



# How to be a powers theorist about functional laws, conservation laws and symmetries

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## Abstract

This paper defends an account of the laws of nature in terms of irreducibly modal properties (aka *powers*) from the threat posed by functional laws, conservation laws and symmetries. It thus shows how powers theorists can avoid ad hoc explanations and resist an inflated ontology of powers *and* governing laws. The key is to understand laws not as *flowing from the essences of powers*, as per Bird (2007), but as features of a description of how powers are possibly distributed, as per Demarest (2017), Kimpton-Nye (2017, 2021) and Williams (2019); call this *the Powers-BSA*. This underappreciated powers-based account of laws is continuous with actual scientific practice and *thereby* quite naturally accommodates functional laws, conservation laws and symmetries. This paper thus positions the Powers-BSA as the leading anti-Humean account of the relationship between laws and properties.

**Keywords** Conservation laws · Functional laws · Powers · Symmetries · Explanation

## 1 Introduction

Powers theorists offer an anti-Humean ontology of irreducibly modal properties in terms of which they seek to explain laws of nature (e.g., Bird, 2007; Chakravartty, 2003, 2007). However, it has been objected that powers cannot explain functional laws (Vetter, 2012), conservation laws, or symmetries (Bigelow et al., 1992; Bird, 2007, chap. 10; Livianos, 2010; French, 2014; Ioannidis et al., 2020). Ioannidis et al. (2020) take these problems to motivate a “dualist” anti-Humean ontology of powers *and* governing laws to account for nomic regularities. This strikes me as a serious overreaction, which, if taken seriously, is likely to do more damage than good to the powers metaphysic by rendering it a sheer ontological profligacy. Hence the need for this paper in which I show how to be a powers theorist about laws, *including* functional laws, conservation laws and symmetries, in an ontologically light-weight

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manner that is continuous with science. The key is to understand laws not as flowing from the essences of powers one-to-one as per Bird (2007, 46) and Chakravartty (2003), but as features of a description of how powers are possibly distributed, as per Demarest (2017), Kimpton-Nye (2017, 2021, 2022) and Williams (2019); call this *the Powers-BSA*. This paper thus positions the Powers-BSA as the *leading* anti-Humean account of the relationship between properties and laws.

## 2 Powers-based laws

Alexander Bird's *dispositional essentialism* (DE) (Bird, 2007) is the most prominent powers-based account of laws of nature<sup>1</sup> and is the prime target of threats from functional laws, conservation laws and symmetries. So, it will be useful to outline DE now.

The dispositional essentialist slogan is “*laws flow from the essences of properties*” (e.g., Bird, 2007, 5) More precisely:

(DE)  $L$  is a law if, and only if,  $L$  is derivable from the essence of a potency.

Where a *potency* is a fundamental property with a dispositional essence, aka a *power*.

According to the simple conditional analysis of dispositions, for  $x$  to possess the *disposition to yield manifestation  $M$  in response to stimulus  $S$* , let's denote this “ $D_{(S, M)}$ ”, is for  $x$  to be such that if it *were*  $S$  then it *would be*  $M$ :

(CA)  $D_{(S, M)}x \leftrightarrow (Sx \square \rightarrow Mx)$

Bird does not endorse (CA) as an analysis of dispositions. Rather, Bird takes (CA) as a necessary equivalence between dispositions and conditionals (2007, 43), which he writes as:

(CA $\square$ )  $\square(D_{(S, M)}x \leftrightarrow (Sx \square \rightarrow Mx))^2$

“Essentially dispositional properties are ones that have the same dispositional character in all possible worlds; that character is the property's *real* rather than merely nominal essence.” (Bird, 2007, 44). So, from the claim that  $P$ , has a dispositional essence Bird infers that for any world,  $w$ , and individual,  $x$ , such that  $x$  instantiates

<sup>1</sup> For relevantly similar views see also Ellis (2001) and, in particular, Chakravartty (2003, 2007).

<sup>2</sup> Bird is not worried about putative counterexamples to (CA) for fundamental dispositional properties because, he argues, fundamental dispositions are not subject to *finks*: “finkishness is not [...] possible for fundamental dispositions. For if the manifestation is instantaneous, then [...] there is no opportunity for the finkish intervention to occur. If, on the other hand, time is quantized, and the manifestation occurs at the next possible moment, there is no intervening possible moment at which the finkish intervention can occur.” (Bird 2007, 62). And developments in physics indicate, according to Bird, that the prospects of “antidote-free fundamental properties [...] are promising”. (Bird 2007, 63).

