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Calling for Explanation: The Case of the Thermodynamic Past State

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Abstract: Philosophers of physics have long debated whether the Past State of low entropy of our universe calls for explanation. What is meant by "calls for explanation"? In this article we analyze this notion, distinguishing between several possible meanings that may be attached to it. Taking the debate around the Past State as a case study, we show how our analysis of what "calling for explanation" might mean can contribute to clarifying the debate and perhaps to settling it, thus demonstrating the fruitfulness of this analysis. Applying our analysis, we show that two main opponents in this debate, Huw Price and Craig Callender, are, for the most part, talking past each other rather than disagreeing, as they employ different notions of "calling for explanation", and then proceed to show how answering the different questions that arise out of the different meanings of "calling for explanation" can result in clarifying the problems at hand and thus, hopefully, to solving them.

Keywords: Past Hypothesis; Calling for Explanation; Craig Callender; Huw Price

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1 Introduction

What facts call for explanation? While the notion of explanation itself has been studied for many years and is still a central topic of interest and research (Woodward 2014), the question of which facts call for explanation and what it means for facts to call for explanation—whatever we take "explanation" to mean—has been studied less (Baras 2019; Baras, *unpublished*; White 2005). In this paper we address this question, but instead of exploring in the abstract which facts call for explanation and what that implies, we study a case where this point is under debate. This case study will also illustrate how clarifying what calls for explanation in a particular case can help disentangle philosophical as well as scientific debates, thus contributing to making progress in them.

The debate we shall address concerns a question at the foundations of statistical mechanics: is the so-called "Past State" posited in the so-called "Past Hypothesis" (both presented in the next section) in need of explanation? Two of the main proponents of each side of the debate, Huw Price and Craig Callender, have conveniently presented their views on the question of whether the Past State calls for explanation in a pair of papers (Price 2002; Callender 2004a) and repeat their arguments in a second pair of papers (Price 2004; Callender 2004b), and we will focus on the Price–Callender debate as our case study. One of the interesting outcomes of our analysis will be that Price and Callender are merely talking past each other rather than disagreeing.[1]

We shall illustrate the fruitfulness of our analysis of "calling for explanation" by showing that the disambiguation can help us make progress in understanding whether the Past Hypothesis

[1] We present our reading of Price and Callender's arguments. As is often the case, there may be other ways to understand them; we shall not discuss those, nor defend our reading, mainly since we take this debate as a case study for discussing more generally what calls for explanation.

calls for explanation, and consequently how one should proceed in studying and explaining this hypothesis, thus contributing towards providing tools for future work on the Past Hypothesis. By doing so we in no way imply that this exchange and our analysis of its nature and implications exhaust the entire discussion of the Past Hypothesis: we take from this debate only certain aspects that best serve our purpose of illustrating the notion of "calling for explanation" and the fruitfulness of clarifying it.

As we show, the term "calls for explanation" and similar expressions are used to express distinct claims. While we carry out our analysis using the Price–Callender debate, we emphasize that the different meanings of "calls for explanation" identified here are applicable to other contexts as well.

In Section 2 we present the Past Hypothesis; Section 3 disambiguates the notion of "calls for explanation"; In section 4 we analyze the claims made by Price and Callender applying the distinctions of the previous section; and in section 5 we demonstrate how the lessons of this paper will help us make progress in determining whether indeed the Past Hypothesis calls for explanation.

2 The putative subject of explanation: The Past State

The second law of thermodynamics says that the entropy of isolated systems cannot decrease towards the future. This law describes and generalizes regularities that are found in experience, and arguably the most important aspect of these regularities is that they are time a-symmetrical: the second law describes phenomena that are different towards the past than towards the future. Because of this nature of the phenomena described by the second law, it is taken to be one of the most important arrows of time. This law enjoys immense empirical support, so much so that many people concur with Einstein's famous saying that thermodynamics "is the only theory of universal content concerning which I am convinced that, within the framework of the applicability of its basic concepts, it will never be overthrown." (Einstein 1970, p.33).

At the same time it is agreed that the second law (as well as other laws of thermodynamics) is *non-fundamental*, in the following sense: since the matter, that behaves according to the laws of thermodynamics, fundamentally consists of the particles described by the fundamental theories of physics (e.g., the standard model and quantum mechanics[2]), it is usually assumed (or at least hoped) that the regularities described in the second law can be derived as *theorems* of the principles of fundamental physics (or at least to be shown as *compatible* with them); this is the project of Statistical Mechanics.[3] In this sense Statistical Mechanics is sometimes seen as a "high level theory" or, as Einstein (1919) preferred to call it, a "constructive theory" (where thermodynamics is the corresponding phenomenal "principle theory").

One of the main problems facing the attempts in Statistical Mechanics to derive a theorem that would explain and be the mechanical counterpart of the second law of thermodynamics is that

[2] Often, and here too, the discussion focuses on *classical* statistical mechanics (see e.g. Uffink 2007, Frigg 2008). We agree with Wallace 2001 and Ladyman and Ross 2007 that, since in contemporary science classical mechanics is considered strictly speaking false, the success of classical statistical mechanics should be explained by its preserving certain explanatory and predictive aspects of the contemporary theories.

[3] Introductions to the foundations of statistical mechanics, with an emphasis on philosophical problems, including an account of the Past Hypothesis, are Albert (2000), Hemmo and Shenker (2012), Shenker (2017a,b).

the fundamental theories of physics are time-symmetric.[4] Since it is a point of logic that time-asymmetric conclusions cannot be validly derived from time-symmetric assumptions (van Fraassen 1989), the second law of thermodynamics (even in probabilistic versions) cannot be a theorem of fundamental physics *alone*. To derive the second law, the fundamental theories of physics need to be supplemented with *auxiliary hypotheses*, the nature of which is under debate in contemporary literature (Shenker 2017b; Shenker 2017a).

