic defense of the "at-at" view of velocity, see Russell (1937). See Tooley (1988), Bigelow and Pargetter (1990), Arntzenius (2000), Carroll (2002), Lange (2005), Easwaran (2014), Builes (2020), and Builes and Teitel (2021) for further discussion on both sides of the debate.

[4] Arntzenius (2000) motivates the intrinsic view of velocity precisely because it is compatible with (what we call) **Markovian Determination.**

[5] Although the Schrödinger Equation is Markovian, one might worry that alternative interpretations of quantum mechanics that either modify or supplement the Schrödinger Equation might violate Markovianism. However,

that the fundamental dynamical equations of classical physics are usually taken to be second-order differential equations (e.g. "F=ma", where "a" is the second time-derivative of position), whereas the fundamental dynamical equation of quantum mechanics, Schrödinger's equation, is a first-order differential equation which does not require temporal derivatives to solve.[6] Given that we have overwhelming empirical reasons to favor quantum theories over classical theories, in all likelihood this objection does not apply to the physics of the actual world.

Our second response is that, even if classical physics were true, and even if velocities were extrinsic in classical physics, there is still a sense in which the spirit of Markovianism is true. The present may not be enough to determine everything, but little of the past is needed. The state of the world yesterday (and all of the history before then) is irrelevant, given the state of the world during the past five minutes. Similarly, the state of the world five minutes ago is also irrelevant, given the state of the world during the past five seconds, and so on. In general, for any moment in the past, that moment can be seen to be irrelevant given a smaller interval between that moment and the present. Only an arbitrarily small interval from the past to the present is needed to determine all future events.

Such a failure of Markovianism, then, naturally leads to the following nearby principles. For any arbitrarily small positive interval of time *i*, let H_i be the proposition that exactly describes the intrinsic state of the history of the universe up to and including interval *i*, and let I be the proposition that exactly describes the intrinsic state of *i*. Finally, let *i*+ refer to the history of the universe strictly after *i*.

> **Near Markovian Determination**: For any (arbitrarily small) positive interval of time *i*, if it is nomically necessary for *i*+ to have some intrinsic property *P* given H_i, then it is nomically necessary for *i*+ to instantiate *P* given I.
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> **Near Markovian Chance:** For any (arbitrarily small) positive interval of time *i*, Ch_L(*i*+ will instantiate P | I) = Ch_L(*i*+ will instantiate P | H_i).

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popular accounts of how the Schrödinger Equation should be modified or supplemented are still Markovian. For example, Bohmian mechanics adds a (Markovian) first-order guidance equation that does not require velocities to solve (e.g. see Maudlin 2019: 143), and according to the "orthodox" account of the collapse of the wave function, the objective chances for collapse upon measurement are supplied by the intrinsic state of the wave function at the time of measurement.

[6] It is worth noting that there are alternative formulations of classical mechanics, such as Hamiltonian Mechanics, that utilize first-order differential equations. A natural reading of Hamiltonian mechanics is that it treats facts about position and momentum as equally fundamental, which implies that facts about momentum (and velocity) are not reducible to facts about masses and positions, contrary to the reductionist "at-at" view of velocity. So, whereas a Newtonian formulation of classical physics might suggest that classical physics violates Markovianism, a Hamiltonian formulation of classical physics suggests that classical physics satisfies Markovianism. For more on the philosophical implications of different formulations of classical physics (as well as other physical theories), see North (2021).

Let us say that our world is *Nearly Markovian* just in case both **Near Markovian Determination** and **Near Markovian Chance** are true.

All of our best physical theories, from Newton on, have been Nearly Markovian. Some of our best physical theories, such as our best quantum theories, are uncontroversially Markovian, independently of any debate about the metaphysics of vector quantities. However, all of our best physical theories are *compatible* with being Markovian, perhaps subject to debates about whether certain vector quantities are intrinsic to a time or not. Let us say that physical theories of this kind are *Markovian**.

What science tells us is that there are very strong reasons to think that our world is Markovian*. This strikes us as a very surprising fact. The question we want to ask is: *why*? Why is it that our world is Markovian*? After all, it seems easily conceivable for there to be a world that is neither Markovian nor Nearly Markovian, as the wizard case illustrates above.

Our goal will be to argue that Markovianism* shouldn't be surprising if you're a Presentist. In fact, we will be arguing that certain versions of Presentism entail that our world must be Markovian*. Before we do that, however, we will first argue that Eternalism doesn't give us any reason to expect that our world should be Markovian*.

