

The Simplicity of Physical Laws

Eddy Keming Chen*

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Abstract

Physical laws are strikingly simple, although there is no *a priori* reason they must be so. I propose that nomic realists of all types (Humeans and non-Humeans) should accept that simplicity is a fundamental epistemic guide for discovering and evaluating candidate physical laws. The proposal addresses several problems of nomic realism and simplicity. A consequence is that the oft-cited epistemic advantage of Humeanism over non-Humeanism disappears, undercutting an influential epistemological argument for Humeanism. Moreover, simplicity is shown to be more tightly connected to lawhood than to mere truth.

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*Department of Philosophy, University of California, San Diego, 9500 Gilman Dr, La Jolla, CA 92093-0119. Website: www.eddykemingchen.net. Email: eddykemingchen@ucsd.edu

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1 Introduction

Physical laws are strikingly simple, although there is no *a priori* reason they must be so. My goal in this paper is to articulate and clarify the view that simplicity is a fundamental epistemic guide for discovering and evaluating the fundamental laws of physics.

Many physicists and philosophers are realists about physical laws. Call realism about physical laws *nomic realism*. It contains two parts. First, physical laws are objective and mind-independent. Second, we have epistemic access to physical laws.¹ Nomic realism apparently contains an epistemic gap: if physical laws are objective and mind-independent, it is puzzling how we can have epistemic access to them, since laws are not direct consequences of our observations. The gap can be seen as an instance of a more general one regarding theoretical statements on scientific realism (Chakravartty 2017).

In response to the epistemic gap, nomic realists invoke super-empirical theoretical virtues, a familiar example of which is simplicity. Simplicity can be used to eliminate a large class of empirically equivalent theories that contain complicated laws. Together with other theoretical virtues, it may even yield a unique theory at the end of inquiry given the totality of evidence. However, there are several difficulties with simplicity (Baker 2022, Fitzpatrick 2022):

1. The problem of coherence: naive applications of the principle of simplicity lead to probabilistic incoherence (sometimes called the problem of nested theories, or the problem of conjunctive explanations).
2. The problem of justification: there is no plausible epistemic justification for the principle of simplicity.
3. The problem of precision: there is no precise standard for simplicity.

These problems are not unique to simplicity. One can ask similar questions about other super-empirical virtues such as unification and informativeness. We face related problems whenever we use super-empirical virtues to guide our theory choice. What one says about simplicity should also apply to other epistemic guides that nomic realism employs. For concreteness, I shall focus on simplicity in this paper.

I develop a framework for thinking about simplicity as a fundamental epistemic guide to physical laws. When we analyze the content of nomic realism, we discover a

¹See Peebles (2024) for a recent example of a physicist’s version of nomic realism.

straightforward solution to the problem of coherence. When we reflect on the applications of simplicity, we find good reasons for taking it as a *fundamental* principle that requires no further epistemic justification. When we consider the variety of cases it applies to, we see it is necessary to maintain a *vague* principle that only takes on precise forms in specific domains.

Is this framework redundant for Humeans? No. It is sometimes believed that, on the best-system account of laws (BSA), we get the simplicity of physical laws for free, because laws are defined to be simple and informative summaries of the mosaic. That is a mistake, because we are not given the mosaic. The principle of simplicity must be added to BSA as an epistemic norm; it guides our expectations about the best system, even when we do not have direct epistemic access to the mosaic. As we shall see, since both Humeanism and non-Humeanism need an independent epistemic principle concerning the simplicity of physical laws, they are on a par regarding the empirical discovery of laws. If there is no problem for Humeans to adopt the epistemic guide, there is no problem for non-Humeans either. As a consequence, the oft-cited epistemic advantage of the former over the latter disappears. (See (Hildebrand 2022, §8) for a similar perspective; see also (Chen and Goldstein 2022, §4.1).) This undercuts an influential epistemic argument for Humeanism (Earman and Roberts 2005). Nevertheless, *the real targets of the simplicity postulate can be different*: on non-Humeanism it is an epistemic guide about which laws we should entertain, while on Humeanism it is ultimately an epistemic guide about which type of mosaics we should take seriously.

Recent works in the foundations of physics and the metaphysics of laws have provided new case studies that call for a more systematic look at the methodological principles required for upholding nomic realism. I offer this framework as a lens to think about various commitments of nomic realism in a more unified way. This may not be the only lens possible, but it has a number of features attractive to nomic realists. For one thing, simplicity is recognized as an important theoretical virtue in scientific practice (Schindler 2022), and it is one principle that nomic realists may already endorse. Its theoretical benefits, as I hope to show, justify the cost of the posit. Although the discussion here is not meant to convince nomic anti-realists, they may still find it useful for understanding a position they ultimately reject.

Here is the plan. First, I clarify nomic realism and its metaphysical and epistemological commitments. I illustrate the epistemic gap by considering three algorithms for generating empirical equivalents. I introduce the principle of nomic simplicity as a tie-breaker and show how it solves the problem of coherence. Next, I examine five additional applications of the principle of simplicity: induction, symmetries, dynamics, determinism, and explanation. The upshot is that simplicity may be more fundamental than many methodological principles we already accept. The applications suggest that the principle is best taken as a fundamental yet vague epistemic principle. The analysis also clarifies why Humeanism has no epistemic advantage over non-Humeanism, regarding our epistemic access to physical laws.

2 Nomic Realism

Nomic realism contains an epistemic gap. Let *nomic realism* denote the conjunction of the following:

Metaphysical Realism: Physical laws are objective and mind-independent; more precisely, which propositions express physical laws are objective and mind-independent facts in the world.²

Epistemic Realism: We have epistemic access to physical laws; more precisely, we can be epistemically justified in believing which propositions express physical laws, given the evidence that we will in fact obtain.³

Nomic realists would like to endorse both theses, and the puzzle is how. It is an instance of a more general puzzle regarding how we can be justified in believing anything beyond the logical closure of empirical evidence. One can already see that it is closely related to issues about the rationality of induction and scientific explanation, which we will discuss in §4. But first, we need to understand what the gap looks like in specific cases. For concreteness, let us look at a Humean account and a non-Humean account, both of which aspire to satisfy nomic realism. The epistemic gap, shared by many realist accounts of physical laws, can be illustrated with the following examples.

2.1 Two Accounts

First, consider the Humean best-system account of Lewis (1973, 1983, 1986), with some modifications:

Best System Account (BSA) Fundamental laws of nature are the axioms of the best system that summarizes the mosaic and optimally balances simplicity, informativeness, fit, and degree of naturalness of the properties referred to. The mosaic (spacetime and its material contents) contains only local matters of particular fact, and the mosaic is the complete collection of fundamental facts. The best system supervenes on the mosaic.⁴

²A weaker version of metaphysical realism maintains that laws are not entirely mind-dependent. That will accommodate more pragmatic versions of the Humean best-system accounts (e.g. Loewer (2007b), Cohen and Callender (2009), Hicks (2018), Dorst (2019), Jaag and Loew (2020), and the volume edited by Hicks et al. (2023)), since on such views the mosaic still partially determines the best system. The arguments below should apply with suitable adaptations.

³The terminology is due to Earman and Roberts (2005). Here I've added the clause "given the evidence that we will in fact obtain." My version of epistemic realism is logically stronger than theirs, since theirs includes all possible evidence we can obtain. I return to the difference in §5.3.