The debate concerning the auxiliary hypotheses is about two issues: one concerns the *prediction* of entropy changes beginning at any given point of time, that is: whether it can be proven that entropy *increases* as described by the second law; and the other concerns the *retrodiction* of entropy changes beginning (and going backwards from) any point of time, that is: whether it can be proven that entropy *decreases* towards the *past* as described by the second law. It turns out that in statistical mechanics those are distinct issues, that involve different kinds of arguments.

The first debate is briefly this. According to the well-known "reversibility objection" (originally by Loschmidt; see Frigg 2008), to each entropy increasing trajectory segment in the state space, that starts at some given initial microstate and ends in the appropriate final microstate according to the equation of motion, there corresponds a "reversed" trajectory segment that starts at the microstate with same position as the final microstate but with reverse velocities, and leads to entropy decrease; and therefore *prima facie* a system is as likely to undergo entropy decrease as

[4] Examples include: (a) classical mechanics; (b) the classical theory of electromagnetism (see Allori 2015); (c) the Schrödinger equation of non-relativistic quantum mechanics without collapse (On whether quantum-mechanical collapse, in the GRW version, can be the origin of thermodynamic time-asymmetry, see Albert (2000) and the criticism in Hemmo and Shenker 2001; 2003; 2005). Regarding the status of the T-asymmetry in the context of the CPT theorem, see Atkinson 2006.

entropy increase.[5] Statistical mechanics attempts to solve this problem by noticing that the initial microstate is a member of a *macrostate*, in which most of the microstates are entropy increasing, and thus, at the macroscopic level, entropy is overwhelmingly highly likely to increase towards the future. This result is based, however, on certain non-trivial auxiliary hypotheses, concerning the dynamics (this is part of the debate around Maxwell's Demon[6]), and the choice of measure by which probability is calculated (this is part of the debate around the so-called typicality approach[7]), both of which are needed in order to prove from mechanics a probabilistic counterpart of the empirically verified second law of thermodynamics. (For an overview of the standard views concerning the solutions of these problems see Frigg 2008.)

The second debate is about the auxiliary hypothesis called the Past Hypothesis, and part of this debate is the case study we use in this paper to illustrate the question of "what calls for explanation". The nature, status and significance of the Past Hypothesis is the subject matter of an ongoing debate in the foundations of physics (Wallace 2017; Frisch 2010; Earman 2006; Loewer 2012; Hemmo and Shenker 2019 and forthcoming.), and in this paper we do not cover all the topics and ideas involved in this debate. Rather, as we said above, since we are interested in using it as our case study of "what calls for explanation", we only focus on the debate on the Past Hypothesis in certain papers by Price (2002; 2004) and Callender (2004a; 2004b). We now provide some background for this particular debate.

[5] We do not discuss here the Poincare recurrence theorem, see Uffink 2007 and Frigg 2008.

[6] See Hemmo and Shenker (2010; 2012; 2016).

[7] See description in Hemmo and Shenker (2015); we return to this debate below.

The Past Hypothesis is an auxiliary hypothesis posited to solve a problem that arises due to the following well-known theorem in classical statistical mechanics.[8] Suppose (as many believe is the case!) that the first above-mentioned difficulties are solved, so that there is *proof*, from the principles of fundamental physics together with some auxiliary hypotheses concerning dynamics and measure, that the entropy of typical systems in typical conditions are extremely highly likely to *increase towards the future*. Specifically, consider a proof that a system S that starts out at time t1 in a microstate that is within some macrostate M is overwhelmingly likely to evolve such that its entropy at a later time t2 will be higher, so that the entropy difference during the time interval t2–t1 is highly likely to be the positive **Δ**E. Then, it follows, *as a corollary to the above proof*, that as we follow the system from t1 backwards in time until t0 (where t2-t1=t1-t0), *retrodicting* its past states, it turns out that it is *as highly likely* that the entropy increases towards the past, so that the entropy difference during the time interval t1–t0 is highly likely to be the negative -**Δ**E. In other words, the corollary is that it is highly likely that the entropy at t1 is at a minimum, with the entropies in both its future (at t2) and past (at t0) are equally likely to be equally higher; therefore we call it "the minimum-entropy theorem".[9] (See further details and implications in Uffink and Valente 2010, 2015.)

One problem that the minimum-entropy theorem raises is that entropy increase towards the past is incompatible with our memories and other records, expressed and generalized by the second

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[8] A similar theorem holds in quantum statistical mechanics if the underlying dynamics is understood to be time-reversal invariant. In this paper we focus on classical mechanics due to the context of the arguments that we address.

[9] Others call it "the parity-of-reasoning problem" or "the reversibility objection", as in Frisch (2010) and Loewer (2012), or "the initial state problem", as in Earman (2006, 401).

law of thermodynamics. Since these records form the confirmatory basis of the theories of physics, which in turn entail this minimum-entropy theorem, the theorem gives rise to a "skeptical catastrophe" (as Albert (2000) called it).[10] To solve this problem, Feynman (1967, 116) proposed that "it [is] necessary to add to the physical laws the hypothesis that in the past the universe was more ordered, in the technical sense, than it is today." It is this hypothesis (to which other writers added some more details, that we do not address here,) that we call "*the Past Hypothesis*" and the state that it posits we call "*the Past State".*[11]

This Past Hypothesis raises a puzzlement (at least prima facie), which will be our focus in studying "what calls for explanation". In *standard* statistical mechanics (in the Boltzmannian tradition[12]) *entropy* is associated with the Lebesgue measure of the macrostate of interest: the entropy of a microstate would be the Lebesgue measure of the macrostate to which it belongs. At

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[10] Another problem, also solved by the Past Hypothesis, is that the sample space (that is, the set of elementary possible events, which is part of the probability space in the standard probability theory following Kolmogorov (1950)) is not sufficiently well-defined, since microstates that are compatible with the macrostate at one moment are deemed strictly impossible (and not only having zero probability) at another moment (but see Wallace (forthcoming) for a different understanding).