$P$  at  $w$ ,  $x$  will be disposed to yield manifestation  $M$  in response to stimulus  $S$  (Bird, 2007, 45):

$$(DE_p) \quad \Box(Px \rightarrow D_{(S, M)}x)$$

Combining  $(CA\Box)$  and  $(DE_p)$  by substituting  $D_{(S, M)}x$  in  $(DE_p)$  for  $(Sx \Box \rightarrow Mx)$  then gives us:

$$(I) \quad \Box(Px \rightarrow (Sx \Box \rightarrow Mx))$$

Where (I) says that, in all possible worlds, if  $x$  instantiates  $P$ ,  $x$  would yield manifestation  $M$  if it were to acquire stimulus  $S$ . Now assume (for conditional proof) that  $x$  instantiates potency  $P$  and acquires stimulus  $S$ :

$$(II) \quad Px \ \& \ Sx$$

From (I) and (II), and with modus ponens for the counterfactual, we can derive:

$$(III) \quad Mx$$

It then follows, by conditional proof, from the assumption in (II) that:

$$(IV) \quad (Px \ \& \ Sx) \rightarrow Mx$$

And finally, since  $x$  is arbitrary, we can generalize, producing:

$$(V) \quad \forall x((Px \ \& \ Sx) \rightarrow Mx)$$

(V) Is a universal generalization derived from a statement about the dispositional essence of potency. Furthermore, since the reasoning (I) through (V) holds in an arbitrary world, (V) is *necessary*:

$$(V\Box) \quad \Box\forall x((Px \ \& \ Sx) \rightarrow Mx)$$

What it is to be a law, according to dispositional essentialism, is to be derivable in accordance with steps (I) through (V) from a proposition characterizing the essence of a potency (for details see Bird, 2007, 43–48). Hence, we see that dispositional essentialism requires that powers and laws are connected one-to-one: for every law, there is one single power from which it derives. Conversely, if some purported law statement could not be derived from the essence of a single power, that statement could not count as expressing a *law*, according to dispositional essentialism. As we will see, this is why functional laws, conservation laws and symmetries cause serious problems.

### 3 Functional laws

Coulomb's law is an example of a *functional* law: it says how determinate magnitudes of *force*, *charge* and *distance* vary with each other.

For Coulomb's law to count as a law according to DE it must be derivable from a proposition about the essence of a power in accordance with steps (I) to (V). However, Coulomb's law as generally stated:

$$\text{Coulomb's law} \quad F = e \frac{eq}{r^2}$$

looks very different from the concluding step:

$$(V) \quad \forall x((Px \ \& \ Sx) \rightarrow Mx),$$

in Bird's derivation.

Step (V), but not Coulomb's law, is a universally quantified *conditional*. So, if there is to be any hope of deriving Coulomb's law in accordance with steps (I) through (V), Coulomb's law must be reformulated. We can begin to make Coulomb's law resemble (V) by presenting it in conditional form:

$$\text{Coulomb's law}^* \quad \textit{If } x \textit{ instantiates charge } e \textit{ and is a distance } r \textit{ from another charged individual } y \textit{ instantiating charge } q, \textit{ then } x \textit{ will exert a force on } y \textit{ equal to } e \frac{eq}{r^2}$$

The schematic "law" (V) tells us only that if  $x$  satisfies some conditions ( $P$  and  $S$ ) it will also satisfy some further condition ( $M$ ); (V) relates  $P$ ,  $S$  and  $M$  in a simple on/off manner. However, implicit in Coulomb's law\*, and absent from (V), is multiple quantification over determinate values of *quantities*, in this case *charge*, *force* and *distance*. The challenge is in fleshing out the details of how we are to integrate the quantitative nature of Coulomb's law into the derivation of (V) from (I).