⁴A key difference between this version and Lewis's (Lewis 1973, 1983, 1986) is that the latter but not the former requires fundamental laws to be regularities. The other difference is the replacement of perfect naturalness with degree of naturalness. See (Chen 2022b, sect.2.3) for more in-depth comparisons. On Humeanism, the mosaic is traditionally required to be about local matters of particular fact. There are other Humean accounts of laws; see Roberts (2008) for an example.

BSA satisfies metaphysical realism, even though its laws are not metaphysically fundamental. Given a particular mosaic (spacetime manifold with material contents), there is a unique best system that is objectively best.⁵

Next, consider a recent non-Humean account according to which laws govern and exist over and above the material contents (Chen and Goldstein 2022):

Minimal Primitivism (MinP) Fundamental laws of nature are certain primitive facts about the world. There is no restriction on the form of the fundamental laws. They govern the behavior of material objects by constraining the physical possibilities.

MinP satisfies metaphysical realism, because the primitive facts about the world are taken to be objective and mind-independent. It is minimal in the sense that it places no restrictions on the form of fundamental physical laws.⁶ MinP is compatible with fundamental laws taking on the form of boundary conditions, least action principles, and global spacetime constraints.⁷ (Chen and Goldstein 2022) also posit an epistemic principle called “Epistemic Guides” that we will discuss in §5.3.

2.2 The Epistemic Gap

Do BSA and MinP vindicate epistemic realism? Their metaphysical posits, by themselves, do not guarantee epistemic realism. This should be clear on MinP. Since there is no metaphysical restriction on the form of laws, if laws are entirely mind-independent primitive facts about the world, how do we know which propositions correspond to the laws? However, an analogous problem exists on BSA. This claim may surprise some philosophers, as it is often thought that BSA has an epistemic advantage over non-Humean accounts like MinP, precisely because BSA brings laws closer to us. BSA defines laws in terms of the mosaic, and the mosaic is all we can empirically access (Earman and Roberts 2005).

The problem is that *we are not given the mosaic*. Just like physical laws, the mosaic postulated in modern physics is a theoretical entity that is not entailed by our observations. Our beliefs about its precise nature, such as the global structure of spacetime, its microscopic constituents, and the exact matter distribution, are as theoretical and inferential as our beliefs about the physical laws. They are all parts of a theory about the physical world. Just as defenders of MinP require an extra epistemic principle to infer what the laws are, defenders of BSA require a *similar* principle to infer what

⁵For the sake of the argument, for now I set aside the worry of “ratbag idealism” and grant Lewis’s assumption that nature is kind to us (Lewis 1994, p.479). Even if a revised version of BSA satisfies only the weaker version of metaphysical realism for which laws are not entirely mind-dependent, it does not automatically secure epistemic realism, as we shall see.

⁶In this paper, I shall use “fundamental laws,” “fundamental physical laws,” “physical laws,” and “laws” interchangeably.

⁷See Adlam (2022b) and Meacham (2023) for related views, and Hildebrand (2020) for an overview of non-Humeanism. The arguments below, with suitable adaptations, apply to other versions of non-Humeanism, including the Powers Best-System Account (Powers BSA) developed by Demarest (2017) and Kimpton-Nye (2017). There is also an epistemic gap between our evidence and the best systematization of the exact power distributions in the actual world and other possible worlds. See Schwarz (2023) for a detailed discussion. Defenders of Powers BSA can adopt a version of PNS to guide their epistemic expectations about the likely power distributions.

the mosaic is like. The latter, on BSA, turns out to be a strong epistemic principle concerning what we should expect about the best system given *our limited evidence*, which because of its limitation pins down neither the mosaic nor the best system.

After all, on BSA laws are not summaries of our observations only, but of the entire spacetime mosaic constituted by the totality of microphysical facts, a small minority of which show up in our macroscopic observations. The ultimate judge of which system of propositions is the optimal true summary depends on the entire mosaic, a theoretical entity. (For this reason, BSA should not be confused with a version of strict empiricism.) And in current physics, our best guide to the mosaic is our best guess about the physical laws. At the end of the day, both MinP and BSA require a super-empirical epistemic principle concerning physical laws. On neither account does the epistemic principle follow from the metaphysical posits about what laws are. This has ramifications for a debate between Humeans and non-Humeans, to which I return in §5.3.

To sharpen the discussion, let us suppose, granting Lewis's assumption of the kindness of nature (Lewis 1994, p.479), that given the mosaic ξ there is a unique best system whose axioms express the fundamental law L :

$$L = BS(\xi) \tag{1}$$

with $BS(\cdot)$ the function that maps a mosaic to its best-system law.⁸ Let us stipulate that for both BSA and MinP, physical reality is described by a pair (L, ξ) . For both, we must have that $\xi \in \Omega^L$, with Ω^L the set of mosaics compatible with L . This means that L is true at ξ . On BSA, we also have that $L = BS(\xi)$. So in a sense, all we need in BSA is ξ ; L is not ontologically extra. But it does not follow that BSA and MinP are relevantly different when it comes to epistemic realism.

Let E denote our empirical evidence consisting of our observational data about physical reality. Let us be generous and allow E to include not just our current data but also all past and future data about the universe that we in fact gather. There are two salient features of E :

- E does not pin down a unique ξ . There are different candidates of ξ that yield the same E . (After all, E is a spatiotemporally partial and macroscopically coarse-grained description of ξ .)
- E does not pin down a unique L . There are different candidates of L that yield the same E . (On BSA, this is an instance of the previous point; on MinP, this is easier to see since L can vary independently of ξ , up to a point.)

Hence, on BSA, just as on MinP, E does not pin down (L, ξ) . There is a gap between what our evidence entails and what the laws are. Ultimately, the gap can be bridged by adopting simplicity (among other super-empirical virtues) as an epistemic guide. Nevertheless, it helps to see how big the gap is so that we can appreciate how much work needs to be done by simplicity and other epistemic guides.⁹

⁸We might understand pragmatic Humeanism as recommending that we use another best-system function $BS'(\cdot)$ that is "best for us."

⁹It is worth contrasting the current setup with the influential framework suggested by Hall (2009,

2.3 Empirical Equivalence

The epistemic gap can be illustrated by considering cases of empirical equivalence. If different laws yield the same evidence, it is puzzling how we can be epistemically justified in choosing one over its empirically equivalent rivals, unless we rule them out by positing substantive assumptions that go beyond the metaphysical posits of nomic realism. In the literature (see for example Kukla (1998)), there are suggestions about how to algorithmically generate empirically equivalent rivals, but some of them are akin to Cartesian skeptical scenarios (Stanford 2023), such as the evil-demon hypothesis. Here I offer three new algorithms, modeled on concrete proposals considered in recent discussions in the philosophy of physics. They have more limited scopes and should be less controversial.

I shall use a fairly weak notion of empirical equivalence, according to which L_1 and L_2 are empirically equivalent with respect to actual evidence E just in case E is compatible with L_1 and L_2 . This criterion, with the emphasis on actual data E , is weaker than the notion of empirical equivalence according to which two laws should agree on not just actual data but all possible data (data that can in principle be measured in the actual world as well as those in any nomologically possible world). I will drop the explicit reference to E in what follows. There are two reasons for using the weaker criterion. First, it is sufficient for illustrating the epistemic gap. Second, what is in-principle measurable in the actual world and in nomologically possible worlds depends on what the laws are. Using actual data instead of all possible data provides a more level playing field when discussing different hypotheses about laws.