[11] A more recent and influential version of this idea is by Albert (2000, 96), who coined the term "Past Hypothesis". For various versions and critical discussions of Feynman's and Albert's hypotheses, see Sklar (1973); Price (1997); Loewer (2001; 2012); Callender (2010); Wallace (2017); Hemmo and Shenker (2012); Earman (2006); Goldstein, Tumulka and Zanghi (2016). Albert's Past State - according to his Past Hypothesis - is not only of low entropy, but must contain details that explain the particular macroscopic states of affairs throughout the evolution of the universe, thus supporting his notion of "records" and their reliability.

[12] For the Gibbsian tradition see Frigg (2008). We don't address this view here, in which the problems that arise are different.

the same time, in some prevalent understandings of the foundations of statistical mechanics (e.g. Albert 2000), the *probability* of finding a system in a given macrostate (that is, in a microstate that belongs to a given macrostate) is *also* associated with the Lebesgue measure of that macrostate.[13] The fact that the same measure is used for probability and for entropy leads to the following problem: the Past Hypothesis is the conjecture that the universe was (initially, or in the remote past,) in a state of extremely *low entropy*, that is, in a *highly improbable* state. To wit, among the various ways in which the universe *could* have started out (as far as physics is concerned), the *actual* way it came to be was a highly *improbable* one.

Is the Past Hypothesis, thus construed, puzzling? Does the claim that the universe started out in the Past State, which is an extremely improbable kind of state, call out for explanation? What does it mean for the Past Hypothesis, and the Past State in it, to call for explanation? What are the possible ramifications if they do?

In the general debates concerning the Past Hypothesis, these questions come up, sometimes more implicitly and other times more explicitly. Price (2002,2004) and Callender (2004a, 2004b) address this topic explicitly, providing important details for using the Past State as a case study for the question of "what calls for explanation". We describe the Price–Callender debate in Section 4. In preparation, we distinguish in Section 3 between several different senses of "calling for explanation".

[13] For the difference between the *concepts* of entropy and information and their respective measures see Hemmo and Shenker 2012, chaps. 6–7, and Shenker 2019.

3 What does "E calls for explanation" mean?

When one claims that some purported fact or state of affairs "calls for explanation", what precisely is this metaphor used to express? In this section, we distinguish between several types of claims that may be intended by such statements. How these can be applied to the Past State will be illustrated in sections 4 and 5.

Let us begin with some clarificatory notes. First, these questions are distinct from the better-known question of what constitutes an explanation. We remain neutral on this controversial issue.

Second, sometimes the term "explanation" is used as a success term, meaning that if h explains e, h must be true. In this paper, we are often interested in hypothetical claims of the sort: <If *h* were true, then it would explain *e*>. Hence when we use the term "explanation" it is a shorthand for a potential explanation which may or may not be a true proposition.

Third, there is a meaning of "calls for explanation" that we wish to set aside. Sometimes when one states that a fact calls for explanation, all that is being implied is that one finds the given fact surprising or especially interesting, and would very much like to know what its explanation is, if it has one. This affective sense of "calls for explanation" is not what philosophers argue about when they argue whether some fact calls for explanation. Therefore, the affective sense of "calls for explanation" is not among the meanings that we focus on in this paper.

With these clarifications in mind, let us return to our question. Suppose we have some potential explanandum E about which people are arguing whether or not it calls for explanation. What can they mean by E calling for explanation? Let us look at three options (there may be more, but we focus on these because they are relevant to the Past State debate).

The options we explore are the following:

> (I) We currently lack an explanation of E.
>
> (II) It is possible to explain E.
>
> (III) We have reason to disbelieve theories that imply that E is without any explanation.

We now elaborate on each of these meanings.

(I) Sometimes when E is said to call for explanation, what is meant is primarily that we currently lack an explanation for it. Typically, the context is one in which we would like to have one, for one reason or another. Explanations plausibly come in different degrees and kinds. Therefore, sometimes what may be meant is not that we don't have any explanation for E, but rather that we lack a fuller explanation or a specific kind of explanation for E.

Whether *we* possess or lack an explanation is relative to a set of assumptions and epistemic circumstances. There is more than one possible reason why we can lack an explanation. Suppose we have a set of background assumptions A. A is a set of propositions that serve as the background theory under which E is being examined by a given subject S at a given moment t. Assumptions need not be true, nor must they be believed.[14]

[14] For instance, A might include the Darwinian theory of evolution and S might work as a biologist but actually disbelieve this theory due to private religious beliefs of his. Yet, when S states during his lab work that some phenomenon calls for explanation, S means that that phenomenon is unexplained if the theory of evolution is assumed.

Case (Ia): A does explain E, but S has *thus far* (that is, up to time t) failed to discover how. In this case, E may call for explanation (given A) at time t1, but not at time t2; or for subject S1, but not for subject S2.