In an attempt to meet this challenge, we can apply a reverse engineering strategy: first we attempt to find an instance of (V) that appropriately captures the quantitative nature of Coulomb's law—Coulomb's law\* is an informal first shot. From there, we can work out what sort of characterization of charge, i.e., what instance of (I) might allow us to derive the relevant instance of (V). Coulomb's law is a function that relates several quantities, so, an instance of (V) apt to capture this quantitative nature of Coulomb's law will itself have several variables ranging over quantities—Coulomb's law\* implicitly quantifies over *charge*, *force*, and *distance*. Now, as Vetter (2012) notes, since we don't want any *free* variables, we are presented with two options. Either we fill the variables in with determinates of the quantities related, or we have one, multiply quantified, conditional. For simplicity, Vetter focuses on the derivation of Coulomb's Law from a particular determinate charge: electric charge, or charge  $e$ : ( $1.6 \times 10^{-19}$  C). This yields two candidate formalizations of the informal Coulomb's law\* (Vetter, 2012, 210):

**(V-1)**  $\forall x((x \text{ has charge } e \ \& \ x \text{ is } 5.3 \times 10^{-11} \text{ m from a charge of } 1.6 \times 10^{-19} \text{ C}) \rightarrow x \text{ exerts a force of } 8 \times 10^{-8} \text{ N})$

Or

**(V-V)**  $\forall x \forall r_i \forall q_i ((x \text{ has a charge } e \ \& \ x \text{ is at a distance } r_i \text{ from charge } q_i) \rightarrow x \text{ exerts a force of } F_i = e \frac{eq_i}{r^2})$

**(V-V)** looks more like Coulomb’s law\* than **(V-1)**. However, due to its multiple quantification, **(V-V)** isn’t an instance of (the singly quantified) **(V)**. Thus, **(V-1)** but *not* **(V-V)** may be derived from an instance of **(I)** as the dispositional essentialist would like. The instance of **(I)** from which **(V-1)** derives is the following:

**(I-1)**  $\Box(x \text{ has charge } e \rightarrow (x \text{ is } 5.3 \times 10^{-11} \text{ m from a charge of } 1.6 \times 10^{-19} \text{ C} \Box \rightarrow x \text{ exerts a force of } 8 \times 10^{-8} \text{ N}))$

Whereas to derive **(V-V)** we would require:

**(I-V)**  $\Box(x \text{ has charge } e \rightarrow \forall \text{charges } q_i \ \forall \text{distances } r_i (x \text{ is at distance } r_i \text{ from } q_i \Box \rightarrow x \text{ exerts a force } F_i = e \frac{eq_i}{r^2})$

The tension now is that **(I-V)** but not **(I-1)** adequately characterizes *electric charge*, due to its greater generality. But **(I-V)** is not an instance of **(I)**, whereas **(I-1)** is an instance of **(I)**. To see this, consider the following: in both **(I)** and **(I-V)** it is the bit after the first arrow ‘ $\rightarrow$ ’ that characterizes charge  $e$ . The difference between **(I)** and **(I-V)** is that the main connective in the characterizing clause in the former is the counterfactual conditional, whereas in the latter it is the universal quantifier (Vetter, 2012, 210, see also vetter 2015, 52). So, the latter, but *not* the former, permits a derivation of an instance of **(V)** in accordance with the dispositional essentialist account of natural law. We are thus forced to choose between sticking with Bird’s account *or* adequately capturing the relationship between *electric charge* and Coulomb’s Law, but, according to Vetter (2012, 212), we cannot do both [see also Kistler (2011, 2020) for similar worries].

Perhaps we could relinquish the conditional characterization of dispositional properties and, accordingly, the derivation of a law in accordance with steps **(I)** to **(V)** and thus open the door to an alternative derivation of functional laws from something like multi-track dispositional properties. If this could be made to work, it would still be a concession that DE does not provide an account of functional laws, since definitive of DE is the derivation of a law from a *fundamental* dispositional property, which Bird thinks must be *single track* (Bird, 2007, 22–23), *in accordance with (I) to (V)*. But more importantly for present purposes, this strategy would not help to account for *global* laws (to be discussed next) because it would still be in the business of linking properties and laws one-to-one. So, in the interest of providing a more unified account of functional laws and global laws (the problem cases for DE) an alternative solution is required, and that is what I aim to provide in this paper.

Ioannidis et al. take the problem of accounting for quantitative laws to motivate the need for governing laws:

[I]t is because the charge's behaviour *is governed by Coulomb's law* that the charge's power to attract and repel other charges is manifested in the way that it [is]. (2020, 7).

In other words, since the functional nature of Coulomb's law cannot be derived from the essence of charge in accordance with steps (I) to (V) as the dispositional essentialist would like, a governing law must be introduced to pick up the explanatory slack. But Ioannidis et al. think that powers are still required to solve what they call "the Governing Problem" which is the problem of accounting for how and why it is that properties are governed (2020, sec. 4) and has its roots in the *inference problem* (Lewis, 1983; van Fraassen 1989) for non-Humean accounts of laws. I think this inflation of the non-Humean ontology is an unnecessary overreaction given the availability of the alternative solution that I will propose.

