A puzzle about laws and explanation

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Abstract

In this paper, we argue that the popular claim that laws of nature explain their instances (*explanatory laws*) creates a philosophical puzzle when it is combined with the widely held requirement that explanations need to be underpinned by ‘wordly’ relations (*explanatory realism*). We argue that a “direct solution” to the puzzle that accounts for both *explanatory laws* and *explanatory realism* requires endorsing at least a radical metaphysics. Then, we examine the ramifications of a “skeptical solution”, i.e., dissolving it by giving up at least one of these two claims, and argue that adopting it is more favorable to Humean reductionists than to anti-reductionists about laws of nature.

Keywords Laws of nature · Humeanism and non-humeanism about laws · Explanation

1 Two popular theses about laws and explanation: The puzzle

The physicist and Nobel laureate Stephen Weinberg has famously stated that ‘[t]o tell a physicist that the laws of nature are not explanations of natural phenomena is like telling a tiger stalking prey that all flesh is grass’ (Weinberg 1992: pp. 28–29). Here, we will show that the popular and seemingly innocuous claim that laws of nature explain their instances, when combined with another innocent-seeming thesis about explanation, leads to a philosophical puzzle. We argue that a “direct solution” keeping both claims commits one at least to radical metaphysical positions (Sect. 2). We will then argue that a “skeptical solution”, i.e., resolving the puzzle by revising at least one of these two claims, is more favorable to Humean reductionists than to anti-reductionists about laws (Sect. 3). This line of argument adds a novel twist to

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the current debate about laws and explanation in which explanatory considerations are usually considered to be problematic solely for Humean reductionism about laws.¹

The assumption that the laws explain their instances is pervasive not only among scientists but also among metaphysicians of laws of all stripes. Representing Humean reductionism, Barry Loewer states that Humean best-systems laws ‘support counterfactuals and explain their instances’ (Loewer 2007: p. 320). From the anti-reductionist camp, important adherents of the Dretske-Tooley-Armstrong (DTA) theory and dispositional essentialism agree that ‘[l]aws are not merely summaries of their instances; typically, they figure in the explanation of the phenomena falling within their scope’ (Dretske 1977: p. 262); and that laws ‘explain their instances, indeed they explain the regularities we find in nature’ (Bird 2007: p. 86). Finally, also the most prominent advocates of the nomic preservation account (see Lange 2009b: p. 288) and primitivism about laws (see Maudlin 2007: p. 8) subscribe to the claim that laws explain facts about their instances. Thus, the following thesis about laws seems to be popular among scientists and philosophers alike:

(explanatory laws) The fundamental laws of nature explain their instances.²

There are at least two different readings of *explanatory laws*:

- (a) A first reading is that the fact *that it is a law that all Fs are Gs* together with the fact *that Fa* explains the fact *that Ga*.³ According to this reading, *that it is a law that all Fs are Gs* is a *partial* explainer that together with the fact *that Fa* fully explains the fact *that Ga*. Here is a toy example from Alexander Bird: Suppose ‘I look for an explanation of its [a certain stone’s] hardness. The simplest explanation available is that this stone is a diamond and that it is a law that diamonds are hard’ (Bird (2007: p. 86); see also Lange (2013: p. 257) and Maudlin (2007: p. 130) for the claim that the laws are partial explainers).
- (b) According to a second reading, *that it is law that all Fs are Gs* *fully* explains coinstantiations of properties by particulars, i.e., facts of the form *that this (particular) F is (also) a G*: Why is this particular piece of metal on my desk (also) an electrical conductor? Because it is law that metals are electrical conductors. Analogously, a dynamical law *fully* explains temporal successions of events. Thus, ‘questions of the form *Why did event 2 follow event 1?* are given answers of the form *because it is a law that events of type 2 follow events of type 1*’ (Emery 2019: p. 1542).

¹ The preferred Humean reduction is the best-systems-account, according to which, roughly put, laws are identified with the contingent generalizations belonging to the best systematizations of the total distribution of particular non-modal matters of fact (see Lewis 1973a, 1983; Jaag and Loew 2020 defend a recent modified version). Throughout this paper, we use the label ‘anti-reductionism’ for all non-eliminativist views of laws that reject the Humean reductionist claim that the facts about laws can be reduced entirely to non-modal matters of fact.

² We are agnostic to what extent this holds also for non-fundamental laws, assuming that there are any.

³ We use fact-talk here in a non-committal way and, for matters of simplicity, follow the relevant literature in assuming that laws are general facts such as *that all Fs are Gs* although the candidates for fundamental laws from physics are not stated in this simplistic way (see Maudlin 2007: p. 11).

Actual explanatory practice in science provides evidence for both readings of *explanatory laws*.⁴ Therefore, we do not take the two readings as being alternatives but as stating two different but equally important aspects of the explanatory scope of laws. Thus, in order to account for *explanatory laws*, a philosophical account of laws should capture both.⁵

As is indicated in the first quote from Bird above, laws are not only supposed to explain facts about their particular instances but also regularities (among their instances).

- (c) The fact *that it is law that all Fs are Gs* fully explains the fact *that all Fs are Gs*; and more generally, the fact *that it is a law that p* fully explains the fact *that p*.⁶

In the present paper, however, we focus on *explanatory laws*, i.e., on the claim that laws explain their particular instances and thus on (a) and (b), although *mutatis mutandis* a similar puzzle as stated below seems to arise also for (c).