Whether or not E has an explanation given A, and thus whether or not E calls for explanation in sense (Ia), can be a matter of controversy, in virtue of a controversy about whether some purported explanation really counts as an explanation for E. As an illustration, consider our case study of the Past State. It is sometimes claimed that (a) *most* of the microstates (relative to the Lebesgue measure) within the Past State macrostate are such that, when they evolve according to the mechanical equations of motion, they give rise to a world in which the second law of thermodynamics obtains; such microstates are said to be *typical* within the Past State; and (b) this typicality explains the fact that the second law obtains in our universe. Suppose that the background assumptions A, (endorsed by person S at time t), concerning the conditions that prevailed in the early universe as well as the way in which 'typicality' is to be determined, *are* or *imply* (a). Even given this supposition, there is a controversy concerning (b). Some writers think that typicality explains the thermodynamic nature of the universe; others think it does not. Among the former is Dürr (2001, p. 131), who emphasizes that the typicality itself explains the actual matters of fact; among the latter are Pitowsky (2012) and Hemmo and Shenker (2015) who emphasize that typicality is explanatorily relevant only to the extent that it amounts to probability.[15]

[15] These writers differ also on the way to determine whether a state is typical or not, that is, whether or not (a) obtains: Dürr (2001) and Goldstein (2012) think that the typicality of the initial conditions of the universe (or of a sufficiently isolated subsystem thereof) must be determined according to the Lebesgue measure of sets of microstates, justifying the use of the Lebesgue measure either on some a-priori grounds

Case (Ib): A is *insufficient* to explain E; Perhaps there is some further assumption A1 such that A∪A1 would be sufficient to explain E but A1 is unknown or unavailable to S at the moment. That A in itself doesn't explain E is not a temporary matter of fact, nor one that depends upon S's capabilities or state of knowledge at some given moment. Rather, it is a fact concerning the relation between A and E themselves: whatever "explanation" might be, A is not (or cannot give rise to) an explanation of E—for all times and for all persons.

Case (Ic): A implies that E has no explanation. This can happen, for instance, if A includes the assumption <E is an explanatorily fundamental fact>. It would then not only be the case that, assuming A, we have no explanation for E and never will have one, but rather, that assuming A there *can't* be an explanation for E. This leads us to the next, modal meaning of calling for explanation.

We provide further illustrations for cases (Ia–c) in the next sections.

Suppose we conclude that E *has* no explanation, given A. In this case a further question arises. Is it *possible* to explain E? This is where the second meaning of "E calls for explanation" comes in.

A second meaning of "E calls for explanation" is:

(II) It is possible to explain E.

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or by its roles in some theorems in mechanics; while Hemmo and Shenker (2015) show that these roles are irrelevant for the use of the Lebesgue measure to determine typicality, as well as probability in our context. A similar debate arises in the context of Bohmian Mechanics, see Hemmo and Shenker 2015.

Typically, we would say that E calls for explanation in this sense if it is the case that we not only *want* E to be explained, but we also think that attempts to find such an explanation may be *successful*. We distinguish between three types of such modal claims.

(IIa) The first type of claim involves a metaphysical modality. As before, whether E *can* be explained is relative to a set of assumptions. The claim that it is possible to explain E amounts to the claim that, given a set of assumptions A, it is possible (metaphysically, or conceptually) that E has an explanation. In this sense, to deny that E calls for explanation amounts to the claim that A entails that E has no explanation (case (Ic) above).

(IIb) The second type of claim is about our epistemic prospects. If it is possible for E to have an explanation, we may wonder whether it is possible for *us* to ever learn, or at least gain some justification for believing, some particular explanation for E. Sometimes, when we claim that E calls for explanation, part of what is being claimed is that it is epistemically possible for us to learn in the future (or gain some justification for a belief about) what the explanation for E is. It may be that even if E has an explanation, we have no way of learning what it might be, due to our epistemic limitations. Whereas (IIa) was about the relationship between E and A, (IIb) is more focused on the person S who is trying to explain E.

(IIc) The third type of claim is practical. Although it is not, strictly speaking, a disambiguation of (II), it is another claim in the vicinity that is sometimes mixed up with the previous two types of claims. If E is such that we currently lack an explanation for it (given A), and it is such that it might have an explanation and that the explanation may be discoverable, a further question to ask is the practical one, namely, whether it is worth our while to try and discover it. Some facts may be too trivial (or to lack any importance for any of our purposes) to deserve allocating resources to investigate them. Let us call this sense of "calls for explanation" the *practical sense*.

We provide examples for (II) below, based on our case study.

A third meaning of "calling for explanation" is:

(III) We have reason to disbelieve theories that imply that E is without any explanation.

Since we believe that this is the main sense of calling for explanation that Callender (2004a, 2004b) has in mind, and since this sense is a bit less straightforward than the previous ones, let us present it by generalizing intuitions about a paradigmatic example.

Suppose a seemingly ordinary coin is tossed many times and lands consistently in the alternating sequence HTHTHTHTHT… (H=heads; T=tails). If we initially assumed that the coin was an ordinary one and that the tosses were independent of one another, we would intuitively feel not only surprised but possibly uncomfortable. The intuition is that something is wrong about our assumptions. We should therefore revise our assumptions and believe that the tosses are dependent and that for each toss there is some mechanism or human manipulation that makes the coin land on the opposite side of the previous toss. This is what we should do if we were fully confident that the event occured, that is, that indeed a coin was tossed and landed in this sequence. If, however, we were less confident, for example if rather than seeing the coin being tossed an acquaintance told us about this coin, it might make more sense to just disbelieve the acquaintance that the event occured.