Algorithm A: “Moving” parts of ontology (what there is in the mosaic) into the nomology (the package of laws).

General strategy. This strategy works on both BSA and MinP. Given a theory of physical reality $T_1 = (L, \xi)$, if ξ can be decomposed into two parts ξ_1 & ξ_2 , we can construct an empirically equivalent rival $T_2 = (L \& \xi_1, \xi_2)$, where ξ_1 is moved from ontology to nomology. One of the upshots is that evidence collected in any region of spacetime underdetermines the laws, since it does not pin down what belongs in the ontology and what in the nomology.

Example. Consider the standard theory of Maxwellian electrodynamics, T_{M1} :

- Nomology: Maxwell’s equations, Lorentz force law, and Newton’s law of motion.
- Ontology: a Minkowski spacetime occupied by charged particles with trajectories $Q(t)$ and an electromagnetic field $F(x, t)$.

Here is an empirically equivalent rival, T_{M2} :

- Nomology: Maxwell’s equations, Lorentz force law, Newton’s law of motion, and

2015). To distill a core idea of BSA, Hall imagines a Limited Oracular Perfect Physicist (LOPP) who has as her evidence all of ξ and nothing else. Her evidence E_{LOPP} contains vastly more information than E , our total evidence characterized above. On BSA, E_{LOPP} , plus the assumption that E_{LOPP} is exhaustive of the entire mosaic (the “that’s all” clause), pins down (L, ξ) . Notice that E_{LOPP} (and the “that’s all” clause) is as theoretical for Humeans as for non-Humeans. The Humean’s best guess about what is in E_{LOPP} depends on her expectation about what L looks like given E .

an enormously complicated law specifying the exact functional form of $F(x, t)$ that appears in the dynamical equations.

- **Ontology:** a Minkowski spacetime occupied by charged particles with trajectories $Q(t)$.

Our evidence E is compatible with both T_{M1} and T_{M2} . The outcome of every experiment in the actual world will be consistent with T_{M2} , as long as the outcome is registered as certain macroscopic configuration of particles (Bell 2004). We can think of the new law in T_{M2} as akin to the Hamiltonian function in classical mechanics, which is interpreted as encoding all the classical force laws, except that specifying $F(x, t)$ is much more complicated than specifying the standard Hamiltonian. Both $F(x, t)$ and the Hamiltonian are components of respective laws of nature that tell particles how to move.¹⁰ Algorithm A illustrates the possibility that we can be mistaken about what the ontology is and what the laws are. If T_{M2} is the correct theory, what we commonly believe to be a bit of ontology turns out to be a feature of the laws.¹¹

Algorithm B: Changing the nomology directly.

General strategy. This strategy is designed for MinP. We can generate empirical equivalence by directly changing the nomology. Suppose the actual mosaic ξ is governed by the law L_1 . Consider L_2 , where $\Omega^{L_1} \neq \Omega^{L_2}$ and $\xi \in \Omega^{L_2}$. L_1 and L_2 are distinct laws because they have distinct sets of mosaics. Since E (which can be regarded as a coarse-grained and partial description of ξ) can arise from both, the two laws are empirically equivalent. There are infinitely many such candidates for Ω^{L_2} . For example, Ω^{L_2} can be obtained by replacing one mosaic in Ω^{L_1} with another outside Ω^{L_1} , by adding some mosaics to Ω^{L_1} , or by removing some non-actual mosaics in Ω^{L_1} . L_2 is empirically equivalent to L_1 since E is compatible with both.¹²

Example. Let L_1 be the Einstein equation of general relativity, with $\Omega^{L_1} = \Omega^{GR}$, the set of general relativistic spacetimes. Suppose that the actual spacetime is governed by L_1 , so that $\xi \in \Omega^{L_1}$. Consider L_2 , a law that permits only the actual spacetime and completely specifies its microscopic detail, with $\Omega^{L_2} = \{\xi\}$. Insofar as our evidence E arises from ξ , it is compatible with both L_1 and L_2 . Since it needs to encode the exact detail of ξ , in general L_2 is much more complicated than L_1 . (L_2 is a case of strong determinism. See Adlam (2022a) and Chen (2024a, 2023) for more discussions on strong determinism.)

Algorithm C: Changing the nomology by changing the ontology.

General strategy. This strategy is designed for BSA. On BSA, we can change the nomology by making suitable changes in the ontology (mosaic), which will in general change what the best system is. Suppose the actual mosaic ξ is optimally described by the actual best system $L_1 = BS(\xi)$. We can consider a slightly different mosaic ξ' , such

¹⁰Note that we can decompose the standard ontology in many other dimensions, corresponding to more ways to generate empirically equivalent laws for a Maxwellian world. This move is discussed at length by Albert (2022). Similar strategies have been considered in the “quantum Humeanism” literature. See Miller (2014), Esfeld (2014), Callender (2015), Bhogal and Perry (2017), and Chen (2022a).

¹¹I thank an anonymous reviewer for suggesting this clarification.

¹²See Manchak (2009, 2020) for more examples.

that it differs from ξ in some spatiotemporal region that is never observed and yet E is compatible with both ξ and ξ' . There are infinitely many such candidates for ξ' whose best system $L_2 = BS(\xi')$ differs from L_1 . Alternatively, we can expand ξ to $\xi' \neq \xi$ such that ξ is a proper part of ξ' . There are many such candidates for ξ' whose best system $L_2 = BS(\xi')$ differs from L_1 , even though E is compatible with all of them.

Example. Let L_1 be the Einstein equation of general relativity, with $\Omega^{L_1} = \Omega^{GR}$, the set of general relativistic spacetimes. Suppose that the actual spacetime is globally hyperbolic and optimally described by L_1 , so that $L_1 = BS(\xi)$. Consider ξ' , which differs from ξ in only the number of particles in a small spacetime region R in a far away galaxy that no direct observation is ever made. Since the number of particles is an invariant property of general relativity, it is left unchanged after a “hole transformation” (Norton 2019). Since ξ is globally hyperbolic, we can use determinism to deduce that ξ' is incompatible with general relativity, so that $L_1 \neq BS(\xi')$. Let L_2 denote $BS(\xi')$. $L_1 \neq L_2$ and yet they are compatible with the same evidence we obtain in ξ . Since ξ' violates the conservation of number of particles, L_2 should be more complicated than L_1 .

We have considered three algorithms that establish the existence of empirically equivalent rival laws, for a world like ours. Moreover, we can combine such algorithms to produce more sophisticated examples of empirical equivalence.¹³ They are inspired by recent discussions in philosophy of physics. None of them requires Cartesian skepticism. Our evidence underdetermines the laws, on both BSA and MinP. If such algorithms are allowed, how can we maintain epistemic realism? We may summarize the puzzle about nomic realism:

Puzzle about Nomic Realism: In such cases of empirical equivalence, what justifies the acceptance of one candidate law over the other?

3 The Principle of Nomic Simplicity

It has been recognized, correctly on my view, that nomic realists need to invoke theoretical virtues as a way to choose among empirically equivalent laws underdetermined by evidence. An important example is the *principle of simplicity* (PS), according to which simplicity is a guide to truth and can be used as a tie-breaker for empirical equivalents. I explain why PS faces a problem of coherence (§3.1), formulate a better alternative which I call the *principle of nomic simplicity* (PNS) (§3.2), discuss how it breaks ties (§3.3), and generalize the core idea in three ways (§3.4).