#### 4 Conservation laws and symmetries

Conservation laws and symmetries are problematic for dispositional essentialism in virtue of their *global* nature, which means that there is not plausibly any one property from which these laws "flow". (Bigelow et al., 1992; Bird, 2007, sec. 10.3.2; Ioannidis et al., 2020, 7–9).

Consider conservation laws first, these laws hold for *closed systems*. So, one might be tempted to say that the conservation laws hold in virtue of the property of being a closed system. However, the property of being a closed system does not look like a *fundamental* property and so, according to the Birdian account of laws, this property is not one from which a real law of nature may derive. Furthermore, the only truly closed system is the entire universe. Alternatively, then, one might be tempted to say that conservation laws flow from the essence of the property of *being a world like ours*. But this "explanation" of conservation laws in terms of the property of being a world like ours strikes many as too ad hoc (Bird, 2007, 213; French, 2014; Ioannidis et al., 2020).

Symmetries are transformations that an entity may undergo while leaving certain properties of the entity unchanged, such transformations include rotations, reflections, boosts in velocity, translations in time or space. Noether's theorem links symmetries and conservation laws. Each continuous symmetry of the Lagrangian corresponds to a conserved quantity: a system's being invariant under translation in space corresponds to its momentum being conserved and a system's being invariant under translation in time corresponds to its energy being conserved, to give just two examples. Livianos (2010) has leveraged this fact to cast doubt on the dispositional essentialist account of property *identity*. But for present purposes, the relevance of symmetries is just that they appear to be another case of global laws that are not amenable to explanation in terms of the essence of some *particular* property, as the dispositional essentialist account of laws would have it.

Bigelow et al. (1992) advocate (something close to) the idea that conservation laws and symmetries hold in virtue of the property of *being our universe*.<sup>3</sup> Bird entertains this move, but ultimately deems it too ad hoc (2007, 213), and others agree (French, 2014; Ioannidis et al., 2020).<sup>4</sup> Bird's preferred response is to deny that conservation laws and symmetries are objective features of the world itself, and to instead maintain that they are eliminable features of our *representation* of the world, which thus require no metaphysical explanation. However, Ioannidis et al. raise an important objection to Bird on this score: they cite the role of symmetry principles in the prediction of new particles as evidence for their being *ontic* as opposed to mere representational features (Ioannidis et al., 2020, 9). All this again leads Ioannidis et al. to posit governing laws in addition to powers to play the extra constraining role evinced by conservation laws and symmetries.

In short, conservation laws and symmetries seem to evade the DE account of laws, which links laws and properties one-to-one, because there seems to be no one property in particular from the essence of which these laws could be said to flow.

## 5 Powers-BSA

The Powers-BSA (Demarest, 2017; Kimpton-Nye, 2017, 2021; Williams, 2019, sec. 10.1) is an alternative to Bird's canonical account of the relationship between laws and powers. In this section, I will outline the main features of and motivations for the Powers-BSA, which will allow me to then show how it can account for functional laws (Sect. 6), and conservation laws and symmetries (Sect. 7) in a principled manner and without the help of governing laws. The upshot is that the powers ontology is extricated from Bird's *specific* conception of the powers-laws relationship (but see also Chakravartty 2003, 2007) and the notoriously difficult counterexamples therein.

Properties, according to the Powers-BSA, are *powers* in the minimal sense that they are metaphysically necessarily connected with the dispositions that they confer upon their bearers. Powers thus induce metaphysically necessary (just *necessary*, from now on) connections between their individual *instances*.

The BSA (best system analysis) is an account of laws primarily pioneered by Lewis (1973, 1983, 1994) in the context of his Humeanism (but see also Ramsey 1990; Mill 1843). BSA laws supervene on the spatiotemporal distribution of properties (which Lewis conceives of as quiddities) by efficiently *describing* that distribution. More precisely: laws of nature are the axioms of the systematization of information about the spatiotemporal distribution of properties that strikes the optimal trade-off between strength and simplicity [the criterion of *fit* and the tricky issue of

<sup>3</sup> More precisely, Bigelow et al. say that global laws hold in virtue of the *natural kind* of which our universe is a member. But nothing of significance hangs on this detail.