How might we generalize the example? A popular suggestion is that there is a property that some facts have, sometimes referred to as *strikingness*, that gives us reason to expect them to have an explanation (perhaps a special kind of explanation).[16] In our example, suppose that the fact that the coin landed in the alternating sequence (call this fact E) is *striking*; and call our assumptions (that the coin tosses are fair and independent) A. In this example, given the background assumptions A it seems that fact E has no explanation (or at least not an explanation of the right kind). Statement (III) above is that this situation is *unacceptable*, and therefore we must change it in one of two ways: either we disbelieve A, or we disbelieve E. Concluding that the tosses are dependent would be an example of rejecting the background assumptions A (and accepting an alternative set of assumptions A′, e.g. the tosses are dependent, that does not imply that E has no explanation). Rejecting the unexplained statement E could amount, in this case, to holding that the sequence—the purported explanandum—never occurred. For example, if a friend told you about the coin, you have a good reason to doubt that the friend was telling the truth. Let us call this sense of "calls for explanation" the *epistemic sense* since it implies that there are reasons for belief or disbelief.

[16] In other contexts, this idea is used to support far-reaching conclusions: that our universe was intelligently designed (van Inwagen 1993; White 2018; Manson 1998), that there are many universes other than the one we inhabit (Leslie 1989; Parfit 1998), that our universe is teleological in some non-theistic way (Mulgan 2015; Nagel 2012), that there are no mathematical (Field 1989) or normative mind-independent facts (Street 2008) and even that our knowledge of first-order logic is faulty (Schechter 2010; 2018).
There is a theoretical question here whether the claim is just that E must have an explanation, or a stronger claim, that E must have a particular kind of explanation. For the purposes of this article, the distinction won't come into play because the debate has thus far focused on the weaker claim, that we should expect the past state to have an explanation at all. This usage of "calling for explanation" will be explored in depth in a book that Dan Baras is in the process of writing. For preliminary discussion, see Baras (2019) and Baras (2020).

We have described in total five meanings of “calls for explanation”. In the next two sections we will see how these apply to the Past State.

4 In what sense might the Past State call or not call for explanation?

With these distinctions in hand, we can approach the past-hypothesis debate and see in what sense the disputants claim that the Past State does or does not call for explanation. As we said, our case study will focus on the published debate between Price and Callender. We stress once more that it is not our goal to interpret Price and Callender’s particular arguments *per se*. As is often the case, their precise views may be interpreted in more than one way, and we present here one possible such interpretation, having in mind our main goal, which is using their exchange as a means to learn about calling for explanation.

When Price started advocating the view that the Past State calls for explanation, in his 1997 book, *Time’s Arrow and Archimedes’ Point* (pp. 22–48), his main claim seems to have been that the Past State calls for explanation in the first sense (I), that is, that at the time he wrote his book we simply lacked an explanation for it. His claim is contrastive, as he sums it up at the end of the book: “What needs to be explained is the low-entropy past, not the high-entropy future” (p. 262). The fact that entropy was low in the past is what we lack an explanation for, whereas the fact that entropy has been increasing ever since is (assumed to be) well-explained by statistical mechanics. Callender, in his 2004 papers, does not deny that as things stood at the time he wrote these papers the Past State was unexplained. Thus, if there is anything that is being debated, it is *not* that the Past State calls for explanation in sense (I).

Consider now the following quote from Price’s later article:

> Would it really be plausible to suggest that physicists should sit on their hands and not even *try* to explain it?... [T]he issue is whether it is appropriate to try. (Price 2002, 115)[17]

The claim presented here is a practical one: It is worthwhile for physicists to try and come up with an explanation of the Past State. The claim is that they should devote their time and other resources to this project.[18] In our list above, it is of type IIc. As such, it only makes sense if you first assume that we don't currently have an explanation for the Past State (I), that it is possible for this state to have an explanation (IIa), and that it is possible for us to discover the explanation (IIb). Price, at least in this quote, seems to think that it is this practical claim that is being disputed by his opponents.

Is that correct? Consider the following quote from Callender, one of Price's main disputants. In this quote Callender turns to compare the case of the Past Hypothesis with a case concerning the so-called "*standard model*" in particle physics. We do not need to go into the details of this field of physics and of its standard model, and for our purposes suffice is to follow Callender in bringing into our discussion this case and noticing the similarities which he thinks are important. As Callender describes, some physicists feel that certain elements of the "standard model" are ad-hoc, and there is an ongoing debate on whether these elements should be endorsed as "brute facts" or whether they call for explanation. Callender asks:

> [I]s *everything* to be explained? Will all models of the universe be deficient until physics answers why there is something rather than nothing? Surely that is too strong an

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[17] Price (2004, 230) repeats this claim using similar wording.

[18] Note that this was probably what Price intended to imply in the 1997 book as well, though he isn't explicit there. Otherwise, what is the point of his argument that the Past State is currently unexplained?

> explanatory demand to impose on physics. Again [as with the Past Hypothesis; DB&OS] it seems to me that it's perfectly within the rights of the physicist to find something ugly about the standard model and want to devise an alternative without so many knobs. When that alternative exists and is shown to be empirically adequate, we can then compare the two. It may well be that it is superior in various empirical (one would hope) and theoretical ways... Similarly, knowing beforehand that the Past Hypothesis needs explanation seems too strong. (Callender 2004b, 248)

While Callender clearly claims that we don't know in advance whether the Past Hypothesis has an explanation, he concedes that it is possible that physicists will be able to either come up with such an explanation, or devise a better theory without the Past Hypothesis. That means that he believes that it is possible that the Past State has an explanation (IIa) and that it is possible that we will discover the explanation (IIb). He doesn't go here as far as to say that it is a worthwhile project to try and discover this explanation (IIc). However, once he made the other two concessions, it is difficult to reject the claim that it is worth the effort.