3. Eternalism and Markovianism

To say that our universe is Markovian* is to describe a certain natural regularity in the universe. Within the metaphysics of science, there are two very different approaches to accounting for natural regularities, so it will be useful to consider two very different kinds of Eternalist views. According to *Non-Humeanism*, the world doesn't merely *happen* to conform to law-like natural regularities. Instead, there is some robust sense in which things *have* to conform to such regularities. In order to capture this intuition, different Non-Humeans appeal to different metaphysical posits - the intrinsic causal powers or dispositions of physical properties, necessitation relations between universals, metaphysically fundamental facts about laws, etc.[7] Humean theories don't make any such metaphysical posits. For Humeans, laws of nature merely *summarize* the distribution of matter through space and time, or the "Humean mosaic", in a simple and informative way.[8] All facts about laws, counterfactuals, causation, chance, etc. ultimately hold in virtue of certain patterns in the Humean mosaic. Within the Humean mosaic,

[7] For a sampling of different Non-Humean approaches that appeal to causal powers or dispositions, see Shoemaker (1980), Bird (2007), Strawson (2008), Heil (2010), Jacobs (2011), and Demarest (2017). See Dretske (1977), Tooley (1977), and Armstrong (1983) for classic developments of the view that laws are explained by appeal to necessitation relations between universals. See Carroll (1994, 2018), Maudlin (2007), and Kment (2014) for developments of the view that laws are fundamental. For an accessible and general overview of different Non-Humean theories, see Hildebrand (2020).

[8] For an introductory survey of Humeanism about laws of nature, together with how it might respond to various objections, see Bhogal (2020a).

there are no necessary connections between disjoint regions of spacetime: specifying the intrinsic state of one region of spacetime (e.g. the past) doesn't put any constraints whatsoever on the intrinsic state of any other disjoint region of spacetime (e.g. the future).

It is clear that on an Eternalist Humean metaphysics, there is no particular reason to expect that the Humean mosaic should satisfy Markovian laws, Nearly Markovian laws, or even any laws at all. According to Humeanism, the world is simply a vast mosaic of local intrinsic qualities, and there is no particular reason why one logically possible Humean mosaic should be actualized over any other. If we're lucky, the local qualities in our Humean Mosaic might line up in just the right way to be neatly summarized by a simple Markovian description, but there is no *a priori* guarantee that this will be so. It might be that the most simple and informative patterns in the mosaic are best summarized by a Non-Markovian description, or it might even be that the mosaic does not conform to any simple or informative patterns at all.[9]

One might think that Eternalist Non-Humean theories would have a better time of accounting for Markovianism*, but on closer inspection, it's hard to see why that should be so. Let us grant, for example, that if some version of Non-Humeanism were true, then we should expect that our universe should be "regular". Still, there are all sorts of highly regular universes that are neither Markovian nor Nearly Markovian. To take a very simple toy example, consider an infinite "binary" universe, where time is discrete and infinite in the past and future, and at any given time, the universe can be in one of two states, which we can label "0" and "1". Consider the following universe:

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The laws governing such a universe could be extremely simple and regular: "For any time t, [the state of the universe at t+1 = the state of the universe at t] iff [the state of the universe at $t \neq$ the state of the universe at t-1]". However, such a universe would manifestly violate Markovianism. How the world evolves from t to t+1 would crucially depend on what happened before t.[10] Examples like this can easily be multiplied: there are an infinity of highly regular universes that are not Markovian*. Non-Humean theories need to appeal to something much more specific than the regularity of the universe if they are to successfully account for Markovianism*. Let us now

[9] There is a substantial debate between Humeans and Non-Humeans about whether Humean laws can explain natural regularities (e.g. see Lange (2013, 2018), Schumener (2019), Dorst (2019), Bhogal (2020b), Hicks (2021), and Emery (forthcoming)). However, we do not intend to take a stand on this debate about the nature of explanation here. As we will further discuss later (in section 5), we are only making the weaker epistemic point that, given Humeanism, one should not expect that the universe conforms to Markovian Laws *a priori*. In a Bayesian setting, this amounts to the claim that one's prior probability in Markovianism given Humeanism should not be particularly high.

[10] One could interpret this toy example as being Nearly Markovian, if one allows the "dynamic" properties of "coming from a 0" and "coming from a 1" to be instantiated in the present, because those properties could play the role of "velocities" in determining future states. But we can easily consider a similar toy model (e.g. …000111000111…) that is clearly neither Markovian nor Nearly Markovian.

look more closely at three of the most popular versions of Non-Humeanism to see if they can account for why our world is Markovian*.

First, consider an account that is based on relations between universals. Such an account seeks to secure regularities of the form "All Fs are Gs" by means of a "necessitation relation" *N* holding between the universals *F* and *G*. In order to secure Markovianism*, an argument would have to be given as to why any combination of laws (or at least "typical" combinations of laws) of the form "All Fs are Gs", where *F* and *G* correspond to universals, must be Markovian*. We're skeptical that such an argument can be given. Part of our skepticism stems from the fact that it's unclear how such an account is meant to deal with scientifically realistic examples of laws of nature in the first place, which tend to be of the form of differential equations rather than of the form "All Fs are Gs".[11] In particular, such an account doesn't seem to give any special role to *time* in these relations between universals, so it's unclear how such a view could account for Markovianism*, since Markovianism* is a precise claim about how the laws of nature are supposed to relate to time.