3.1 The Problem of Coherence

The *principle of simplicity* (PS) has intuitive appeal, as paradigm examples of physical laws are strikingly simple and simpler than other candidates that yield the same data. Moreover, in the examples of empirical equivalence discussed before, the simpler law does seem like the better candidate.

¹³For example, in certain settings, we can change both the ontology and the nomology to achieve empirical equivalence. For every wave-function realist theory, there is an empirically equivalent density-matrix realist theory Chen (2019). Their ontology and nomology are different, but no experiment can determine which is correct.

What does it mean for simplicity to be a guide? A guide is not a guarantee. Inferences in the context of uncertainty, even when epistemically justified, are fallible. We can make mistakes when relying on the principle of simplicity. Perhaps the actual physical laws are less simple than the ones we regard as laws, based on the principle of simplicity. I think a realist should admit this possibility. Indeed it is a hallmark of realism that we can be wrong, even when we follow scientific methodology. This uncertainty can be formulated with epistemic probabilities:

Principle of Simplicity (PS) Other things being equal, simpler propositions are more likely to be true. More precisely, other things being equal, for two propositions L_1 and L_2 , if $L_1 >_S L_2$, then $L_1 >_P L_2$, where $>_S$ represents the comparative simplicity relation, $>_P$ represents the comparative relation of epistemic prior probabilities.¹⁴

PS regards simplicity as a guide to *truth*. A proposition being simpler raises its epistemic prior probability of being true relative to a more complicated proposition. Although this is close to the usual gloss that simplicity is an epistemic guide, it is the wrong principle for nomic realists. PS faces an immediate problem—the problem of nested theories, or sometimes called the problem of conjunctive explanations.¹⁵

Problem of Coherence PS leads to probabilistic incoherence.

Whenever two theories have nested sets of mosaics, say $\Omega^{L_1} \subset \Omega^{L_2}$, the probability that L_1 is true cannot be higher than the probability that L_2 is true (Figure 1). For concreteness, consider an example from spacetime physics. Let Ω^{GR} denote the set of mosaics compatible with the fundamental law in general relativity—the Einstein equation, and let Ω^{GR^+} denote the union of Ω^{GR} and a few random mosaics that do not satisfy the Einstein equation. Suppose there is no simple law that generates Ω^{GR^+} . While the law of *GR* (the Einstein equation) is presumably simpler than that of GR^+ , the former cannot be more likely to be true than the latter, since every model of *GR* is a model of GR^+ , and not every model of GR^+ is a model of *GR*. This is an instance of the problem of nested theories, as Ω^{GR} is a subclass of and nested within Ω^{GR^+} .

3.2 The Correct Principle

I propose that *simplicity is a fundamental epistemic guide to lawhood*. Roughly speaking, simpler candidates are more likely to be laws, all else being equal, in terms of epistemic prior probabilities. This principle solves the problem of coherence in a straightforward way. It also secures epistemic realism in cases of empirical equivalence where simplicity is the deciding factor. In particular, we should accept this principle:

Principle of Nomic Simplicity (PNS) Other things being equal, simpler propositions are more likely to be laws. More precisely, other things being equal, for two

¹⁴It may be too demanding to require a total order that induces a *normalizable* probability distribution over the space of all possible laws. It is less demanding to formulate PS in terms of comparative probability.

¹⁵The problem has been much discussed in philosophy of science but seldom discussed in foundations of physics. It was first raised by Popper (2005) against the Bayesian proposal of Wrinch and Jeffreys (1921). For recent discussions, see Sober (2015), Schupbach and Glass (2017) and Henderson (2023).

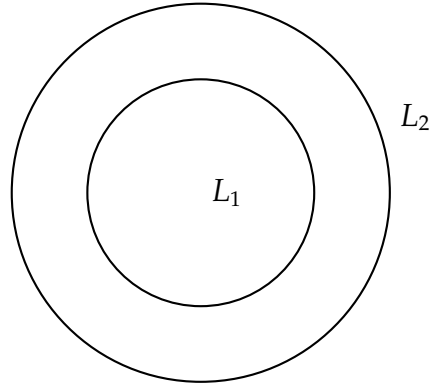


Figure 1: L_1 cannot be more likely to be true than L_2 , since every model of L_1 is a model of L_2 .

propositions L_1 and L_2 , if $L_1 >_s L_2$, then $L[L_1] >_p L[L_2]$, where $>_s$ represents the comparative simplicity relation, $>_p$ represents the comparative relation of epistemic prior probabilities, and $L[\cdot]$ denotes *is a law*, which is an operator that maps a proposition to one about lawhood.¹⁶

From the perspective of nomic realism, one can consistently endorse PNS without endorsing PS. Some facts are laws, but not all facts are laws. Laws correspond to a special set of facts. On BSA, they are the best-system axioms. On MinP, they are the primitive facts that constrain physical possibilities.

We are ready to see how PNS solves the problem of nested theories. Recall the earlier example of GR and GR^+ . Even though we think that the Einstein equation is more likely to be a law, it is less likely to be true than the equations of GR^+ . I suggest that what simplicity selects here is not truth in general, but truth about lawhood, i.e. whether a certain proposition has the property of being a fundamental law.

Let us assume that fundamental lawhood is factive, which is granted on both BSA and MinP. Hence, lawhood implies truth: $L[p] \Rightarrow p$. However, truth does not imply lawhood: $p \not\Rightarrow L[p]$. This shows that $L[p]$ is logically inequivalent to p , which is the key to solve the problem of coherence.

On PS, in the case of nested theories, we have probabilistic incoherence. If L_1 is simpler than L_2 , PS suggests that $L_1 >_p L_2$. However, if L_1 and L_2 are nested with $\Omega^{L_1} \subset \Omega^{L_2}$, the axioms of probability entail that $L_1 \leq_p L_2$. Contradiction!

On PNS, the contradiction is removed, because *more likely to be a law* does not entail *more likely to be true*. If L_1 and L_2 are nested, where L_1 is simpler than L_2 but $\Omega^{L_1} \subset \Omega^{L_2}$, then $L_1 \leq_p L_2$. It is compatible with the fact that $L[L_1] >_p L[L_2]$ (see Figure 2 for an example). What we have is an inequality chain:

$$L[L_2] <_p L[L_1] \leq_p L_1 \leq_p L_2 \quad (2)$$

This is a simple solution to the problem of nested theories / problem of coherence.¹⁷

¹⁶For example, $L[F = ma]$ expresses the proposition that $F=ma$ is a law. The proposition $F=ma$ is what Lange (2009) calls a “sub-nomic proposition.”