<sup>4</sup> Though see Chakravartty (2019) who is more sympathetic to this kind of response, he takes it to be no more "arcane or grandiose" than alternative explanations of symmetries etc. in terms of fundamental laws and structure, as eliminative ontic structural realism would have it (e.g., French 2014).

*chance* is omitted for brevity, though see Kimpton-Nye (2017, sec. 5) for relevant discussion].

According to the *Powers-BSA*, laws describe not just the actual distribution of powers, but *all possible* distributions of powers. Powers-BSA laws are the axioms of the deductive systematization of all *possible* spatiotemporal distributions of powers that maximises strength, simplicity and perhaps other virtues.

## 5.1 Continuity with science: necessity and pragmatism

By systematizing all possible distributions of powers, laws (plausibly) come out *metaphysically necessary*.<sup>5</sup> This accounts for the fact that laws are held fixed in various counterfactual suppositions and thus play an important role in scientific reasoning and explanation.<sup>6</sup> Furthermore, by rendering the laws metaphysically necessary, the Powers-BSA can demystify metaphysical modality and assimilate the epistemology of modality to familiar scientific epistemology (see Edgington, 2004; Maudlin, 2007; Wilson, 2013, 2020 on the benefits of collapsing physical and metaphysical modality).

One might question the relevance of the *powers* component of the Powers-BSA: if laws gain their necessity by systematizing all *possible* property distributions, why does it matter if those properties are powers? As Demarest (2017, 49) has argued, if properties could freely recombine any which way, worlds would differ from one another *radically*. There would then be no non-trivial patterns across such disparate worlds and, so, no BSA-laws. But the fact that powers constrain how they are possibly distributed suggests that there will be a degree of similarity even between the most disparate worlds and, hence, that there *will* be non-trivial patterns in the inter-world distribution of powers. These patterns can then be identified with laws and will hold of necessity.

Once we admit powers, why not just take the laws to be the specific dispositional relations with which powers are necessarily connected? I take this to be tantamount to the Birdian approach: the essences of powers are constituted by dispositional relations and these are the laws. Besides the problems just discussed for canonical Birdian dispositional essentialism, one might worry that laws, so conceived, may not be of any use to cognitively limited creatures such as ourselves insofar as we are interested in navigating the world, making predictions, and pursuing our general scientific interests. If laws were particular dispositional relations, then they might turn out to be numerous and highly specific. At least, there would be as many laws as there are relations between fundamental properties. And this could turn out to be a lot of

<sup>5</sup> Why? The laws, on this view, describe all of modal space and, plausibly, facts about modal space are themselves necessary. To put the point in the language of possible worlds: even if possible worlds vary with respect to which powers are instantiated, by describing the distribution of powers across *all* possible worlds the laws come out necessary because what they describe, viz., facts about all possible worlds, are themselves necessary in that these do not vary from world to world. See Kimpton-Nye (2022, sec. 4.1) for more on this.

<sup>6</sup> Ioannidis et al. worry that necessary laws are problematic in light of counterlegal reasoning in science (2020, 9–10), but see Handfield (2004) and Kimpton-Nye (2020) for responses.



laws indeed if there turns out to be a great many fundamental properties each with many different dispositional “tracks”. If this were the case, the relevance of any particular such “law” to the overall temporal evolution of the universe will be swamped by the vast nexus of laws of which it is a part. Laws so conceived will hardly resemble the very useful, general, and tractable laws found in actual science. Plausibly, the usefulness of laws should not be hostage to empirical fortunes in this way.

Of course, it might turn out that there are very few fundamental properties each with very few dispositional tracks and hence very few fundamental dispositional relations that would qualify as laws. This would be good news as far as simplicity and perhaps usefulness of laws is concerned, but the problem now is one of epistemic accessibility. There is no guarantee that we should ever come to know the fundamental nature of reality, but I don’t think that this should be a barrier to our having knowledge of the laws. And besides, the point at the end of the previous paragraph still applies: plausibly, the usefulness of laws should not be hostage to whether or not there turns out to be many or few fundamental properties since it is part of the scientific conception of laws that they are useful to us. Hence, I propose a (modalized) BSA account of laws with a pragmatic flavour. The “best” system is the one that works best for *us* given our interests, abilities and epistemic limitations.<sup>7</sup> On this account, a failure to know the fundamental nature of reality is no obstacle to our having knowledge of the laws because knowledge of certain higher-level regularities that are explanatorily and predictively useful *for us* can suffice.