And so, the question arises: when Callender argues that the Past State *doesn't* call for explanation, what precisely is he claiming? In light of the above, what he must be disputing is that the Past State calls for explanation in sense III, the epistemic sense.[19]

Consider the following quote, in which Callender summarizes his conclusion:

> I urge the view that it is not always a serious mark against a theory that it must posit an 'improbable' initial condition [e.g. the Past State]. (Callender 2004a, 195)

[19] Craig Callender confirmed our interpretation in personal correspondence. We thank him for that.

The quote suggests that indeed his claim is that the Past State *doesn't* call for explanation in sense III. Callender's imagined interlocutor believes that it counts against a theory if it includes the Past Hypothesis and implies that the Past State is a brute fact. The interesting thing is that, although Callender's articles are presented as responding to Price, Price, to the best of our knowledge, nowhere endorses the view that Callender is arguing against. Callender's claim is that the Past State *doesn't* give us reason to reject theories that leave it unexplained. He also clearly thinks that improbability is not a sufficient condition for something to call for explanation in this sense. At times he seems to be making a stronger claim, that boundary conditions never call for explanation (in sense III). At other times he makes an even stronger claim, that nothing calls for explanation (in sense III). We discuss some of his arguments in the next section.

Let us now consider what we've learned by getting clearer about what it means for something to call for explanation. We've learned that Price and Callender, who seem to be arguing about whether the Past State calls for explanation, may be talking past each other. Price argues that the Past State calls for explanation in senses I and II(a–c). Callender accepts these claims, but argues that the Past State doesn't call for explanation in sense III. Price, as far as we can tell, never claimed that it does call for explanation in this sense.

This is not the only case in which writers talk past each other; and so, noticing this fact is not our main point here. Our main task is to disambiguate the notion of "calling for explanation", and the discovery of the nature of this exchange is the first outcome of this project. The second—and more important—outcome is that it may help to make progress in the debate around the Past Hypothesis, as we illustrate in the next section.

5 So, does the Past State call for explanation?

By now it is clear that in order to answer the question of whether the Past State calls for explanation, we must ask ourselves what sense of "calling for explanation" do we mean. We have distinguished five different senses in which the Past State may call for explanation, and we shall now examine each in turn, describing briefly how the Past State is, or can be, addressed in its light. This account is not meant to be exhaustive: we bring only examples that illustrate how the disambiguation presented in this article, concerning the notion of "calling for explanation", can help us resolve debates concerning the Past State, thus demonstrating how it can be applied in other cases as well.

a. Do we currently possess an explanation for the Past State? (I)

Usually, the Past State is taken to be a fundamental postulate in statistical mechanics (Feynman 1965, Albert 2000).[20] As usually thought of, statistical mechanics comprises of mechanics (classical or quantum) together with some auxiliary hypotheses, one of which is the Past State hypothesis, and in this theoretical context, this hypothesis cannot be explained from within the theory in a non-circular way (Shenker 2017a,b). In section 3 we presented Case (Ib) in which E is not explained by the set of assumptions A because A is insufficient to explain E; and this is the case here: mechanics by itself is *insufficient* to explain the Past State, and so the Past State must be added to it, as an auxiliary hypothesis.

[20] Hemmo and Shenker 2019 argue that it is not fundamental but derivative, but not from mechanics by itself, but from some contingent facts concerning the physical basis of our mental states. We do not address this idea here, and we focus on the standard understanding of the status of the Past Hypothesis.

However, we also noted, in presenting Case (Ia), that it may be that E is not explained, at the time of interest, by the set of assumptions A because *at that time* S doesn't know how to construct the explanation of E based on A. This type of case is useful to understand the state of the art, if the set of assumptions A is adjusted as follows. Physics is a collection of theories (with complex relations between them), and one may attempt to explain the Past Hypothesis by embedding statistical mechanics within a broader theory, or adding another theory to it (we are not committed to any theoretical structure here). The key is to identify which parts of physics comprise the relevant set of assumptions A, and then to construct the explanation of E on their basis.

An example is the proposal of Carroll and Chen (2004) and Carroll (2010). These writers offer a conjecture about the structure and dynamics of the universe in the framework of general relativity theory, according to which the ontology is one of a multiverse, in which fluctuations give rise to "baby universes". The initial state of the parent universe is of *high* entropy, and the details of the proposed model entail that it is *likely* that a baby universe that starts off in a *low* entropy state will be generated. While without this model the Past State seems to be unlikely, within this model it becomes likely and, arguably, thereby explained. In this sense, whereas A (i.e. mechanics) does not explain E (i.e. the Past Hypothesis), an extended set of assumptions $A \cup A1$ (including general relativity and some specific assumptions) may explain it (see critical discussion in Winsberg 2012).

Do we have good reason to believe that Carroll's conjecture is correct? That is a different question. We will return to it shortly.

b. Is it possible that the Past State has an explanation? (IIa)

The fact that some explanations for the Past State have been suggested, such as Carroll and Chen's proposal mentioned above, is a reason to believe that, whether or not their explanation is correct, it is at least *possible* that some explanation of the Past State exists. Is there, then, any reason to believe that the Past State *cannot* have an explanation? Callender (2004a, 198) mentions the following argument which, if sound, would establish the impossibility of explaining the Past State: If (1) an explanation of a state (in the above sense) must contain an *earlier* state, and if (2) the Past State is an *initial* state of the universe, meaning that there was no earlier state, then the Past State cannot have an explanation. Callender does not believe this argument is sound because he rejects premise (1).