¹⁷My solution in the context of laws is, in some aspect, similar to the solution proposed by Henderson (2023) in terms of a “generative view” of scientific theories. Henderson suggests that we regard theories

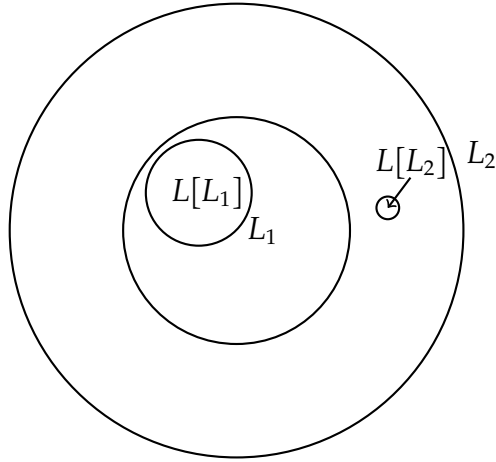


Figure 2: L_1 and L_2 are nested, while $L[L_1]$ and $L[L_2]$ are not. In this model, $L[L_2] <_P L[L_1] \leq_P L_1 \leq_P L_2$.

In §3.3, we apply PNS to break to the ties among empirical equivalents. In §3.4, we generalize the core idea to other theoretical virtues and apply it to the problem of coherence for non-nested theories.

3.3 Simplicity as a Tie Breaker

PNS is useful for resolving cases of empirical equivalence constructed along Algorithms A-C in §2.3.

For Algorithm A, T_2 will in general employ much more complicated laws than T_1 . For example, the laws of T_{M2} specify $F(x, t)$ in its exact detail. Given that $F(x, t)$ is not a simple function of space and time coordinates, the laws of T_{M2} are not simple. In contrast, the laws of T_{M1} need not specify something so complicated. PNS suggests that other things being equal, we should choose T_{M1} over T_{M2} . In a Maxwellian world, we should postulate the existence of fields in the ontology and not in the nomology.¹⁸

For Algorithm B, L_2 will in general be more complicated than L_1 , if Ω^{L_2} is obtained from Ω^{L_1} by adding or subtracting a few mosaics. For example, a strongly deterministic theory of some sufficiently complex general relativistic spacetime, as described in the example, needs to specify the exact detail of that spacetime and employ laws much more complicated than the Einstein equation. PNS suggests that other things being equal, we should choose the Einstein equation over such strongly deterministic laws.¹⁹

For Algorithm C, even though the mosaics of L_1 and L_2 are not that different, if L_1 is a simple system, then in general L_2 will not be. In fact, given enough changes from the

with nested sets of mosaics as containing different schemas or general principles, which can be used to generate different sets of specific hypotheses and hence regarded as mutually exclusive. Henderson focuses on causal model selection and curve fitting problems. It will be an interesting and fruitful project to explore how our proposals relate and whether they mutually support each other.

¹⁸In my view, earlier versions of quantum Humeanism with a universal wave function are like T_{M2} , and choosing them violates PNS. In contrast, the version of quantum Humeanism suggested in Chen (2022a) solves this problem, as the initial density matrix is as simple as the Past Hypothesis.

¹⁹Not all strongly deterministic theories are overly complex. See Chen (2024a) for a simple candidate theory that satisfies strong determinism.

actual mosaic, there may not be any optimal system that simplifies the altered mosaic to produce a good system.

PNS is to be contrasted from the simplicity criterion in the Humean best-system account of lawhood (§5.3). They are different kinds of principles: the latter is a metaphysical definition of what laws are, while the former is an epistemic principle concerning ampliative inferences based on our total evidence. Even if a Humean expects that the best system is no more complex than the mosaic, it does not follow that she should expect that the best system is relatively simple, since there is no metaphysical guarantee that the mosaic is “cooperative.” As an analogy, if we are merely told that Alice is no shorter than Bob, we cannot conclude that Alice is tall. To evaluate that, we need more information about Bob’s height. Based on Algorithm 1, we have examples such as T_{M1} and T_{M2} for which Humeans cannot distinguish based on local or global evidence. Even to decide what the actual evidence is ultimately about, and what the local region of mosaic is like (*just particles* or *particles and fields*), Humeans need to appeal to something like PNS. Both Humeans and non-Humeans can be uncertain about the laws, and both need a new principle to justify epistemic realism. If Humeans are epistemically warranted in making such a posit, non-Humeans are too.

3.4 Generalizations

We can generalize the lesson in several ways. First, simplicity need not be the only fundamental epistemic guide to lawhood. Other theoretical virtues can serve in similar roles. For example, informativeness and naturalness are two such virtues. A simple equation that does not describe much or describe things in too gruesome manners is less likely to be a law. We can formulate a more general principle:

Principle of Nomic Virtues (PNV) For two propositions L_1 and L_2 , if $L_1 >_O L_2$, then $L[L_1] >_P L[L_2]$, where $>_O$ represents the relation of overall comparison that takes into account all the theoretical virtues and their tradeoffs, of which $>_S$ is a contributing factor, $>_P$ represents the comparative probability relation, and $L[\cdot]$ denotes *is a law*, which is an operator that maps a proposition to one about lawhood.

Since $>_O$ need not induce a total order of all possible candidate laws, the corresponding $>_P$ need not induce a total order either.²⁰ What is overall better is a holistic matter, and it can involve trade-offs among the theoretical virtues such as simplicity, informativeness, and naturalness. PNV should be thought of as the more general epistemic principle than PNS. (For the application of PNV, see footnote #25.)

Second, in explanatory contexts where we do not postulate physical laws, we can rely on a more general principle:

Principle of Explanatory Virtues (PEV) For two propositions L_1 and L_2 , if $L_1 >_O L_2$, then $Exp[L_1] >_P Exp[L_2]$, where $>_O$ represents the relation of overall comparison that takes into account all the theoretical virtues and their tradeoffs, of which of which $>_S$ is a contributing factor, $>_P$ represents the comparative probability

²⁰Nevertheless, in the cases of empirical equivalence discussed in §2.3, there are clear winners in terms of overall comparison.

relation, and $Exp[\cdot]$ denotes *is an explanation*, which is an operator that maps a proposition to one about explanations.

If we endorse PEV, we may view epistemic guides for lawhood as similar to the criteria for inferences to the best explanation (IBE). Choosing a law over any other candidate on the basis of nomic virtues is similar to choosing an explanation over any other based on IBE. (See also footnote #36.)

Finally, the problem of nested theories and the suggested solution are generalizable.²¹ Suppose we have two hypotheses L_1 and L_2 that *do not have nested sets of mosaics*. Suppose further that L_1 better balances theoretical virtues than L_2 does. If we naively conclude that L_1 is more likely to be true than L_2 , it can still lead to probabilistic incoherence. To see this, consider $L_1 \vee Q$, with Q being much worse than L_2 such that the disjunction also has a much worse balance of theoretical virtues than L_2 . Applying the naive principle again, L_2 is more likely to be true than $L_1 \vee Q$. However, probabilistic coherence demands the opposite, since $L_2 <_P L_1 \leq_P L_1 \vee Q$. The root of the problem is that “more likely to be true” transmits under entailment, but theoretical virtues (and their balance) do not. That L_1 is more theoretically virtuous than L_2 does not imply that $L_1 \vee Q$ is more theoretically virtuous than L_2 . In contrast, PEV eliminates the mismatch, since “more likely to be an explanation” does not transmit under entailment either. Even though L_1 is more likely to be an explanation (for the target phenomenon) than L_2 , $L_1 \vee Q$ is not more likely to be an explanation than L_2 . It is probabilistically coherent to endorse:

$$Exp[L_1 \vee Q] <_P Exp[L_2] <_P Exp[L_1] \leq_P L_1 \leq_P L_1 \vee Q \quad (3)$$

As Ned Hall insightfully observes, the strategy is available whenever we encounter epistemically significant features that do not transmit under entailment. We should connect such features not to the likelihood of truth, but to something else. I shall mainly focus on PNS, but what I say below also apply to PNV and PEV.