Second, consider primitivist account of laws, according to which there are metaphysically fundamental facts of the form "it is a law that P", where there is no further analysis of the relevant notion of lawhood. We are skeptical that such an account is able to account for why our world is Markovian* mainly because we agree with Hildebrand (2013) that such an account has trouble explaining why there are *any* regularities in the universe. The main trouble that Hildebrand points to is that, because laws are entirely primitive on this account, there doesn't seem to be any independently motivated constraints on which kinds of propositions can count as primitive laws. In particular, consider any proposition P that describes some highly irregular and complicated pattern in perfectly natural terms. If laws are entirely primitive, why can't it be a fundamental law that P is true? However, if there are no constraints on what laws there can be, then the posit of primitive laws provides no constraints for how the "Humean mosaic" could be. For any Humean Mosaic, no matter how complicated and irregular, there could be primitive laws that are compatible with such a Humean mosaic. In effect, the primitivist account of laws has the opposite problem as the previous account of laws in terms of universals. According to the universals account, laws *must* be of the form "All Fs are G", where *F* and *G* correspond to sparse universals. Such an account seems to be *too* restrictive, because it's unclear how such an account is meant to capture physically realistic examples of laws. However, the primitivist account is far too permissive, because it doesn't provide any principled constraints for what gets to count as a law.

At this point, the defender of the primitivist account of laws could just stipulate that their preferred primitive operator "it is a law that" can only apply to certain propositions. After all, it is their primitive, so they can stipulate how they intend it to work. Perhaps one could say that

[11] For related criticisms, see Wilson (1987) and Maudlin (2007).

only propositions that are sufficiently universal or general can count as laws (Carroll 1994: 21-22), or perhaps one could say that only propositions that describe how physical states evolve through time can count as laws (Maudlin 2007: 10-15). In fact, one could simply stipulate that only propositions that describe Markovian* regularities can be laws! However, Hildebrand (2013: 6-7) argues that these kinds of maneuvers don't help primitive laws account for natural regularities. Because these constraints are not independently motivated by any analysis of what laws are supposed to be, they only manage to gain explanatory power by reducing their prior plausibility.[12]

Let us lastly consider Non-Humean views which appeal to the causal powers of fundamental physical properties. We think that such a view has the best chance of accounting for why Markovianism (and hence Markovianism*) should be true, although we still have some reservations for how that account is supposed to go. Our proposal on behalf of these kinds of views is to try to secure Markovianism by appealing to the fact that the causal powers of physical properties must act in *local* ways. In other words, if a spatiotemporal event *c* is to causally influence a spatiotemporal event *e*, it can only do so by causally influencing a chain of intermediary spatiotemporal events between *c* and *e*. Our example of the wizard clearly violates this locality constraint: the wizard's magic spell yesterday causally influenced some event tomorrow without any mediating causal influences in the present. In effect, Markovianism can be seen as the thesis that there cannot be causal action at a *temporal* distance, whereas a principle of locality is meant to rule out any causal action at a *spatiotemporal* distance.

Although we think such an account holds some promise, we have two main worries. Our first worry is that there are both historical and contemporary examples of physical theories that violate a general locality condition on causation. For example, Newton's original account of gravitation was certainly Markovian*, but it explicitly included causal action at a *spatial* distance: the gravitational influence of one physical body on another distant physical body was instantaneous and did not causally influence any events between those two physical bodies. In contemporary times, certain interpretations of Quantum Mechanics, such as Bohmian Mechanics, also have spatially non-local causal interactions, even though they are Markovian*.

Our second (and more important) worry takes the form of a dilemma. Either it is metaphysically necessary that Non-Humean causal powers must obey a locality condition, or it is not. If it is taken to be metaphysically necessary, then there should be some deeper story as to *why* such a principle is meant to be metaphysically necessary. After all, while a locality condition on the causal powers of fundamental physical properties is certainly intuitive, it seems both logically

[12] It's also worth noting that, although Maudlin (2007) intends his account of "fundamental laws of temporal evolution" to explain later states of the universe in terms of earlier ones, Maudlin doesn't specify that such laws need to be Markovian (or Nearly Markovian). For example, our initial toy example of a binary world of 0's and 1's could be interpreted as having a primitive law that explains how future states evolve from earlier ones, even though it is not Markovian.

and conceptually possible that there might be violations of locality, as witnessed by scenarios that are both conceivable (e.g. our wizard) and scientifically realistic (e.g. Bohmian Mechanics).[13] On the other hand, if such a principle is merely contingent, then this Non-Humean strategy owes us some explanation for why we should expect ourselves to be in a world that exclusively operates according to local causal powers rather than a world that (partially) operates according to non-local causal powers.