Before we go on to the second thesis at issue here, we want to address a potential worry about our formulations of (a), (b) and (c). There is an important distinction between law-involving facts of the form *that it is law that p* that explicitly attribute law-status to certain facts and facts of the form *that p* to which law-status is attributed by facts of the former type. We use Lange's (2009a: p. 17) terminology and call the former 'nomic facts' and the latter 'sub-nomic' facts.⁷ In (a), (b) and (c) above, we follow Bird (2007: p. 86), Emery (2019), and Hoeltje et al. (2013: p. 516) and equate the *explanantia* in *explanatory laws* with nomic facts of the form *that it is a law that p*. Claiming that such nomic facts do the explaining, however, may not be entirely uncontroversial (see Marshall 2015). Especially proponents of the DTA-account and primitivists about laws who deny that laws are generalizations might hold that a law *l* itself—in the case of Armstrong, a higher-order fact of the form $N(F,G)$, or, in the case of Maudlinian primitivism, a fundamental law of temporal evolution conceived of as an entity of a *sui generis* kind—(partially) explains its instances and not just nomic facts about laws of the form *that it is a law that l*. For our purposes, it is sufficient to note that however the *explanantia* in *explanatory*

⁴ For examples of actual scientific explanations of the form of (a), see Lange (2013); for examples of the form of (b), see Emery (2019).

⁵ An anonymous referee has pointed out that there is a further reading of *explanatory laws*, namely that facts of the form *that it is a law that all Fs are Gs* fully explain conditional facts of the form *that if Fa then Ga*. We do not dispute that this is a further legitimate reading of *explanatory laws* that deserves further inquiry. However, the core explanatory role of laws in science arguably is explaining (successions of) non-conditional occurrent facts or events as stated in (a) and (b), and it is not entirely obvious how a law's explaining such conditional facts gets us to the law explaining non-conditional occurrent facts or events. Therefore, we focus our discussion on readings (a) and (b). But we will flag when adopting a conditional reading might make a difference to the arguments given.

⁶ Not only sub-nomic facts are in the explanatory scope of laws. For instance, arguably Kepler's laws are explained by Newton's laws of motion together with the law of universal gravitation. However, in this paper we bracket such 'inter-law' explanations.

⁷ Miller (2015: p. 1330) refers to facts of the former kind as 'metanomological'. See also Marshall (2015) for making this distinction explicit.

laws are construed, there is the question how they do the explaining and therefore the puzzle we present below arises.

The second thesis at issue here is a widely-accepted realist conception of explanation:

(explanatory realism) Explanations need to be underpinned.

The idea fueling *explanatory realism* is that an explanation, full or partial, does not float free but ‘must be grounded in some objective relation of dependence or determination holding for the *explanans* and the *explanandum*’ (Kim (1993: p. xii); see also Audi (2012), Ruben (1990), and Schaffer (2016a); for critical discussions of explanatory realism see Taylor (2018), and Thompson (2016)).

Although *explanatory laws* and *explanatory realism* seem to be appealing and innocuous at least for philosophers of a realist stripe, they make for a profound puzzle. The latter requires a backing of the explanation stated in the former: According to *explanatory laws*, the (facts about) laws are literally (part of) the *explanans* of facts about their instances; hence *explanatory realism* requires that there is some determinative relation that connects the facts about laws to facts about their instances bestowing explanatory priority upon the former.⁸ But now the question arises: *What is this underpinning relation?*

Before we review several attempts to answer this question, two remarks on the puzzle it creates.

First, it is general. Stating it does not require specific and maybe controversial assumptions about the exact nature of laws and thus, challenges reductionist as well anti-reductionist views. In this respect, it is different from the much-discussed circularity-argument against Humean reductionism (for extensive references, see fns. 29 and 30 below), Bird’s (2007: ch. 4.4.2) regress-problem for the Dretske-Tooley-Armstrong account of laws, and Barker’s and Smart’s (2012) objection to

⁸ There is the worry that this reasoning presupposes a strong reading of *explanatory realism* according to which every instance of a partial explanation is underpinned by some worldly determinative relation (see Kim 1988), and Audi (2012) for such a strong version of *explanatory realism*). But there may be weaker readings of *explanatory realism* available according to which it is sufficient that in any full explanation there is some determinative relation to underpin it (see Taylor (2018) for distinguishing strong and weak versions of explanatory realism). On such a weaker reading, if the laws are only partial explainers, it does not follow that there is a determinative relation that connects the facts about laws to facts about their instances. Two comments on this: First, notice that this potentially affects our reasoning only on the first reading (a) of *explanatory laws* above according to which the laws are only partial explainers. According to the second reading (b) of *explanatory laws*, a law is supposed to be the *full* explanation of a corresponding succession of events. Thus, there needs to be an underpinning relation between the law and the corresponding succession also on a weak reading of *explanatory realism*. Second, and more importantly, several authors explicitly do subscribe to the claim that there is a determinative explanation-underpinning relation that connects the facts about laws to facts about their instances: Mumford (2004: p. 3) maintains that any realistic view of laws is bound to claim that ‘[l]aws play a role in truthful explanation if and only if they exist and, in some way, determine that which they explain.’ Maudlin (2007: p. 174) clearly subscribes to this as well when he claims that ‘laws of temporal evolution operate [...] from th[e] initial state to generate or produce later states.’ And more recently, Emery (2019) argues that the explanatory relation between laws and their instances is grounding (see 2 (iii)).