Explanations that turn to earlier states are usually causal explanations. There is a variety of notions of causation,[21] and one of the conditions often mentioned as being part of a causal relation is that of temporal order: the cause is supposed to precede the effect (see Frisch 2014). Having in mind this kind of explanation may underlie premise (1). Notice, however, that not all causal explanations assume this temporal structure. (For example, see Faye (2018) on backwards causation, and Menzies (2017) on counterfactual theories of causation). Considerations that emphasize a temporally symmetrical structure of the universe may militate against this line of thinking. Indeed, the very idea that the Past State is *initial* (or in the past) rather than *final* (or in the future) already assumes a temporal asymmetry. Callender, following Price's (1997) lead,

[21] There is also a debate on whether there are causal relations in the world at all, according to science (especially physics), and if so, what are they. See for example Russell (1913), Norton (2007, 2009), Cartwright (1983, 2004), Ben Menahem (2018).

objects to the second premise of the argument on the grounds that it makes the concept of explanation time-asymmetrical, and, given that our best theories of physics are time-symmetrical, we should not require our explanations to have such a time asymmetric property. Such time asymmetries exemplify what Price has called a *temporal double standard*.

While Callender rejects the previous argument, he seems to accept a modified time-symmetric version of it. According to this version, the Past State is a *boundary* state of the universe, rather than an initial state, and then he proceeds to say that boundary states cannot have explanations. Why can't a boundary state have an explanation? According to one standard thought on this matter the maximum that can be said is this. Mechanics is based on differential equations which require some so-called "initial conditions" in order to yield solutions, but the term "initial" here should not be misleading: *any* condition that is compatible with whatever empirical knowledge we have concerning the state of affairs that prevailed at *some* (*any*) point of time are acceptable.[22] The requirement of empirical adequacy with whatever we know the facts to be at a given point of time is the maximum that can go into the "initial" conditions, since they provide the fullest explanation that the theory of mechanics can provide. Whether or not this constraint amounts to "explaining" those initial conditions is a point we leave open. Moreover: as we shall discuss shortly, the notion of boundary conditions may be expanded if the universe is described using other theories, e.g. within cosmological models such as those by Carroll and Chen (2004) and Carroll (2010). These considerations illustrate that whether or not boundary states can have

[22] Hoefer 2002 builds on this insight to clarify the notion of "determination" associated with the problem of free will.

explanations depends on what it means for a state to be a boundary condition, and what constraints go into determining it.

Moreover, while some authors indeed think of the Past State as necessarily being an *initial* state (Albert 2000, 96), this is not universally agreed. Recall that the Past Hypothesis is meant to provide a temporal symmetry breaking in order to fit our memories and other available records, that tell us that the entropy in the past was lower than it is now. If so, then it may suffice to say, as Feynman (1967, 116) does, that “it [is] necessary to add to the physical laws the hypothesis that *in the past* the universe was more ordered, in the technical sense, than it is today.” (our italics). “The past” here needn’t necessarily be the remotest past, i.e., the initial state of the universe, and for the same reason, it need not be a boundary state. By contrast, a low entropy Past State that is not initial may be problematic in a sense pointed out by Albert (2000), since in that case the records that should justify beliefs concerning the state of affairs between the low entropy Past State and the initial state (which may in this case have higher entropy) may not be reliable, and lead to a “skeptical catastrophe” within the scientific theories that describe the early universe (Albert 2000, Ch. 6); and for this reason Albert prefers the Past Hypothesis to say “that the world first came into being in whatever particular low-entropy highly condensed big-bang sort of macrocondition it is that the normal inferential procedures of cosmology will eventually present to us” (Albert 2000 p. 96).

Once again, the possibility of explaining the Past State is illustrated by the model of Carroll and Chen (2004) and Carroll (2010), mentioned in the previous subsection. This model provides an explanation of the Past State of the universe in terms of another state of the multiverse, which “precedes” it albeit not in the temporal sense of the term: the Past State is explained as the state in which a "baby universe" is created in the "parent" universe, at a moment which is initial *for* that baby universe. Does that make the Past State a boundary state of our baby universe? Or does the fact that it is explained by a "preceding" state make the Past State not count as a boundary condition? Notice that Carroll's model assumes that the universe (of which our universe is but a fluctuation), in turn, started out in some state (namely, a high entropy state in the appropriate sense of the term) within which the fluctuation that "creates" our "baby universe" is described. Within that model the claim is that the high entropy state has high probability. How should this probability be determined, and does this high probability mean that it does not call for explanation? That high entropy state is, too, a boundary condition within the expanded theoretical context; Can that boundary condition be explained? Should it be explained? These are conceptual questions that we leave open.

c. Should we expect to discover an explanation for the Past State?

If it is possible for the Past State to have an explanation, the initial presumption should be that we might be able to learn about it. To be sure, there are reasons to have low expectations, that is, to have low credence in the claim that we will one day discover the explanation of the Past State, even if one exists. Knowledge after all requires epistemic justification. It might be impossible to have substantial enough or even any evidence of what happened before the Past State (as noted earlier, "before" here may be in a non-standard sense). Such a state is so incredibly distant from our epistemic reach. Callender raises this issue when he, inspired by Hume, argues that:

> [S]ince the cosmos happens only once, we cannot hope to gain knowledge of any regularities in how it is created. This, I take it, implies that we will not be able to defend any grand principle of how contingent matter–energy sources are distributed at the

> boundaries of the universe, for what justification would we ever have for such a principle? (Callender 2004b, 246)

However, Callender's argument is questionable. It is not clear why the fact that the cosmos happened only once implies that we can't gain knowledge of how it came about. It might follow, if the only possible way of learning about the origins of our universe is by enumerative induction. But why think that this is the case? The assumption, prevalent perhaps in Hume's days, that enumerative induction is the only legitimate form of ampliative reasoning, is no longer common ground. Inference to the best explanation, for instance, is considered by many to be an independent form of rational inductive reasoning. To take a familiar example, we can have justified beliefs about subatomic particles even though we cannot observe them and thus cannot learn about them via enumerative induction (Harman 1965, 89; Weintraub 2018, 191).