The motivations here are naturalistic. I don’t think it is the (naturalistic) metaphysician’s place to propose a metaphysics of laws that risks rendering those laws epistemically inaccessible to science, or useless to scientists, given that scientists themselves are plausibly working under the assumption that they know all sorts of laws and have good prospects of coming to know others and that laws help them do useful things such as building computers and spacecraft. The present strategy is to offer a metaphysics of laws that mirrors scientific practice in certain respects. Scientists are interested in providing strong simple generalizations that unify apparently disparate phenomena. The BSA component of the powers-BSA mirrors this aspect of scientific practice and *thereby* ensures the epistemic accessibility of laws via typical scientific methods of inquiry (see, e.g., Lewis, 1994; Loewer, 1996; Cohen & Callender, 2009; Hall, 2015; Demarest, 2017; Williams, 2019). As I will discuss in Sects. 6 and 7, it is its continuity with science in virtue of being pragmatic, that enables the Powers-BSA to so elegantly accommodate functional laws, conservation laws and symmetries.

The foregoing is relevant to another potential worry: granting the problems with the Birdian approach on which laws are derived one-to-one from property essences in accordance with steps (I) to (V), why think that we need to go all the way to the powers BSA to solve the problems? Couldn’t laws follow from property essences in a way that is not one-to-one but also not in accordance with the powers-BSA? If

<sup>7</sup> See, e.g., Cohen and Callender (2009), Hall (2015), Hicks (2017), Dorst (2017), Loew and Jaag (2020) on pragmatism and the BSA, and Williams (2019, Sec. 10.1) on achieving continuity with science by twinning an ontology of powers with a BSA-account of laws.

there were an alternative with comparable naturalistic credentials (and other virtues) to the powers-BSA then it would certainly be worthy of consideration. But if the proposal were, say, less *holistic* than the powers-BSA, then I'd worry that it might not succeed in mirroring the unificatory aspect of scientific practice quite as well as the powers-BSA does. And if it sought to derive laws from property essences in a more local manner, even if not one-to-one, then I'd be concerned that the epistemic worries may come back to bite. What's more, anything more "local" than the powers-BSA may struggle to capture the global conservation and symmetry laws (see Sect. 7, below). This is of course not to say that there could be no plausible middle road between Birdian dispositional essentialism and the powers-BSA, but such an alternative would have to be developed in sufficient detail before its merits could be properly assessed. As it stands, the powers-BSA, and the original BSA from which it descends, is quite well understood and independently well motivated (for the sorts of naturalistic reasons discussed). So, it makes sense to apply this view to the problems at hand.

## 6 Functional laws (solved)

In Sect. 3 we saw that DE precludes the possibility of functional laws. Far from being precluded from being laws, functional relationships look like excellent candidates for lawhood given the Powers-BSA.

Consider again Coulomb's Law

$$\text{Coulomb's law} \quad F = e \frac{q}{r^2}$$

Which tells us how determinate values of the determinable quantities *force*, *charge* and *distance* vary with each other. Coulomb's law is a function which takes as input determinate values of charge for distinct individuals and the distance between those individuals and outputs a value for the force of electrostatic attraction between those individuals. This has implications for the possible distributions of determinate instances of force and charge throughout spacetime.

So, insofar as laws are efficient summaries of the possible spatiotemporal distributions of concrete property instances that are useful for us, as the Powers-BSA would have it, Coulomb's Law is a good candidate for lawhood. Coulomb's Law is a strong, simple, and hence *useful*, way of conveying information about the possible distributions of determinate instances of *force* and *charge*. Far more useful, that is, than an infinitely long list of highly specific statements each of which tells us that some particular determinate value of force can be instantiated between individuals with particular determinate values of charge at some specific distance of separation. Functional relationships are well suited to presenting information about possible distributions of powers in a way that is easily accessible to us and useful for our practical and scientific endeavours. Hence, functional relationships are very likely to feature as axioms in our best systematization of all possible distributions of powers. Functional laws pose no problem in principle for

the Powers-BSA and, indeed, it is eminently plausible that functional relations will feature as Powers-BSA laws.

Ioannidis et al., sum up the problem that Coulomb's law poses for powers-based laws as follows:

How does charge 'manage' the information that is available to it? [...] [H]ow does the concrete charge happen to be sensitive to the right kind of information available in the inventory of possible values in such a way that Coulomb's law is satisfied? (2020, 7)

to which they swiftly respond:

[I]t is because the charge's behaviour *is governed by Coulomb's law* that the charge's power to attract and repel other charges is manifested in the way it does and not the other way around. (2020, 7)

But this response assumes that dispositional essentialism, according to which specific properties fully encode laws of nature because the latter flow from the essences of the former, is the only powers-based account of laws available.