Bird's dispositional essentialism involving a regress of higher-order (manifestation-) relations.

Second, it is also different from van Fraassen's inference-problem, which requires to 'show that on the advocated account of laws, the assertion *It is a law that [all Fs are Gs]* entails *[all Fs are Gs]*' (van Fraassen 1989: p. 81). As we have stated above, our focus here is not on explanatory claims of the form of (c). But more importantly, ensuring this entailment is not sufficient (and presumably also not necessary) for providing a relation between nomic facts like *that it is a law that all Fs are Gs* and sub-nomic facts like *that all Fs are Gs* that bestows explanatory priority to the former. Consider the following two models of $\Box(\textit{It is a law that all Fs are Gs} \rightarrow \textit{all Fs are Gs})$:

- (M1) *That it is law that all Fs are Gs* is identical to *that all Fs are Gs*. (True on a naïve regularity theory.)
- (M2) *That it is a law that all Fs are Gs* essentially depends on *that all Fs are Gs*. (True on more sophisticated regularity theories.)

Although M1 and M2 are plausibly entailment-conferring and thus solve the inference-problem, they do not solve our puzzle, since they do not provide a relation between nomic facts and regularities that bestows explanatory priority to the former: Identity (M1) arguably bestows no explanatory priority, and the essential dependence stated in M2 arguably bestows the opposite explanatory priority.⁹

2 Direct solutions

In this section, we will show that a "direct solution" to our puzzle by providing an underpinning relation at least commits one to a heavy-duty metaphysics. So, let us look at possible candidates for underpinning nomic explanations:

(i) *Causation*: The paradigm explanation-underpinner is causation. However, a causal connection does not seem to be suitable in the case of nomic explanations, since although the antecedent- or initial-conditions of a law may well be causes, a law itself seems to be of the wrong type of entity to figure as a *relatum* in a causal relation. As Marc Lange aptly notes '[a] law is a 'because' but not a cause' (Lange (2009b: p. 288); see also Emery (2019: sec. 4) and Maudlin (2007: pp. 155–156)).¹⁰ Notice, that this does not rely on restricting causation to event-causation. For instance, on plausible models of general causation such as presented in Woodward and Hitchcock (2003), laws are not eligible candidates for causes either: a law is not the kind of 'thing' that can be intervened on (cf. Hicks (forthcoming)).

⁹ That does not exclude that certain other (non-Humean) solutions to the inference-problem might also solve the explanatory problem stated here (see Sect. 2 (iii)).

¹⁰ Occasionalists who identify the laws with God's general volitions that are supposed to be the causes of the motions of bodies probably disagree (see Psillos 2018: sec. 4; cf. Foster 2004 for a similar more recent view).

Moreover, even setting the category-mistake-worry aside, thinking of laws as causing their *explanandum* facts, states or events seems to leave one with an unhappy choice: Either the (total) antecedent- or initial-condition of a law is never a complete cause, or there is some systematic causal overdetermination going on: although the (total) antecedent- or initial-condition is a full cause of the *explanandum* fact, state or event, the corresponding law always contributes some additional causal ‘influence’.

Finally, causation seems to be inadequate if we want to make room for synchronic non-causal nomic explanations by so-called laws of coexistence such as the law for the simple pendulum, Ohm’s law and Boyle’s law (see Hempel 1965: p. 352).¹¹

(ii) *Laws (of nature)*: The underpinning relation we are looking is an explanatory relation that establishes an invariant connection between (facts about) laws and their instances. So, maybe the underpinning relation is itself a law. Moreover, even if it is claimed that nomic explanations are underpinned by causation or a non-causal explanatory relation like grounding (see (iii) below), it seems plausible that a corresponding law is working in the background (see Paul and Hall (2013: pp. 7–9) for claiming that causation is law-governed and see Kment (2014), Schaffer (2017a) and Wilsch (2015) for the role of laws in grounding).

However, if the underpinning is provided by a law, in order for a law *l* to (partially) explain one of its instances *i*, there must be a further ‘higher-order’ law *l** (involved in the) underpinning (of) this explanation. Worse, a regress seems to be lurking by reapplying our two principles: by *explanatory laws*, *l** itself has an explanatory capacity. Since *l** apparently connects *l* and *i*, also *l** seems to (partially) explain *i*. However, that explanation in turn needs to be backed according to *explanatory realism* and thus (given the assumption under scrutiny that nomic explanations are underpinned by laws) a further law *l*** is needed and so on (see Bird (2005) for a similar regress-objection against Armstrong’s theory of laws).

So, the *prima facie* innocuous assumptions of *explanatory laws* and *explanatory realism* seem to lead to the postulation of additional ‘higher-order’ laws and

¹¹ It might be held that the non-causal nature of these laws concerns only the connection between the states or properties related in the law (e.g., the connection between pressure and volume of an ideal gas in the case of Boyle’s law). However, that these states are not related causally per se does not entail that the law itself is not a cause of these states. Thanks to an anonymous referee for the pointer. However, if it was maintained that, say, the pressure of an ideal gas is not a cause of its volume while Boyle’s law is a cause of the gas’s volume, according to reading (a) of *explanatory laws* the following issue arises: We have a case of a *single full explanation* (the gas’s pressure together with Boyle’s law fully explains the gas’s volume) that is somehow a result of two partial explanations that are *ex hypothesi* each underpinned by a different relation (the explanation by the pressure by a non-causal relation, the explanation by the law by causation). However, it is questionable whether there is a coherent story about how causation (widely assumed to be diachronic) and the relevant synchronic non-causal relation ‘interact’ in backing this single full explanation. Analogous issues are presented and further developed in the subsequent discussions of options (iii) and (iv).