There are further questions we can ask about PNS, which I shall return in §5. In the next section, I discuss five additional theoretical benefits of PNS, evidence that it is a worthy principle.

4 Theoretical Benefits

To further illustrate the theoretical benefits of PNS, I discuss five issues that are important to nomic realists: induction, symmetries, dynamics, determinism, and explanation. Accepting PNS allows us to say the right things in a systematic way.

4.1 Induction

On nomic realism, Hume’s problem of induction²² is closely related to the problem of underdetermination. We want to know what physical reality (L, ξ) is like. Given our limited evidence about some (coarse-grained and limited) part of ξ and some aspect of L , what justifies our inference to other parts of ξ or other aspect of L that will be

²¹I thank Ned Hall for suggesting this generalization.

²²For a helpful and updated review, see Henderson (2022).

revealed in upcoming observations or in observations that could have been performed? Without being told what (L, ξ) is like, we presumably have no epistemic justification for favoring (L, ξ) over any alternative compatible with our limited evidence (§2.3). On a given L we know what kind of ξ to expect. But we are given neither L or ξ . Without further assumptions, it seems difficult to make sense of the epistemic rationality of induction.

Hume connects the problem of induction to a principle of uniformity:

if Reason determin'd us, it would proceed upon that principle *that instances, of which we have had no experience, must resemble those, of which we have had experience, and that the course of nature continues always uniformly the same.* (*A Treatise of Human Nature*. 1.3.6.4)

We label the principle as follows:

Principle of Uniformity (PU) Nature is uniform.

Hume sometimes paraphrases PU as the supposition that “[from] causes which appear similar we expect similar effects” or the supposition that “the future will be conformable to the past” (*An Enquiry Concerning Human Understanding*, §4.2). One way to understand Hume’s argument is that, because induction presupposes PU and there is no non-circular justification for PU, there is no non-circular justification for induction.²³ A potential response is to postulate a fundamental principle, such as PU, that justifies induction but itself requires no further justification.

On nomic realism, is PU the right principle to postulate to inductively learn about physical reality (L, ξ) ? When we consider three possible interpretations of what PU demands of (L, ξ) , we realize PU is not what we want or need for induction. Instead, I suggest we should postulate PNS.

First, suppose PU demands that evidence E be uniform, in the sense that given the same experimental setups, the outcomes are always the same. That is not always useful for induction. Experimental setups are never exactly the same, and neither are the outcomes of experiments. They are similar in some respects but not others. Moreover, our evidence for physical theory typically consists in a variety of different types of experiments and observations, which allow us to cross-check the same theory from different angles. For example, our evidence for general relativity comes from a variety of sources (Misner et al. 1973, Thorne and Blandford 2017), and it is better that they are not all of the same type.

Second, suppose PU demands the uniformity of the mosaic ξ . However, the mosaic we inhabit is not uniform; there are many different kinds of objects, properties, and structures. We do not live in an empty universe that is completely homogeneous and isotropic. The spacetime region we inhabit is quite different from regions with violent collisions of stars and merging of black holes. What happens on earth is significantly different from even a nearby patch—the core of the sun, where nuclear fusion converts hydrogen into helium. The variety and complexity in the matter distribution does not diminish our confidence in the rationality of induction. In fact, thermodynamic

²³Unlike Armstrong (1983) or Foster (2004), I do not suggest that some versions of nomic realism escape Hume’s argument.

non-uniformity is arguably necessary for the observed temporal asymmetries in our universe, which may be a precondition for induction.²⁴

In fact, Algorithm A in §2.3 shows that neither version of PU is sufficient for inductive learning about physical reality. Assuming complete uniformity of observations and physical phenomena in all corners of the universe, we still do not know what to infer from actual evidence. Observations about the mosaic do not directly reveal what the mosaic is like, as made clear by cases such as T_{M1} and T_{M2} . Even if in some region we observe pointer readings about the values of “electromagnetic fields,” we are not automatically warranted to conclude that electromagnetic fields exist in that region. If we do not know what is revealed in actual observations, we do not know what is revealed by possible observations in unobserved regions.

Finally, suppose PU demands the uniformity of the law L . This interpretation shifts the focus from the mosaic to the law. However, it is still the wrong principle. Some regard the uniformity of L to mean that it has the form “for all x , if Fx then Gx ,” which is a regularity, i.e. a universally quantified statement about the mosaic, holding for everything, everywhere, and everywhen. The problem is that the principle may be vacuous, as any statement can be translated into a universally quantified sentence. That I have five coins in my pocket on January 1, 2024 is equivalent to the statement that, for everything and everywhere and everywhen, I have five coins in my pocket on January 1, 2024. Suppose we understand the uniformity of L to mean that it does not refer to any particular individual, location, or time. That version is no longer vacuous, but is too restrictive. There are candidate laws that do refer to particular facts, such as the Past Hypothesis of statistical mechanics, quantum equilibrium distribution in Bohmian mechanics, the Weyl curvature hypothesis in general relativity, and the No-Boundary Wave Function proposal in quantum cosmology (§4.3). These laws can be accepted on scientific and inductive grounds, and may be required to ultimately vindicate our inductive practice. Suppose we understand PU to mean that the same law applies everywhere in spacetime. That version is again vacuous, as even an intuitively non-uniform law can be described as a uniform law with a temporal variation, such as

$$F = ma \text{ for } (-\infty, t] \text{ and } F = \frac{1}{7}m^5a \text{ for } (t, \infty) \quad (4)$$

with F given by Newtonian gravitation and t a time in the far future. The disjunctive law applies everywhere in some spacetime.

Under various interpretations, PU is not the appropriate ground for inductive learning about (L, ξ) . In contrast, PNS is a better choice for nomic realists. With PNS, we can rationally prefer $F = ma$ to (4) when available evidence underdetermines them. What induction ultimately requires is the reasonable simplicity of physical laws, and a simple law may well give rise to a complicated mosaic with an intricate matter distribution. PNS allows laws about boundary conditions and particular individuals. Some simple laws may even have spatiotemporal variations, such as a time-dependent function $F = \frac{1}{t+k}ma$ for some constant k . As long as the variations are not too extreme as to require complicated laws, we can still inductively learn about physical reality based

²⁴See Albert (2000). See Wallace (2010) and Rovelli (2019) for the importance of the hydrogen-helium imbalance in the early universe to the existence of the relevant time asymmetries.

on available evidence, even in a non-uniform spacetime with dramatically different events in different regions.