We therefore conclude that existing versions of Eternalist Humeanism and Non-Humeanism have a difficult time accounting for why we should expect our world to be Markovian*.

4. From Presentism to Markovianism

There's a sense in which Markovian laws always treat the present time as special. If the world is to be Markovian, the causal influence that the past has on the future must always be implicit in the present. A natural place to look for an explanation of Markovianism, then, could be a theory in which the present time is metaphysically privileged in some way. In this section, we will see how certain versions of Non-Humean Presentism can account for this remarkable feature of the laws of nature.[14] The rough idea for why Presentism might secure Markovianism is straightforward: the reason why the past cannot constrain the future in ways that go beyond the present is because *the past is not real*. There can be no causal constraints on the future that are not implicit in the present if the present is all there is!

Although this rough idea is intuitive enough, it needs to be developed carefully. It's not true that *any* version of Non-Humeanism together with *any* version of Presentism entails that the world is Markovian. Here is one such example. Consider again our toy binary world:

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Suppose that Presentism is true and there are primitive Non-Humean Laws. Although Presentists do not believe in any past or future entities, they still typically acknowledge that there are facts about what *was* the case and what *will* be the case. For any positive natural number N, let $WILL_N(P)$ be the proposition that P will be the case N units of time from now, and let $WAS_N(P)$ be the proposition that P was the case N units of time in the past. Let "**1**" be the proposition that "the world is in state 1" and let "**0**" be the proposition that "the world is in state 0". Then, the following might be a primitive metaphysical law that describes the evolution of our toy world: "It is always the case that: [($WILL_1$(**0**) and **0**) or ($WILL_1$(**1**) and **1**)] iff ~[(WAS_1(**0**) and **0**) or

[13] See Chalmers (2002) for an extended defense of the claim that a certain kind of idealized conceivability entails metaphysical possibility.

[14] Unfortunately, Humean versions of Presentism face the very same problem as Humean versions of Eternalism. Given a Humean metaphysics, there is no particular reason to expect one distribution of logically possible local qualities in space(time) over any other.

(WAS_1(**1**) and **1**)]". Such a law explicitly violates Markovianism, which shows that Presentism and Non-Humeanism on their own don't entail that our world is Markovian.

What this example shows is that, even though Presentists think the past doesn't *exist*, they still typically allow that there are *truths* about the past, and so there's a worry that such truths might place causal constraints on the future that are not implicit in the present.

Still, there are independently motivated versions of both Non-Humeanism and Presentism such that, when they are combined with generic versions of Presentism and Non-Humeanism (respectively), entail that our world is Markovian. We will consider each in turn.

4.1 Presentism with Non-Humean Causal Powers

We'll first consider how any version of Presentism, combined with a specific version of Non-Humeanism, entails that our world is Markovian.

According to the Non-Humean view that we will be considering, the causal constraints on the future are set by the causal powers of fundamental physical entities. In particular, on such a view, there are no primitive laws or necessitation relations: the *only* way there can be any causal constraints on the future is by way of the causal powers of fundamental physical entities. We'll begin by giving a flat-footed argument for why such a view entails Markovianism given Presentism. Then we'll consider an important objection.

In order to secure Markovianism (so the argument goes), what needs to be shown is that the causal constraints on the future (i.e. on what will happen) set by the causal powers of presently existing fundamental physical entities are the very same causal constraints on the future set by the causal powers of both past and present fundamental physical entities. However, this is trivial given the assumption of Presentism: there simply *are* no causal powers had by past entities, because there are no past entities!

It's important to note the crucial role that both Presentism and the Non-Humean casual power view have in this argument. On the assumption that both past and present entities exist, it is a wide open question whether there are any causal powers had by past objects that set causal constraints on the future that go beyond the causal powers of presently existing objects. However, given Presentism, there is no chance that the causal powers of past entities can go beyond the causal powers of present entities. After all, only existing things can have causal powers. Moreover, on the assumption that the causal constraints on the future can come from some other source besides the causal powers of physical objects (e.g. primitive laws that relate tensed truths about what *was* the case with tensed truths about what *will* be the case), then the

argument fails to go through as well. The argument only has a chance of going through if both of these assumptions are granted.