even to an endless cascading of such laws.¹² Is this regress benign or vicious? We do not have a general story about what makes a regress vicious. This regress, however, seems to be troubling for at least three reasons: First, postulating an infinity of different laws violates a parsimony constraint on fundamental metaphysics: since *explanatory laws* concerns fundamental laws, we end up with an infinite array of fundamental laws involved in the explanation of a single instance. Second, arguably one of the main reasons for introducing metaphysically robust laws is their role in explaining their instances. However, as the regress shows, in order to do exactly this job, further laws need to be introduced. And third, usually fundamental laws are held to be discovered by fundamental physics. However, it is highly unlikely that one day physicists come up with an infinite array of such ‘higher-order’ laws.

Can this regress be avoided?¹³ A first option would be to restrict *explanatory laws* to first-order laws only. However, such a general restriction is not desirable, since plausibly at least some higher-order laws have explanatory power (see, e.g., Lange 2009a: sec. 3.5 for arguing that symmetries are meta-laws that explain conservation laws). If instead *explanatory laws* is restricted only to first-order and *some* higher-order laws, in order to avoid adhocery, a reason would be needed why only *some* higher-order laws have an explanatory capacity other than just stopping the above described regress. A second option to avoid the regress might be to postulate a ‘generic’ higher-order law like *that it is a law that laws explain their instances*. The idea is that the postulation of such an additional law would not create an endless regress of laws, since it can do all the ‘higher-order-explaining’: that a particular law *l* (partially) explains one of its instances *i*, is underpinned by *the law that laws explain their instances*. That *the law that laws explain their instances* explains why *l* (partially) explains *i*, is again underpinned by *the law that laws explain their instances* and so on. For this to work, however, at a minimum *the law that laws explain their instances* must be applicable to itself. However, a self-governing-law is quite unlike all the laws we know from science. We cannot discuss that option further here, but such an ‘exotic’ self-governing-law seems similarly problematic as the postulation of a cascading of different laws.

(iii) *Grounding*: It has been argued that laws explain by grounding their instances (see Emery 2019; cf. Hildebrand 2020). Assuming that grounding is a constitutive type of explanation and that, in the case of full grounding at least, the grounded is

¹² You might worry that this regress is not special, because it is simply an instance of a very general regress problem: If an explanation is underpinned by an underpinning relation *U*, it may always be asked what underpins *U*’s underpinning. The case of iterated grounding may be an instance of this: if *Γ* grounds *φ*, it might be further asked what grounds *that Γ grounds φ* (see Litland 2017). The regress above, however, is different because of the special nature of the underpinner: if the underpinner is a (higher-order) law, by *explanatory laws*, this additional law must be an explainer/*explanans* itself that explains its instances (and this further explanation needs to be underpinned again by *explanatory realism* and so on). So, the regress is driven by an ‘intrinsic’ feature of laws, namely their explanatory capacity as stated in *explanatory laws*. And it is at least not immediately clear that other underpinning relations have a corresponding feature to *explanatory laws* that makes them explainers/*explanantia* themselves and thus, by themselves, generate further explanations that need to be underpinned.

¹³ Thanks to an anonymous referee for bringing this up.

‘nothing over and above’ its ground (see, e.g., Fine 2001; Schaffer 2009), a grounding-account of nomic explanation is hardly acceptable for Humeans, DTA-theorists or dispositionalists.¹⁴

There are two challenges for grounding-theorists about nomic explanations: First, several theorists (e.g., Armstrong 1983; Carroll 1994; Maudlin 2007; Tooley 1977) have argued that the laws are to a high degree independent from their particular instances and even that a law could have existed as an uninstantiated law without having any positive instances. Assume that, say, we want to know ‘[w]hy was the event of applying a net force of 1 N to the rock [of mass 1 kg, starting at rest] at t_1 followed by the rock traveling at a speed of 1 m/s at t_2 [1 second later]?’ (Emery 2019: p. 1541). Remember, according to the second reading (b) of *explanatory laws*, *that it is a law that $f=ma$* (see Emery 2019) fully explains this fact. Now, on standard conceptions of grounding, if the fact *that it is a law that $f=ma$* were to (fully) ground the above succession of events, the former would have to metaphysically necessitate the latter. However, that contradicts the independence of laws according to which *that it is a law that $f=ma$* could have obtained without this particular instance or even without having any single positive instance at all. In fact, any plausible account of nomological or natural necessity should render it nomologically possible that (at least) one single of a law’s actual positive instances is missing.¹⁵ That its link to necessitation threatens to make grounding inappropriate for underpinning nomic explanations is also revealed if we take seriously the possibility of fundamental indeterministic laws: the instances of an indeterministic law are not nomologically (and *a fortiori* not metaphysically) necessitated by and thus are not grounded in (or supervenient upon) their total nomic antecedents; yet also indeterministic laws arguably explain their positive instances.