According to the Powers-BSA, modally robust regularities such as Coulomb's law are manifestations of the *various* actual and possible interactions among the modally invariant constraining natures of *different* powers. Nothing needs to be said about how Coulomb's law *flows from the essence of* any specific power because the Powers-BSA does not posit specific powers considered in isolation as the source of laws. There is thus no question of charge "managing" any information and no problem presented by the fact that Coulomb's law cannot be derived from the essence of charge alone. Coulomb's law earns its status as a law because it efficiently conveys information about how determinate values of charge, force and distance vary with one another across modal space.

Coulomb's law and other regularities arise out of the multifarious interactions among all, or at least a great many, of the powers instantiated in the world and these regularities earn lawhood status by being useful to creatures like us. It is thus the global and pragmatic nature of the Powers-BSA that enables it to accommodate functional laws and avoid the critiques of Vetter and Ioannidis et al.

Does this suggestion make it *mysterious* or objectionably coincidental that properties "conspire" to interact in such a way as to satisfy the very simple regularity that is Coulomb's law (and *mutatis mutandis* for other laws)? I don't think so. The possible property distributions are not purely coincidental in the way that distributions of the Humean's quiddities may be thought to be since it is still the modal natures of properties themselves that are constraining their possible distributions and thus giving rise to, or metaphysically explaining, the regularities in question. But if you still think that there is some coincidence here why not also think that it is a coincidence that the essences of the Birdian dispositional essentialist's properties are such as to give rise to a regular, ordered, *lawful* world? Of course, property essences or modal natures could have been way more "chaotic" and given rise to no regularity or order at all, but I think this is just as much a problem for traditional dispositional essentialism as it is for the powers-BSA.

What the latter views (but not Humeanism) offer is a *metaphysical* explanation of regularities in terms of the natures of those properties regularly distributed. We can push the question *why* the natures of properties metaphysically explain the regularities that they do, but this may be an explanatory demand too far, explanation must bottom out somewhere.

Finally, instead of the present proposal, one might take the problem discussed in Sect. 3 as motivating a view of powers as multi-track determinable properties which would then be capable of grounding functional laws one-to-one (Vetter, 2012, 2015 might be read as proposing something along these lines, see Sect. 3, above). But this would not help with the problem of *global* conservation laws and symmetries which, as discussed, do not seem to be grounded in any particular properties. In the interest of providing a unified account of all laws of nature, then, the present suggestion seems preferable and it is to global laws to which I turn next.

## 7 Conservation laws and symmetries (solved)

Conservation laws say that certain physical quantities are conserved in all interactions; a closed system could not lose or gain conserved quantity, *C*, in a given time-interval. This has implications for the possible spatiotemporal distributions of conserved quantities. For example, *C* could not be distributed such that a closed system instantiates *C* with magnitude 5 at time *t*<sub>1</sub> and instantiates *C* with magnitude 10 at some later time, *t*<sub>2</sub>. Symmetry principles specify transformations (such as boosts in velocity or rotations) that an entity can undergo while certain properties of that entity remain unchanged. So, if *C* is invariant under rotational translation, an entity that instantiated *C* with magnitude 5 and underwent a rotational translation would still instantiate *C* with magnitude 5 after the translation, all else being equal. Conservation laws and symmetries thus articulate constraints on how properties are possibly distributed throughout spacetime, hence they look like good candidates for lawhood, given the Powers-BSA.<sup>8</sup>

The global nature of conservation laws and symmetries poses a problem for dispositional essentialism because it makes it hard to say from which property essence, or essences, *in particular* they are supposed to flow. But, as discussed, the Powers-BSA rejects the idea that laws are so “local” as to have their metaphysical source in particular properties considered in isolation. Instead, laws are features of an integrated description of all possible distributions of all powers. Global principles are thus prime candidates for lawhood given the more *holistic* Powers-BSA account of laws.