While we think this flat-footed argument has considerable intuitive force, it faces a subtle objection. It is certainly true that there are no causal powers had by past objects if Presentism is true. However, one might wonder whether the causal powers of *present* objects might be sensitive to certain tensed truths about what *was* the case. Here is how we think this objection should be developed. It's uncontroversial that one and the same causal power might have different effects in different circumstances. For example, one and the same electron might be disposed to behave in different ways in the presence of different environmental conditions (e.g. in the presence of different electric fields). However, what if there are present causal powers whose effects are conditional on the "environmental conditions" of different tensed truths obtaining? For example, what if there is a present causal power C such that, if it *was* the case that P, it will exhibit effect E_1 and if it *was* the case that Q, it will exhibit effect E_2? In order for this objection to be a problem for Markovianism, the relevant tensed truths (WAS(P) and WAS(Q)) would have to fail to nomically supervene on the whole of present physical reality. If they did nomically supervene on the whole of present physical reality, then such truths would already be implicit in the present physical state of the universe, nullifying the threat they pose to Markovianism.

Our response to this objection isn't that such a proposed counterexample is inherently contradictory or incoherent. Rather, our response is that it goes against the main motivation behind the causal powers approach to Non-Humeanism. The causal powers approach to Non-Humeanism can be broadly thought of as an "Aristotelian" approach to natural necessity, which seeks to locate the source of natural necessity *within* the material world rather than outside of it.[15] Such an Aristotelian approach sharply contrasts with "Platonic" approaches to natural necessity, according to which there are primitive metaphysical posits "outside" of material reality, such as relations between universals or primitive laws, that constrain the activity of material objects. On the Aristotelian approach, the natural thing to say is that the "environmental conditions" that are responsible for the behavior of material objects are set by other *concretely existing physical things* together with the physical properties and relations that they instantiate. For example, it's intuitive that an electron might behave differently in the presence of a (concretely existing) electromagnetic field surrounding it, which is a rich source of its own physical properties and potentialities. Being sensitive to these kinds of concretely existing environmental conditions is vastly different than being sensitive to irreducible tensed truths that fail to nomically supervene on the whole of physical reality. Intuitively, present causal powers are unable to "interact" with such irreducible tensed truths in the way that they can interact with their concrete physical environment.

[15] For more on the Neo-Aristotelian development of the causal powers approach, see Ellis (2002), Groff and Greco (2013), and Simpson et al. (2017). Chen and Goldstein (2021) go so far as to label the causal powers approach to laws as "Aristotelian Reductionism".

In sum, we think that Non-Humean approaches that appeal to causal powers are naturally paired with the claim that *the causal constraints on the future must be grounded in concrete reality*, where "concrete reality" is meant to include all concrete objects, together with their fundamental intrinsic properties and relations. We therefore conclude that, when conjoined with an independently motivated Aristotelian version of the Non-Humean causal powers approach, Presentism can secure Markovianism.

4.2 Non-Humeanism with Nomic Presentism

Suppose, however, that you have independent reasons to be skeptical of Non-Humean causal powers. Is there any other way that Presentism might help secure Markovianism? In this section, we'll argue that, when conjoined with a specific version of Presentism, any version of Non-Humeanism can help secure Markovianism.

The version of Presentism we have in mind can be independently motivated by reflecting on the so-called "truthmaking objection" to Presentism. On the one hand, if Presentism is true, both the past and future are unreal. Reality is entirely exhausted by the present moment. On the other hand, we all think that there are facts about what happened in the past, and most of us think there are also facts about what will happen in the future. But how *can* there be facts about the past and future if there are only presently existing things? What is it about reality that *makes* claims about the past or future true? After all, according to many, truth is supposed to supervene on being. This is the truthmaking objection to Presentism.[16]

In responding to this objection, some Presentists are happy with there being truths about the past and/or future that are not made true by anything in reality (where "reality" is meant to include everything that exists, all of their fundamental properties, and all of the fundamental relations that they stand in). For such philosophers, there is no problem with the Presentist simply saying that it is a primitive, fundamental fact that *there were dinosaurs*, and this fact doesn't need to be further grounded by anything in reality. Other Presentists are uncomfortable with there being truths that don't supervene on being, and so they must find some facts about the present that can ground truths about the past and future.

There are many ways that Presentists have tried to find present grounds for claims about the past and future, and most of these accounts involve extra metaphysical posits that non-Presentists have no need of. But there is one minimal and straightforward strategy that attempts to ground claims about the past and future in terms of the present state of the universe together with the laws of nature. This is a strategy that has been pursued by, for example, Peirce (1934),

[16] For an overview of the truthmaking objection and various Presentist responses to it, see Caplan and Sanson (2011).

Lukasiewicz (1967), Thomason (1970), and Markosian (2013). We can formulate this view as follows:

> *Nomic Presentism*: For any tensed fact P, P is true if and only if (and because) P is nomologically necessary given the present state of the universe.