A second challenge arises in connection with the first reading (a) of *explanatory laws*.¹⁶ Consider a case where a dynamical law is supposed to be a partial explainer and so (fully) explains (later) states only together with its antecedent- or initial-conditions. Claiming that the law’s explanatory contribution is underpinned by

¹⁴ However, some proponents of a radical form of ontic structural realism according to which, roughly put, fundamental reality is exhausted by a vast network of nomic relations, seem to subscribe to such a grounding claim (cf. French 2014: p. 302). It is unclear, though, how we get the vast array of particular matters facts from purely nomic structure, i.e., without ‘inserting’ into the laws some ‘input’ about particular initial conditions. Rosen (2010) suggests that anti-reductionists might be interpreted as claiming that the fact *that p is a law* grounds *that p* . Notice, though, that the “nothing-over-and-aboveness” arguably is less problematic in case the *explanandum* in *explanatory laws* is construed as a conditional fact (see fn. 5 above) than if it is construed as a non-conditional fact as in (a) and (b).

¹⁵ Notice that this worry arises only on reading (b) of *explanatory laws* but does not arise on reading (a) where the law is only a partial explainer. Also, it does not arise if the *explanandum* of *explanatory laws* is a conditional fact as mentioned in fn. 5 above.

¹⁶ Emery (2019) is an in-depth argument that laws (fully) ground successions of events and thus addresses our second reading (b) of *explanatory laws*. However, Emery does not address how a grounding-account fares with respect to our first reading (a) of *explanatory laws* that has been focal in the recent debate about laws and explanation.

grounding raises a question: Is the initial- or antecedent-state also a (partial) ground of the later states?¹⁷ If the answer is ‘yes’, that seems to be in conflict with the widespread assumption that grounding is synchronic in the sense that, in contrast to causation, grounding does not relate distinct events at different times¹⁸; and assuming that the universe has no first moment, that may also compromise grounding’s well-foundedness (see Schaffer 2016a: p. 95). If the answer is ‘no’, one seems to be committed to claiming that only the explanatory contribution of the (dynamical) law is backed by grounding whereas the explanatory contribution of the antecedent- or initial-state is backed, say, by causation. So, we have a case of a *single full explanation* that is somehow a result of two partial explanations that are *ex hypothesi* each underpinned by a different relation (the first by grounding, the second by causation). But then, a story is needed how causation and grounding ‘interact’ in backing this single full explanation. However, as long as it is assumed that there are significant ‘structural’ differences between causation and grounding, it is questionable whether there is a coherent such story. For instance, the former is supposed to relate completely distinct events or states and to be diachronic whereas the latter is supposed to be constitutive and synchronic (see Bernstein 2016; and Schaffer 2016a: sec. 4.5 for these and further structural differences between grounding and causation). It is hard to see how such disparate relations could combine in *one single* (full) explanation, and to our knowledge no one has yet addressed how they could.¹⁹ Worse, on the plausible assumption that something is a partial ground only in case it forms a full ground together with other factors, this alleged ‘mixed’ underpinning is even incoherent: The only thing the law could ‘team up with’ to fully ground the later state is the antecedent- or initial state which *ex hypothesi* is not a ground but a cause.²⁰

In response to these worries, it might be suggested to cap the connections between the notion of ground and the notions of constitution and ‘nothing-over-and-above-ness’ (see Audi 2012). It might be also be denied that (full) grounds metaphysically or nomologically necessitate what they ground (see Emery 2019: sec. 7, and Skiles 2015), that grounding is synchronic, that it cannot relate entirely distinct events, and maybe even that grounding is well-founded (see Bliss 2013). Admittedly, every single deviation from the received view about grounding that is necessary to get a grounding-account of nomic explanation off the ground has been argued for. However, the whole package of deviations seems to leave us with a rather weak notion of ground that threatens to blur the distinction between grounding and causation (see

¹⁷ There are several passages in Maudlin (2007) that might be read as suggesting that the laws together with the initial state (!) ground the (remaining) mosaic of particular facts (cf. Maudlin 2007: p. 182). Loew (2018) tentatively suggests to interpret Maudlin (2007) as claiming that earlier states of the universe ground later states.

¹⁸ This does not exclude that grounding may relate facts concerning different times, such as that the fact that *I am a former philosophy student now* is grounded by the fact that *I was a philosophy student in the past*. Thanks to an anonymous reviewer for the example and the advice to be more specific here.

¹⁹ Notice that we worry about *structurally different partial explanations* ‘making up’ a *single full explanation*, not about mixed explanations consisting of sequences of structurally different explanations, as, e.g., when a physical event causes another physical event which in turn grounds a mental event (cf. fn. 28 below).

²⁰ Thanks to an anonymous referee for pointing this out.

Bernstein (2016); and Schaffer (2016a: sec. 4.5) for relevant distinguishing features; cf. also the discussion in Hildebrand (2020: ch. 3.3)).²¹

(iv) *A sui generis governing relation*: Finally, a *sui generis* governing relation might be posited to provide the relevant underpinning (see Hildebrand 2020). A primitive governing relation seems to make the respective account of laws less parsimonious. Proponents of certain forms of non-Humeanism about laws might not be much moved by parsimony-considerations, since they think additional primitive law(maker)s such as *sui generis* laws (see Maudlin 2007) or instantiations of a higher-order necessitation relation (see Armstrong 1983) need to be posited to explain facts about their instances anyways. However, if governing is a primitive determinative relation it is a *further* cost over and above the primitive non-Humean law(maker): Non-Humeans then not only posit primitive metaphysical entities to explain the pattern of occurrent facts. They also add, as a *further* posit, a primitive explanatory nexus to connect their primitive law(maker)s to facts about their instances.²²