PNS delivers the right results that we can rationally and inductively learn about (L, ξ) , and it is not a vacuous or overly stringent requirement like PU. If laws are simple, they may be completely uniform in space and time or else have a simple spatiotemporal dependence (see equation (7) in §4.2 for a realistic example). The simple laws would be empirically discoverable based on finite and limited evidence about (L, ξ) . PU understood as a requirement for uniform laws may be regarded as a special case of PNS. For these reasons, I suggest we postulate PNS instead of PU as a fundamental epistemic principle underlying inductive learning about physical reality. On nomic realism, part of the problem of justifying induction can be reduced to the problem of justifying our acceptance of simple laws.²⁵

4.2 Symmetries

Symmetry principles play important roles in theory construction and discovery. Physicists routinely use symmetries to justify or guide their physical postulates. However, whether symmetries hold is an empirical fact, not guaranteed *a priori*. So why should we regard symmetry principles to be useful, and what are they targeting? I suggest that certain applications of symmetry principles are defeasible guides for finding simple laws. In such cases, their epistemic value is parasitic on that of simplicity.²⁶

Consider again the toy example in (4). This law violates time-translation invariance and time-reversal invariance. In this case, we have a much better law that is time-translation and time-reversal invariant:

$$F = ma \text{ for all times} \tag{5}$$

The presence of the two symmetries in (5) and the lack of them in (4), indicate that all else being equal we should prefer (5) to (4). We can explain this preference by appealing to their relative complexity. (5) is much simpler than (4), and the existence of the symmetries are good indicators of the relative simplicity. However, in this comparison, we are assuming that both equations are valid for the relevant evidence (evidence obtained so far or total evidence that will ever be obtained). The preference is compatible with the fact that *if* empirical data is better captured by (4), we should prefer (4) to (5).

In the relevant situations where symmetry principles are guides to simplicity, they are only defeasible guides. Symmetry principles are not an end in itself for theory choice. I shall provide two more examples to show that familiar symmetry principles are not sacred, but rather defeasible indicators for simplicity, that can be ultimately sacrificed if we already have a reasonably simple theory that is better than the alterna-

²⁵While PNS may be a ground for induction, by itself it is not sufficient. Other theoretical virtues, such as informativeness and naturalness, are also important. For example, in light of the new riddle of induction (Goodman 1955), we may prioritize simple hypotheses formulated in more natural terms. Hence, nomic realists should consider The Principle of Nomic Virtues (PNV) as the more complete ground for induction. The point here is that simplicity makes an important contribution. Moreover, we may also need to assume that our spatiotemporal location is not too special. See Schwarz (2014).

²⁶For a related perspective, see North (2021).

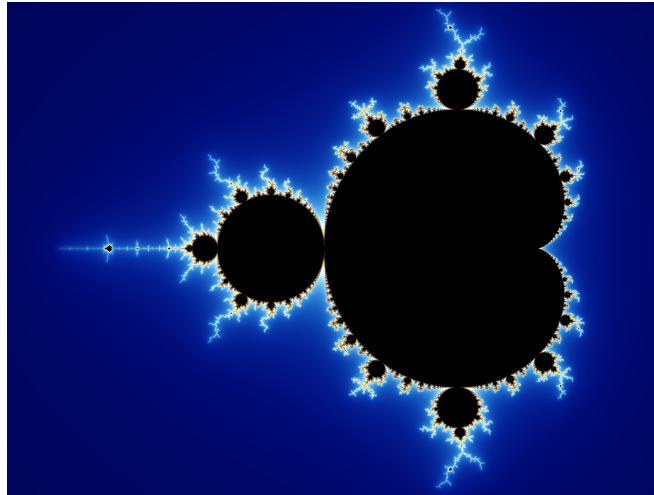


Figure 3: The Mandelbrot set with continuously colored environment. Picture created by Wolfgang Beyer with the program Ultra Fractal 3, CC BY-SA 3.0, <https://creativecommons.org/licenses/by-sa/3.0>, via Wikimedia Commons

tives.

The first is the toy example of the Mandelbrot world (Figure 3). Consider the Mandelbrot set in the complex plane, produced by the simple rule that a complex number c is in the set just in case the function

$$f_c(z) = z^2 + c \tag{6}$$

does not diverge when iterated starting from $z = 0$. (For example, $c = -1$ is in this set but $c = 1$ is not, since the sequence $(0, -1, 0, -1, 0, -1, \dots)$ is bounded but $(0, 1, 2, 5, 26, 677, 458330, \dots)$ is not. For a nice description and visualization, see (Penrose 1989, ch.3-4).) The pattern on the complex plane is surprisingly intricate and rich. It is a striking example of what is called the fractal structure. When we zoom in, we see sub-structures that resemble the parent structure. When we zoom in again, we see sub-sub-structures that resemble the sub-structures and the parent structure. And so on. Interestingly, they closely resemble, but they are not exactly the same. As we zoom in further, there will always be surprises waiting for us. Each level of magnification reveals something new.

Now, let us endow the Mandelbrot set with physical significance. We regard the Mandelbrot set on the complex plane as corresponding to the distribution of matter over a two-dimensional spacetime, which we call the *Mandelbrot world*, ξ_M . We stipulate that the fundamental law of the Mandelbrot world is the rule just described, which we denote by L_M . The fundamental law is compatible with exactly one world.²⁷

The physical reality consisting of (L_M, ξ_M) is friendly to scientific discovery. If we were inhabitants in the Mandelbrot world, we would be able to learn the structure of the whole ξ_M from the structure of its parts, by learning what L_M is. However,

²⁷It is worth noting that the patterns of the Mandelbrot world are not fine-tuned, as they are stable under certain changes to the law. For example, as (Penrose 1989, p.94) points out, other iterated mappings such as $f_c(z) = z^3 + iz^2 + c$ can produce similar patterns.

L_M is not a law with any recognizable spatial or temporal symmetries.²⁸ In fact, the usual notions of symmetries do not even apply to L_M , because it is not expressed as a differential equation. It is compatible with exactly one mosaic, namely ξ_M . Moreover, the physical reality described by (L_M, ξ_M) is a perfect example of an ultimate theory (though not of the actual world). It is an elegant and powerful explanation for the patterns in the Mandelbrot world. What could be a better explanation? I suggest that none could be better, even if it had more symmetries. In this case, we do not need symmetry principles to choose the right law, because we already have a simple and good candidate law. The lack of symmetries is not a regrettable feature of the world, but a consequence of its simple law.

The second and more realistic example is the Bohmian Wentaculus (Chen 2018, 2022a, 2024b). If we adopt the nomic interpretation of the quantum state, which is made plausible by the simplicity of the initial density matrix, we can understand the mosaic ξ_B as consisting of only particle trajectories in spacetime, with the fundamental dynamical law L_B as given by the following equation:

$$\frac{dQ_i}{dt} = \frac{\hbar}{m_i} \text{Im} \frac{\nabla_{q_i} W_{IPH}(q, q', t)}{W_{IPH}(q, q', t)}(Q) = \frac{\hbar}{m_i} \text{Im} \frac{\nabla_{q_i} \langle q | e^{-i\hat{H}t/\hbar} \hat{W}_{IPH}(t_0) e^{i\hat{H}t/\hbar} | q' \rangle}{\langle q | e^{-i\hat{H}t/\hbar} \hat{W}_{IPH}(t_0) e^{i\hat{H}t/\hbar} | q' \rangle} (q = q' = Q) \quad (7)$$

Since the quantum state is nomic, as specified by a law, the right hand side is the canonical formulation of the fundamental dynamical law for this world. Notice that the equation is not time-translation invariant, as at different times the expression

$$\text{Im} \frac{\nabla_{q_i} \langle q | e^{-i\hat{H}t/\hbar} \hat{W}_{IPH}(t_0) e^{i\hat{H}t/\hbar} | q' \rangle}{\langle q | e^{-i\hat{H}t/\hbar} \hat{W}_{IPH}(t_0) e^{i\hat{H}t/\hbar} | q' \rangle}$$

takes on different forms. However, the physical reality described by the Bohmian Wentaculus may be our world, and the equation can be discovered scientifically. The law is a version of the Bohmian guidance equation that directly incorporates a version of the Past Hypothesis. Hence, (L_B, ξ_B) describes a physical reality that is friendly to scientific discovery and yet does not validate time-translation invariance.