Intuitively, Nomic Presentism can be understood as the thesis that all tensed facts are made true by (or hold in virtue of) (i) facts about the present intrinsic state of the universe and (ii) facts about the laws of nature. For example, according to Nomic Presentism, the reason why the moon will still exist in five minutes (and did exist five minutes ago) is because the laws of nature together with the present state of the universe *guarantee* that the moon will exist in five minutes (and did exist five minutes ago).

There are a number of objections one might raise to Nomic Presentism, but since our goal here isn't to give a comprehensive defense of Nomic Presentism, we won't be responding to these objections here.[17] Instead, we only aim to argue that, together with any version of Non-Humeanism, Nomic Presentism implies Markovianism.

To see how this works in detail, let us first focus on **Markovian Determination**. In the context of Presentism, **Markovian Determination** can be reformulated as follows:

> **Markovian Determination**: It is always the case that: if it is nomically necessary that $WILL_N(P)$ (where N is a positive real number and P is a proposition about the intrinsic state of the universe at a time) given the intrinsic state of the present and all facts of the form "$WAS_M(Q)$" (where M is a positive real number and Q is a proposition about the intrinsic state of the universe at a time), then it is nomically necessary that $WILL_N(P)$ given the intrinsic state of the present.

Given Nomic Presentism, **Markovian Determination** follows from a general principle about valid arguments. For any propositions P, Q, and R, if P necessitates Q, then if [(P and Q) necesitate R] then [P necessitates R]. In other words, Q can't necessitate anything beyond P if P already necessitates Q.

When we substitute "P" for the proposition that expresses the complete present intrinsic state of the universe and the laws of nature , "Q" for the conjunctive proposition that conjoins all facts of the form "$WAS_M(Q)$", and "R" for the proposition that $WILL_N(P)$, then this general schema gives us **Markovian Determination**. The crucial point to note is that all facts of the form $WAS_M(Q)$

[17] One obvious worry is that Nomic Presentism might commit one to the open future, and even the open past, if the laws are indeterministic. For a defense of this potentially counterintuitive consequence, see Markosian (1995, 2013).

are *already* necessitated by the present and the laws according to Nomic Presentism. So, such facts cannot possibly necessitate things that go beyond the present and the laws.

An exactly parallel argument applies to **Markovian Chance**. In the context of Presentism, **Markovian Chance** should be reformulated as follows. If we let "H_t" be the proposition that specifies both the present intrinsic state of the universe when *t* is present together will all facts of the form "$WAS_M(Q)$" (where M is a positive real number and Q is a proposition about the intrinsic state of the universe at a time), and T be the proposition that specifies the present intrinsic state of the universe when *t* is present, then we have:

> **Markovian Chance:** It is always the case that: the present chance that $WILL_N(P)$ (where N is a positive real number and P is a proposition about the intrinsic state of the universe at a time) given L is equal to the historical chance that $WILL_N(P)$ given L. In other words, $Ch_L(WILL_N(P) \mid T) = Ch_L(WILL_N(P) \mid H_t)$.

Again, the crucial point is that, given Nomic Presentism, T is nomically equivalent to H_t. In other words, T nomically necessitates H_t (by Nomic Presentism) and H_t nomically necessitates T (by definition). So, for *any* proposition P, $Ch_L(P \mid T) = Ch_L(P \mid H_t)$.

Intuitively, the reason why Nomic Presentism entails Markovianism is because it entails that facts about the past must always be implicit in the present. Nomic Presentists think that there are already strong independent reasons to think this, having to do with the truthmaker objection. It is a surprising and elegant consequence of this response to the truthmaker objection that it automatically secures a striking aspect of our laws of physics.

Before we move on, it's helpful to see how this strategy compares with the previous one. We began with the intuition that the reason why Presentism might help secure Markovianism is because the past cannot place causal constraints on the future that go beyond the present if the past does not exist. However, this intuition faced the worry that there might be *truths* about the past that place causal constraints on the future that go beyond the present. Our first response to this objection was that the causal constraints on the future must supervene on the whole of concrete reality. This strategy was independently motivated by an Aristotelian view of natural necessity, according to which the causal constraints on the future are grounded in facts about the powers and potentialities of concretely existing physical entities. Our second response to this objection was that, insofar as there are truths about the past, such truths must nomically supervene on (present) being. This strategy is independently motivated by the view that all truths must be grounded in being, and it secures Markovianism by making all truths about the past implicit in the present. In sum, our first strategy involves the weaker claim that the causal

constraints on the future must supervene on being, while our second strategy involves the stronger claim that *all* truths must supervene on being.[18]

5. Four Morals

We have argued that certain versions of Non-Humean Presentism entail Markovianism, and hence Markovianism*. We have also argued that there is no particular reason to believe that our universe should be Markovian* given both Humean and Non-Humean versions of Eternalism, and in the absence of any such reason, it seems to us that one should be far from certain that our world is Markovian* *a priori*. Consequently, we think that a straightforward empirical argument can be given for (certain versions of) Non-Humean Presentism.