Moreover, postulating a primitive governing relation does not seem to be an option for proponents of any law-account that in some way makes the laws depended on facts about their instances. Since that might not be obvious, let us briefly explain: Although in the relevant literature there is little consensus about what the governing relation is, there is a broad agreement that, in order to govern, the laws must be independent from the facts about their instances in at least two ways: First, the laws must not reduce to or supervene on facts about their instances (see Armstrong 1983: p. 106; Maudlin 2007: p. 175; Hildebrand 2019: p. 176) and, second, it needs to be metaphysically possible that a law remains a law in all of its models (see Loewer 1996: p. 115; Maudlin 2007: p. 67).²³

The first non-supervenience-condition obviously rules out Humean reductionism. Moreover, although non-supervenience is characteristic for most non-Humean accounts of laws, it is incompatible with dispositionalism about laws which is committed to the claim that '[t]he laws of the world supervene on the totality of the instantiations of potencies' (see Bird 2007: p. 82).²⁴ Mumford (2004) takes the fact

²¹ On a conditional reading as mentioned in fn. 5 above the necessity and well-foundedness of grounding may be maintained. However, as pointed out above, we take it to be the central explanatory role of laws in science to (contribute to) explain non-conditional 'positive' instances and thus focus on *explanatory laws* as expressed in (a) and (b). And in order to capture these two readings, a grounding-account seems to be committed to a rather weak conception of ground.

²² Governing-theorists might construe governing as a primitive operator instead of a primitive relation and deny that an operator-construal involves ontological costs, since it does not amount to positing an additional entity. However, it seems that by introducing a primitive operator, it counts at least as an ideological cost, i.e., as primitive terminology without which the theory cannot be stated. Alternatively, governing might be captured axiomatically (see Schaffer's 2016b) axiomatic solution to the inference-problem). But adding an inference-axiom to your law-theory makes it less simple and thus seems to amount to an additional theoretical cost.

²³ We examine the connection between these two independence-notions and their relation to governing in detail elsewhere.

²⁴ Dispositionalists like Bird (2007) try to 'derive' the laws directly from the essences of fundamental potencies. Others combine a fundamental dispositionalist ontology with a best-systems-account of laws, as for instance Demarest (2017), Kimpton-Nye (2017), Williams (2019: Sect. 10.1), and Vetter (2015: p. 289f.).

that a dispositionalist metaphysics violates non-supervenience about laws to be a reason to eliminate laws altogether and to adopt a ‘lawless’ version of dispositionalism. Bird (2007: ch. 9), by contrast, defends non-governing, supervenient dispositionalist laws.²⁵

The second independence-condition additionally rules out Armstrong’s Aristotelian version of the DTA-account. An empty absolute space devoid of any particles seems to be a model of Newton’s law of gravitation.²⁶ However, since in the entire history of such a world neither mass-, distance-, nor force-universals are instantiated anywhere, the required universals for the Armstrongian necessitation-relation to relate are lacking. Hence, on Armstrong’s Aristotelian view there cannot be a Newtonian empty absolute space and thus Armstrongian laws violate the second independence-requirement on governing laws.

So, it seems that only radical law-accounts such as law-primitivism (see Maudlin 2007) or a Platonist version of the DTA-account (see Tooley 1977; Hildebrand 2020) or of dispositionalism (see Tugby 2013) that cap the laws’ dependence on facts about their particular instances allow for the laws’ independence required for a primitive governing relation.

Finally, it is worth mentioning that such a *sui-generis*-governing-account seems to face a similar challenge as arises for the grounding-view (iii): According to the first reading (a) of *explanatory laws*, a (dynamical) law is a partial explainer and only jointly with its antecedent-state fully explains later states. Even if it is granted that laws stand in a *sui generis* governing relation to the states they explain, the (sub-nomic) initial- or antecedent-states plausibly do not. If instead, say, the antecedent-states explain later states by causing them, the question arises how a primitive *sui generis* governing relation ‘interacts’ with causation in backing *one single full* explanation. Again, structural differences between governing and causation make it difficult so see how they could ‘interact’. For instance, causation is usually construed as diachronic relating earlier to later events or states; governing cannot be, since it relates the laws that are widely regarded to be atemporal.

The above discussion of this selection of four candidates for underpinning nomic explanations – namely causation, laws, grounding, and *sui generis* governing – shows that the tweaking or augmenting of the world’s determinative structure necessary to provide such an underpinning requires adopting radical (non-naturalist) metaphysical positions. Since for many metaphysicians of laws, including Humean reductionists and proponents of various naturalistic versions of anti-reductionism, such radical metaphysics is no option, it is worth examining the ramifications of denying the conjunction of *explanatory laws* and *explanatory realism*.

²⁵ Notice that dispositionalists usually hold that the dispositional natures of properties are prior to the patterns of property instantiations they are supposed to explain and so in a sense are independent from the pattern of property instantiations (see Jaag 2014 for a discussion). Still, most dispositionalists hold that worlds that agree with respect to the total instantiations of potencies are duplicates with respect to the laws and so the laws cannot vary while the facts about their instances remain fixed. However, Platonist dispositional accounts such as advocated by Tugby (2013) might be able to accommodate the non-supervenience of laws by postulating uninstantiated dispositional properties.

²⁶ Maudlin’s (2007: p. 67) more sophisticated example of an empty Minkowski-spacetime casts *mutatis mutandis* the same trouble for an Aristotelian DTA-account.