The global, integrative nature of the Powers-BSA is related to the pragmatic roots of the BSA, which (in agreement with the pragmatic Humeans, see fn. 7, above) I

<sup>8</sup> Perhaps for some “constraint” has an *external governing* connotation. Though for all that’s been said, there is no requirement that the *constraints* articulated be understood as an active *external* source such as a governing law, they may just as well be possible distributions, in keeping with the Powers-BSA.

think are worth emphasising. The Lewisian BSA is a development of Ramsey's idea that laws are

[C]onsequences of those propositions which we should take as axioms if we knew *everything* and organised it as simply as possible in a deductive system. (Ramsey, 1990, 150)

BSA-laws must be integrative; they must take *everything* (or as much of everything as admits systematizing and we could reasonably be expected to come to know) into account in order to effectively maximise the virtues of strength and simplicity and thus satisfy the pragmatic demand on what it is to be a law of nature.<sup>9</sup>

The Powers-BSA satisfies this pragmatic, integrative demand, thus earning the 'BSA' part of its name, as follows. Patterns in possible distributions of powers that we cotton on to arise out of the multifarious and complex possible interactions between *all* powers instantiated in the world. No particular property considered in isolation suffices to metaphysically account for a law of nature, on this account, so the question does not even arise as to from which particular property essences conservation laws and symmetries flow because *no* law is so local as to be fully grounded in any *particular* property essence (this mirrors what was said in the previous section about functional laws). So, far from being problematic exceptions due to their global nature, conservation and symmetry principles are paradigm laws, according to the Powers-BSA, which due to its integrative, pragmatic nature conceives of *all* laws as global. The Powers-BSA and dispositional essentialism are in agreement that lawful regularities have their metaphysical source in powers. But whereas the latter wishes to localize the source of any given law to the essence of a *particular* power, the former takes all laws to have their metaphysical source in all powers considered collectively. This is why *global* conservation laws and symmetries are so naturally accommodated by the Powers-BSA whereas they are so problematic for dispositional essentialism.

Given the Powers-BSA, there is thus no need to provide an ad hoc *property of the world*-type explanation of conservation laws and symmetries, or an inflated ontology of powers *and* governing laws—these global laws are accommodated in a principled way within a monistic anti-Humean ontology of powers.

## 8 Conclusion

Conservation laws and symmetries have been thorns in the side of powers-based accounts of laws of nature for some time, and Vetter's problem of functional laws adds insult to injury. These issues have led Ioannidis et al. (2020) to posit a dualist anti-Humean ontology of powers and laws: powers give the laws something to latch onto and laws pick up powers' explanatory slack.

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<sup>9</sup> There is probably something interesting to say about how to square Lewis's arch realism with the pragmatist influence of Ramsey, but I leave that for another time.

I have argued that this inflation of the anti-Humean ontology is far too hasty. There is still plenty of hope for a monistic ontology of powers, so long as dispositional essentialism, epitomized by Bird's derivation of a law from the essence of a potency, is rejected. By conceiving of laws as flowing from the essences of specific properties in accordance with the derivation in steps (I) to (V), dispositional essentialism is doomed to fail to count functional relationships as laws and its best hope for accommodating conservation laws and symmetries looks incredibly ad hoc. The Powers-BSA is not so hamstrung, it quite naturally accommodates functional laws, conservation laws and symmetries by subsuming them under a more holistic and pragmatic conception of lawhood.

What's more, the Powers-BSA itself is no ad hoc fix—it is independently superior to dispositional essentialism in at least two broad respects. For one, it is continuous with actual scientific practice of systematizing the world and its modally robust patterns in a way that creatures such as ourselves can exploit in pursuit of our practical and scientific endeavours. In contrast, there is no guarantee that the dispositional essentialist's laws, derived as they are from specific property essences, will have these pragmatic features. Furthermore, dispositional essentialism has something of a *virtus dormitiva* flavour to it: laws are supposed to constitute the essences of properties which are supposed to, in turn, explain those very laws. But it hardly seems explanatory stipulate that a law, *L*, is part of the essence of a property, *P*, only to then say that *P*'s essence explains *L*. Yet this is exactly what seems to be going on in the dispositional essentialist account of laws presented in steps (I) through (V) [see Barker (2013), Jaag (2014), Sider (2020, chap. 2), Kimpton-Nye (2021)]. By rejecting the idea that laws flow from property essences, the Powers-BSA avoids the general *virtus dormitiva*-type worry, achieves continuity with science and *thereby* overcomes the challenges of accounting for functional laws and global laws. It is about time, then, that the Powers-BSA replaced dispositional essentialism as the leading anti-Humean account of the relationship between properties and laws.

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