The logic of this argument can be formalized in a Bayesian setting as follows. If we let "NHP" be the proposition that the relevant kind of Non-Humean Presentism is true, then we can formalize our central claim as follows:

(*) For any rational prior Cr, $Cr(\text{Markovianism*}|\ \sim\text{NHP}) << Cr(\text{Markovianism*}|\ \text{NHP}) = 1$.[19]

We have argued for the right hand side of this inequality by arguing that NHP entails Markovianism*, and we have argued for the left hand side of this inequality by going through various different versions of "~NHP" (e.g. Humean Eternalism, Non-Humean Eternalism, and alternative versions of Presentism) and arguing that none of these views gives us reason to expect that Markovianism* should be true. Lastly, we have also argued that we have strong empirical reasons for thinking the actual world satisfies Markovianism*. Applying standard Bayesian confirmation theory, we should substantially increase our confidence in NHP.[20]

We will close by discussing four morals of our overall argument.

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[18] It's an interesting question whether other versions of the "A-theory" of time, according to which the present is somehow metaphysically privileged, can help secure Markovianism. We think that standard versions of non-Presentist A-theories have trouble securing Markovianism. For example, standard versions of the Growing Block theory and the Moving Spotlight theory accept the existence of independently existing, concrete past entities, so they cannot help themselves to the two Presentist strategies that we have defended here. However, there might be some non-standard versions of these other A-theories that can help secure Markovianism. For example, Sullivan (2012) has defended a version of the Moving Spotlight theory where only present things are concrete, spatiotemporally located, and have causal powers. Such a view may be able to secure Markovianism using the strategy discussed in section 4.1.

[19] One way to resist (*) that entirely bypasses the metaphysical debate between Humeans and Non-Humeans is by way of *Subjective Bayesianism*, which is the claim that any probabilistically coherent prior is rationally permissible. So, for example, the Subjective Bayesian might claim that it is perfectly rational to set $Cr(\text{Markovianism*}|\ \sim\text{NHP}) = 1$, even if no reason can be given as to why Markovianism* should be plausible given ~NHP. For a recent critique of Subjective Bayesianism, see Huemer (2017).

[20] It is also worth noting that, in principle, this empirical argument cuts both ways. If one day physicists discover that our world is actually Non-Markovian, then we think this empirical discovery would falsify the relevant versions of Presentism. The fact that these versions of Presentism make precise falsifiable predictions is, we think, a virtue of these theories.

The first moral concerns Presentism. As we've already noted, perhaps the central objection to Presentism is an empirical one: insofar as Presentism requires absolute simultaneity, it seems to be in tension with relativistic physics. However, because we think that Markovianism* provides strong empirical evidence in favor of Presentism, we think the empirical case for/against Presentism is much less clear cut. In light of both of these competing empirical arguments, which should we think is stronger? Although we think that reasonable people can disagree about how to weigh these two arguments, we are inclined to favor the argument from Markovianism*. We have two main reasons for thinking this. First, it seems to us that the empirical case that our world is Markovian* is stronger than the empirical case for thinking that physics does not require a relation of absolute simultaneity. While there are both historical pre-relativistic theories and contemporary quantum theories that require absolute simultaneity,[21] *every* orthodox physical theory that has ever been seriously considered since Newton has been Markovian*. Second, it seems to us that Presentists have two reasonable responses in light of the challenge from relativity. First, although relativistic theories don't *require* absolute simultaneity, it is consistent to supplement these theories with a privileged relation of simultaneity (e.g. by way of a privileged inertial reference frame or a privileged foliation of space-time).[22] It is true that supplementing these theories with a privileged relation of simultaneity goes beyond what physics requires, but metaphysicians commonly take themselves to have good reasons to believe in all sorts of facts that go beyond what physics requires: various kinds of abstract objects, non-natural moral facts, fundamental properties or substances associated with consciousness, concrete possible worlds, etc.[23] Second, some philosophers have even developed versions of Presentism that don't require a relation of absolute simultaneity at all, sidestepping the objection from relativity altogether.[24] However, in the case of Markovianism*, we don't think it is a reasonable response to say that Markovianism* is just an unexplained coincidence. At least to us, the truth of Markovianism* seems far too simple, precise, and elegant a theoretical principle to think it is just a matter of luck that our universe happened to be Markovian*. We think the best way to resist the empirical argument from Markovianism* isn't to say that it is merely a coincidence, but rather to do the hard work of developing an alternative Eternalist account of why Markovianism* should be true. Insofar as the prospects of such an account seem dim, we are inclined to think that the balance of empirical considerations favors Presentism over Eternalism.