3 Skeptical solutions

If a ‘direct solution’ is discarded, the challenge is to provide a viable revised account of nomic explanation that does without the conjunction of *explanatory laws* and *explanatory realism*. However, the purpose of this section is not advertising a specific such “skeptical solution”. Instead, we will spell out some ramifications of denying at least one of *explanatory laws* and *explanatory realism* and argue that either choice is more favorable to Humean reductionists than to anti-reductionists.

Before we explore in more detail the ramifications of dismissing the conjunction of *explanatory laws* and *explanatory realism*, we want to mention a radical reaction to our puzzle, namely viewing it as an argument for eliminativism about laws. *Explanatory laws*, it might be claimed, indeed is essential for the conception of lawhood, and *explanatory realism* is the only viable account of explanation; but assuming that no direct solution is tenable, this shows that the whole conception of a law of nature is defective and should therefore be dumped. However, in light of the role laws play in science and in philosophy and given that this view seems to be attractive neither for reductionists nor anti-reductionists about laws, we take this radically revisionist line as a last resort and move on to less revisionist ways of tackling the puzzle.²⁷

Denying *explanatory laws* sounds still rather revisionist. In order to avoid a blatant discrepancy with scientific practice, if *explanatory laws* is dismissed, an alternative story needs to be told about what the explanatory role of laws consists in. David Lewis, the most popular advocate of Humean reductionism about laws, indeed seems to have denied *explanatory laws*:

It can be agreed that information about the prevailing laws is at least highly relevant to causal information, and vice versa; so that the pursuit of explanation and the investigation of laws are inseparable in practice. But still we can ask whether information about the covering laws is itself part of explanatory information. The covering law theorist says yes; I say no. (Lewis 1986: p. 239).

But, as this quote suggests, rejecting *explanatory laws* does not come down to denying that facts about laws and facts about explanations of particular instances are intimately connected.

Roughly put, according to Lewis’s Humean picture, the laws are identified with those contingent generalizations that pertain to the most effective summaries of the totality of particular matters of fact (see Lewis 1973a: p. 73). The laws, in turn, are crucial in fixing the facts about counterfactuals (cf. Lewis 1973a) and thus the causal facts (cf. Lewis 1973b) which then delineate the facts about what explains what

²⁷ Pace van Fraassen (1989) and Giere (1995), we agree with Earman (1993) that laws play a vital role in science. Moreover, since there are deep connections between laws, counterfactuals, causation, dispositions and explanation, taking laws out of the picture seems to require far-reaching revisions of our (philosophical and scientific) conception of reality.

(cf. Lewis 1986). So, although the laws are not part of the *explanans* of particular matters of facts, they ground or ‘enable’ the holding of (causal) explanatory connections between them (see Roberts (manuscript: 15), Ruben (1990: pp. 199–208), and Schaffer (2017b) for related accounts).²⁸ Similarly, Michael Scriven (1959) has argued against Hempel that ‘the *explanans* need not include reference to any general laws. A law that provides a connection between *explanans* and *explanandum* constitutes a ‘role-justifying ground’ for the explanation by showing, roughly speaking, that the *explanans* is explanatorily relevant to the *explanandum*’ (Salmon 1984: p. 17, fn. 6).

It seems that anti-reductionists as well can claim that the laws play a mediating role in explanations by somehow enabling, underpinning or justifying explanations between sub-nomic (particular) facts or events (instead of construing laws as being itself (part of) the *explanans* of such facts). Thus, also anti-reductionism about laws does not stand or fall together with *explanatory laws*. But the important thing to notice is that such a view denies that the laws are literal explainers of their instances, i.e., it is a way of denying *explanatory laws*. However, denying *explanatory laws* comes down to a significant dialectical drawback for anti-reductionists, since attacking Humean reductionism on the grounds that it is incompatible with *explanatory laws* is arguably the main line of argument against Humean reductionism that can be found in the works of virtually every major proponent of anti-reductionism about laws.²⁹ Here is a recent reconstruction of this argument from Hicks and van Elswyk (2015: p. 435):

(P1) The natural laws are generalizations.	(HUMEANISM)
(P2) The truth of generalizations is (partially) explained by their positive instances.	(GENERALIZATION)
(P3) The natural laws explain their instances.	(LAWS)
(P4) If A (partially) explains B and B (partially) explains C, then A (partially) explains C.	(TRANSITIVITY)
(C1) The natural laws are (partially) explained by their positive instances.	(P1 & P2)
(C2) The instances of laws explain themselves.	(P3, P4, & C1)

²⁸ You might worry that this creates the same kind of problematic complex explanatory structure we worried about in our discussion of the attempts to underpin nomic explanations by grounding or a *sui generis* governing relation in Sect. 2. However, the complex explanatory structure here is importantly different: one fact, namely the fact, say, *that e causes f* is explained by a law (this explanation is underpinned by grounding or enabling); and another different fact, namely the *fact that f* is explained by *the fact that e* (this explanation is underpinned by causation). In this (complex) explanatory structure, contrary to the cases discussed in Sect. 2, no questions arise how explanations that are underpinned by disparate relations combine in one single full explanation.