We see no reason to rule out the possibility that, if the Past State has an explanation, then we will one day discover what it is. However, while we do not think that it is *impossible* to gain such knowledge, Callender may be right that the prospects of gaining knowledge of such a remote occurrence are dim. It is worth distinguishing though between the question of this section, whether we can ever *know* an explanation of the Past State, and a different question, whether there is any benefit to coming up with possible *conjectures*.[23] Even pessimists about our ability to gain *knowledge* about the origins of our cosmos should admit that we can come up with possible theories which, if true, would explain the Past State and for which we may never have enough justification to fully believe.

[23] Smolin (1997, 5) for instance, presents his work as mere speculation. Although, he seems to think of his speculation as a step towards discovery, the possibility of which he seems optimistic about.

We note in this context that it could be an interesting project to figure out what restrictions there might be on good speculation. While significant epistemic justification is not a necessary requirement for good speculation, it is implausible that any theory that accommodates the data counts as good speculation. Plausibly, for a conjecture to be good, it must have some explanatory virtues.

d. Should we try to discover an explanation for the Past State?

If it is epistemically possible that we can discover an explanation of the Past State, even if improbable, then why not try? Of course, perhaps it is more important that scientists spend their time and money finding solutions to the climate crisis than on inquiring into the distant origins of our universe. However, setting such considerations aside, we concur with Price that "Should physicists sit on their hands, and not even try to explain it? They might fail, of course, but that's always on the cards—the issue is whether it is appropriate to try" (Price 2004, 230). Physicists should try. Why not?

e. Is the Past State such that it gives us reason to reject any theory that implies that it is a brute fact?

Claiming that the Past State calls for explanation in sense (III) amounts to the claim that we have reason to reject any theory that both includes the Past Hypothesis, and implies that the Past State is a brute fact. Examples would be people who claim that we should not believe that our universe is the only universe that exists, as opposed to a multiverse, or that the Past State is the initial state of our universe, because those theories would imply that the Past State is a brute fact.[24]

The mere fact that a theory leaves some unexplained facts or even implies that some facts are brute, is—according to many thinkers—not a reason to reject a theory.[25] Arguably, the ultimate explanation of our universe must include some fundamental facts. However, are there reasons to believe of certain facts that, even though we do not possess an explanation for them, we should be quite confident that they are not fundamental? Whether there can be such reasons for belief and whether they might apply to the Past State is a worthy research project.[26]

Winsberg attributes to Carroll the following view:

> [A]ny initial state of the Universe that is unlikely on [a natural a priori] measure requires explanation… Carroll rejects the Past Hypothesis on the above grounds. (Winsberg 2012, 396)

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[24] The claim of Hemmo and Shenker 2019, in which the arrow of time is reduced to contingent local spatial asymmetries in the brain, is not an explanation in terms of "brute facts", since the fact that this brain structure should give rise to the experience of (seemingly) temporal asymmetry is explain within a physicalist theory of mind.

[25] For example, supporters of certain versions of non-reductive physicalism maintain that the fact that certain physical kinds realize certain high-level kinds is brute; see for example Fodor 1974, 1997.

[26] Callender seems to believe that nothing calls for explanation in this epistemic sense. His reasoning, however, is unconvincing. He argues that improbability is insufficient for calling for explanation and seems to think that there's no other theoretical possibility for distinguishing between facts that call for explanation and facts that do not. While we agree that the improbability thesis is a non-starter, there are several alternatives to explore. See Baras (2019; *unpublished*).

This view is precisely the view that Callender argues against (not Price's view), and rightly so. "Requires explanation" is here used in the epistemic sense (III), as a reason to reject a certain theory. However, the mere improbability of a state of affairs is not a sufficient reason to believe that it must be explainable. As Callender argues, improbable occurrences happen all the time that aren't reason to doubt any of our theories. (Just toss a coin a few times, or count the blades of grass on your lawn. The specific result will surely be improbable and, arguably, brute). If we have any reason to believe that the Past State is unlikely to be a brute fact, it must be something other than, or at least in addition to, its improbability.[27] Carroll, because he believes the Past State is unlikely to be brute, explains the low entropy Past State of our universe by taking our universe to be a "baby universe" within a universe for which the initial state is one of high entropy as well as of high probability. What are the reasons for believing that this is indeed the state in which the universe came into being? What assumptions go into endowing this initial state with high probability? In other words, what sort of explanation can be or should be provided for this initial state? We worry that Carroll's theory avoids one boundary condition that calls for explanation (in the epistemic sense of calls for explanation) by positing another boundary condition, thus opening the question of whether that condition also calls for explanation. Whether or not this worry can be resisted is a question we leave open.

Conclusion

Our main task in this paper was to disambiguate, quite generally, what philosophers and scientists mean when they say of some fact that it calls for explanation. We have distinguished a

[27] Of course, even the claim that the Past State is improbable is contestable. In the context of possible boundary conditions of the universe, it is far from clear how probabilities should be determined.

number of possibilities. While they are not exhaustive, they give us a good place to start from when examining other such debates. Applying the result of this conceptual analysis for the case study of the Past State, and in particular for the debate between Callender and Price, prominent representatives of two sides of the debate on whether the Past State calls for explanation, we found that the two sides, at least as we understand them, not only talk past each other, but make, for the most part, compatible claims. More importantly, we have shown that analyzing the debate about the Past Hypothesis along the lines of the different meanings of "calling for explanation" can help us understand better the different arguments involved in this debate, and thus make progress in investigating the debate's subject matter in the philosophical foundations of physics.

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