[21] For example, some interpretations of Quantum Mechanics (e.g. Bohmian Mechanics) require absolute simultaneity, and there are some speculative theories of Quantum Gravity that are formulated using absolute simultaneity as well (e.g. see Monton 2006).

[22] As we noted before, there are some physically unrealistic solutions to the equations of General Relativity that do not admit of any global foliation into times, but precisely because they are physically unrealistic, the Presentist can safely assume that they do not accurately describe the actual world.

[23] In the case of absolute simultaneity, Builes and Teitel (forthcoming) have argued that there are reasons for believing in a relation of absolute simultaneity that are entirely independent of one's views on temporal ontology.

[24] For examples of such theories, see Emery (forthcoming) and Balaguer (MS).

Our second moral concerns Non-Humeanism. Many Non-Humeans have argued that Humeanism is implausible on the grounds that it would be extraordinarily unlikely for the world to be regular if Humeanism were true. Here is how Strawson (2014) makes the point:

> According to [Humeanism], then, the regularity of the world's behaviour is, in a clear sense, a complete and continuous fluke. It is not just that we don't know whether or not there is any reason for it in the nature of things. According to [Humeanism], there is definitely no reason for it in the nature of things. It is … an objective fluke, in the simple sense that there is, objectively or in the nature of things, absolutely no reason at all why regularity rather than chaos occurs from moment to moment.[25] (23)

In probabilistic terms, we might understand this kind of argument as implicitly appealing to the following claim (where "Regular" is the proposition that the world is a regular place):

> (**) For any rational prior Cr, Cr(Regular | Humeanism) << Cr(Regular | Non-Humeanism).

If we combine (**) with the empirical discovery that our world is in fact a regular place, this would give us strong empirical evidence against Humeanism.[26] However, justifying (**) has proven difficult, and Humeans have remained unconvinced. One major difficulty is that it is far from clear how to understand the claim that our world is "regular" in a precise way. Another major difficulty is that, while it may be unclear why we should expect our world to be regular given Humeanism, it is also unclear why we should expect our world to be regular given Non-Humeanism. Why should we expect (say) that metaphysically fundamental laws of nature are simple and regular rather than complicated and irregular? The structurally similar empirical argument for (Presentist) Non-Humeanism that we have defended avoids both of these objections. First, it appeals to a perfectly precise datum about our universe, namely Markovianism*, and second, we have argued that certain versions of (Presentist) Non-Humeanism predict this datum with *certainty*. We therefore hope to have strengthened the overall case for Non-Humeanism, independently of any of our conclusions about the metaphysics of time.

Our third moral concerns the connection between Presentism and Non-Humeanism. In practice, these views tend to be discussed and defended independently of one another. Moreover, opinions greatly differ about their relative plausibility: Non-Humeanism seems to be a much more popular

[25] It is also worth noting that, as a historical matter, Strawson (2014) argues that David Hume himself rejected "Humeanism".

[26] For different discussions of this kind of schematic argument, see Foster (1982), Tooley (2011), Hildebrand (2013), Filomeno (2019), Bhogal (2021), Builes (2021), and Hildebrand and Metcalf (2021).

position than Presentism.[27] However, there is intuitively a close connection between them: both views imply that our world is in some sense a "dynamic" place. Roughly speaking, Non-Humeanism implies that the material world "inside" time is dynamic, whereas Presentism implies that time itself is dynamic.[28] We hope to have provided some more concrete reasons for thinking that Non-Humeanism and Presentism are at their most plausible when defended together.

Our fourth and last moral concerns the meta-metaphysical dispute about whether debates over temporal ontology are substantive in the first place. Some philosophers have argued that such debates are merely verbal, and others have argued that there is no fact of the matter about the correct temporal ontology of the universe. Views of this kind have been defended in different ways by Callender (2000), Meyer (2005), Dorato (2006) Savitt (2006), Norton (2015), and Balaguer (2016).[29] However, if different views in temporal ontology make different empirical predictions (e.g. if certain versions of Presentism predict that Markovianism must be true while other views in temporal ontology do not), then it seems to us that even the most hardcore logical positivist should think that debates over temporal ontology are substantive.[30,31]

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[27] According to the most recent PhilPapers Survey by Bourget and Chalmers (MS), ~54% of philosophers lean towards Non-Humean approaches towards the laws of nature, while only ~27% of philosophers lean towards different versions of the "A-theory" of time.

[28] It should be noted, however, that Non-Humean views have also been developed in a "non-dynamic" setting (e.g. see Chen and Goldstein (2022) and Adlam (2022)).

[29] Balaguer (2016) actually argues that *either* debates in temporal ontology are not substantive or debates in temporal ontology are "physical-empirical" debates. The arguments in this paper support the latter claim.

[30] For other defenses of the view that debates in temporal ontology are substantive, see Sider (2006) and Builes (2019, 2022).

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