²⁹ See Armstrong (1983: p. 40f.), Bird (2007: ch. 4.3.2), Dretske (1977: p. 262), Lange (2013, 2018), and Maudlin (2007: p. 172) for somewhat different versions of the circularity-argument against Humean reductionism. That, of course, is not to say that there are no other arguments against Humean reductionism, such as the important non-supervenience arguments due to Carroll (1994: ch.3), Maudlin (2007: p. 67f.), and Tooley (1977: p. 669). Explanatory considerations are also used in more ‘positive’ inference-to-the-best-explanation arguments for anti-reductionism about laws (see Armstrong (1983: ch. 4.5), Fales (1990), Foster (2004), Hildebrand (2013); see Beebe (2011) for criticism).

In a nutshell, this argument aims to show that Humean reductionism reduces to absurdity when coupled with plausible claims about explanation.³⁰ However, if *explanatory laws* is given up, an essential premise in this popular type of anti-reductionist argument, i.e., (P3) in the version above, is no longer available. So, it seems that the cost of denying *explanatory laws* is significantly higher for anti-reductionists about laws, since they lose one of their most important arguments against their opponents.

Let us now turn to giving up *explanatory realism* (at least in the case of explanations by laws). There are accounts of nomic explanation, such as the deductive nomological (DN) model or a unificationist account of explanation, that do not seem to be bound to *explanatory realism*. Of course, these accounts of explanation have well-known shortcomings and thus a satisfying such model has yet to be developed. Still, in light of our puzzle, sticking to *explanatory laws* might be motivation enough to take the effort to make them work. However, there are two reasons why also going down that road of dissolving our puzzle is especially unappealing for anti-reductionists:

First, although the DN-model or a unificationist account is in principle available also to anti-reductionists about laws (see Armstrong 1983: p. 102), these theories go much more naturally with a reductionist account of laws (see Loewer 1996: p. 113). That is fairly obvious in the case of the DN-model according to which, roughly put, laws construed as universal generalizations (together with specific initial conditions) explain the *explanandum* by entailing it. If that entailment is supposed to be entirely transparent, it is natural to view the laws as being reducible to or ‘constructed from’ their instances.³¹ Also, Loewer’s (1996: p. 120) favored unificationist account of nomic explanation according to which, roughly put, a law explains a range of phenomena by systematizing information about them in an effective way does not require a metaphysical determination relation between *explanans* and *explanandum*. However, such a unificationist account of explanation seems to be tailor made for a Humean best-systems-account of laws (see Miller 2015: p. 1326).

Second and more importantly, *explanatory realism* seems to be a central motive for construing laws (or their lawmakers, respectively) as facts over and above their instances. To see this, let us look a bit closer at the explanatoriness-considerations anti-reductionists put forward to attack Humean reductionism. One major concern is that in the case of a Humean law ‘there is not enough ‘distance’ between it and the facts it is called upon to explain. To get this distance we require an ontological ascent’ (Dretske 1977: p. 267). In order to provide that distance, anti-reductionists including DTA-theorists, law-primitivists (see Maudlin 2007) and subjunctive primitivists (see Lange 2009a) posit laws (or some law-making structures) that do not supervene on the laws’ instances. It seems that if

³⁰ See Dorst (2019), Hicks and Elswyk (2015), Hicks (forthcoming), Loewer (2012), Miller (2015), Marshall (2015), and Roberts (manuscript) for tackling this argument on behalf of Humean reductionism.

³¹ See Loewer (1996: p. 113). That is also the gist of the inference-problem. So, it is not surprising that anti-reductionists have not expressed much sympathy for the DN-model (see Dretske 1977: p. 262).

(nomic) explanations require such metaphysical strictures, a realist conception of explanation is in the background requiring room for a relation of determination connecting the *explanans* to the *explanandum*. Ned Hall even conjectures that the schism between proponents of non-Humean accounts of laws and Humean best-systems-accounts traces

to an even more fundamental difference of opinion over what counts as genuine scientific understanding of some phenomenon. On one view, to understand some phenomenon is, at least in part, to acquire some knowledge about what that phenomenon *genuinely depends on* where it is natural to think that such relations of explanatory dependence must ultimately be grounded in real necessities in nature. But on the rival view, understanding is really targeted at a whole *range* of phenomena and is achieved once one has seen how to *organize one's view of these phenomena* in a cognitively effective manner; this, I think, is the guiding idea behind so-called “unificationist” approaches to explanation. (Hall 2011).

We cannot settle the questions here whether the anti-reductionism-vs.-reductionism-debate about laws in the end boils down to a dispute about the nature of explanation, let alone what the correct view of explanation is. For our purposes, however, it is sufficient to notice that *explanatory realism* seems to play a crucial role in motivating anti-reductionism about laws on explanatory grounds. So, it seems that if *explanatory realism* is given up (if only in the case of nomic explanations!), one major motivation for anti-reductionism about laws is undermined.

The considerations in Sect. 3 show that dissolving our puzzle by giving up at least one of the explanatory claims at issue amounts to a dialectical disadvantage for anti-reductionists: by dismissing *explanatory laws*, the anti-reductionist loses an important argument against reductionism; by giving up *explanatory realism* a central motivation for anti-reductionists is lost.

4 Conclusion

We have presented a new puzzle arising from two popular claims about laws and explanation which raises an important challenge for any philosophical theory of laws of nature. We have shown that *explanatory laws* and *explanatory realism* cannot be met simultaneously unless one is willing to opt for a radical metaphysics. Moreover, we have argued that dissolving this puzzle by giving up or revising at least one of these claims is more favorable to Humean reductionists than to anti-reductionists about laws of nature.

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