In the Bohmian Wentaculus world, symmetry principles can be applied, but the fundamental dynamical law explicitly violates time-translation invariance. In such cases, the lack of symmetries is not a problem, because we already have found the simple candidate that has the desirable features. Again, the time-translation non-invariance is a consequence of its simple law. PNS takes precedence over symmetry principles and are the deeper justification for theory choice.

4.3 Dynamics

We have good reasons to allow fundamental laws of boundary conditions. However, many boundary conditions are unsuitable candidates for fundamental lawhood. Epistemic guides such as simplicity allow us to be selective in postulating boundary condition laws, and to give more weight to proposals that include dynamical laws.

²⁸There is, however, the reflection symmetry about the real axis. But it does not play any useful role here, and we can just focus on the upper half of the Mandelbrot world if needed.

To start, let us review some reasons to posit fundamental laws of boundary conditions. First, cosmologists have suggested that fundamental physical laws should include a law about the initial condition of the universe. This is implicit in Hartle and Hawking's papers about the No-Boundary Wave Function. They postulate a universe (described by a universal wave function) that smoothly shrinks to a point towards the past (Hartle and Hawking 1983). Hartle (1996) suggests that the most general laws of physics involve a dynamical law of fundamental interactions and a law specifying the initial boundary condition of the universe, both of which are crucial for cosmology.

Second, probabilistic boundary conditions are indispensable to the predictive power of certain physical theories (Ismael 2009). If they play the role of underwriting objective probabilities in physics, probabilistic boundary conditions can earn the status of fundamental lawhood. The Past Hypothesis and Statistical Postulate of the Mentaculus theory (Albert 2000, Loewer 2007a) are in this category. We can also consider another case that is independent of the Past Hypothesis, namely the quantum equilibrium distribution in Bohmian mechanics. It says that the initial particle configuration is distributed according to $\rho(q, t_0) = |\Psi(q, t_0)|^2$. This distribution postulate is made plausible but not entailed by the Bohmian dynamics. This probabilistic boundary condition arguably plays the role of a physical law in Bohmian mechanics (Barrett (1995), Loewer (2004), Callender (2007)).

The above examples of boundary condition laws have a common feature: they are simple to specify. Many boundary conditions contain a great deal of correlations, but only a select few are good candidates for fundamental laws, namely those that are also sufficiently simple. One may wonder why we choose the Past Hypothesis, a macroscopic description, over a precise microscopic initial condition of the universe. The answer is that the former is much simpler than the latter and is still sufficiently powerful to explain a variety of temporally asymmetric regularities. The simplicity of the boundary condition laws make it almost inevitable that we will have dynamical laws in addition to boundary condition laws. The scientific explanations of natural phenomena come from the combination of simple boundary conditions and dynamical laws. As such, dynamical laws have to carry a lot of information by themselves.

4.4 Determinism

Nomic realism is often accompanied by other reasonable expectations about physical laws. Here I discuss some issues related to determinism and superdeterminism.

Borrowing ideas from (Montague 1974, pp.319-321), (Lewis 1983, p.360), and (Earman 1986, pp.12-13), I define determinism as follows (also see Figure 4):

Determinism_T Theory T is *deterministic* just in case, for any two mosaics $w, w' \in \Omega^T$, if w and w' agree at any time, they agree at all times.

Intuitively, T is deterministic if and only if no two mosaics compatible with T cross in state space (overlap at any time).

By using Ω_α as the set of mosaics compatible with the actual law, we can define:

Determinism _{α} The actual world α is *deterministic* just in case, for any two mosaics $w, w' \in \Omega_\alpha$, if w and w' agree at any time, they agree at all times.

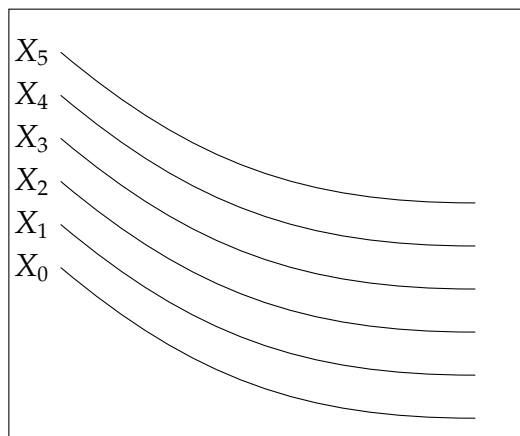


Figure 4: Schematic illustration of a deterministic theory T . Ω^T contains six nomologically possible worlds that do not cross in state space.

Determinism is true just in case the actual world α is deterministic in this sense.

On MinP, given any mosaic ξ , there are many possible choices of L such that $\xi \in \Omega^L$ and nomologically possible mosaics in Ω^L do not cross. Here is an algorithm to generate some such L : construct a two-member set $\Omega^L = \{\alpha, \beta\}$ for which α and β agree at no time (or any Cauchy surface). Any law with such a domain meets the definition of determinism. As long as α is not a world where every logically possible state of the universe happens some time in the universe, there will be many different choices of β that can ensure determinism. Without a further principle about what we should expect of L , determinism is too easy and almost trivial on MinP.²⁹

On BSA, the problem is the opposite. It becomes too difficult for a world to be deterministic. Given the evidence E we have about the mosaic, even though E may be optimally summarized by a deterministic law L , it does not guarantee (or make likely, without further assumptions) that the entire mosaic is optimally summarized by a deterministic law L . Small “perturbations” somewhere in the mosaic, such as those of Algorithm C in §2.3, can easily make its best system fail determinism.³⁰

Hence, there is a question of what nomic realists should say that constitutes a principled reason for thinking that determinism is not completely trivial (on MinP) and not epistemically inaccessible (on BSA).³¹

With PNS, determinism is no longer trivial on MinP. Given any mosaic ξ , even though there are many deterministic candidates compatible with ξ . Not every mosaic will be compatible with a relatively simple law that is deterministic. The non-triviality of determinism on MinP corresponds to the fact that it is non-trivial to find a law that is

²⁹See Russell (1913) for a related argument. Algorithm B in §2.3 provides another example involving strong determinism.

³⁰See Builes (2022) for a related argument.

³¹There are more general definitions of determinism, such as those discussed in Adlam (2022a) and Chen (2024a), that apply to worlds without the structure of “states at a time.” The key argument here with suitable adaptations can still hold. On BSA, strong determinism is very difficult to obtain, as almost any small perturbation somewhere in a strongly deterministic mosaic will render its best system non-strongly-deterministic. Similarly, it is very difficult to obtain what Adlam calls *delocalised holistic determinism*, as small perturbation to the mosaic can take it outside the set of “hole-free” spacetimes. See (Adlam 2022a, §3.3) for a construction.

simple and deterministic, as that is not guaranteed for every metaphysically possible mosaic.

With PNS, determinism is no longer epistemically inaccessible on BSA. This connects to induction. We are justified in believing that the best system of the actual mosaic is relatively simple, even though the actual evidence does not entail that. If the actual evidence can be optimally summarized by a deterministic law restricted to the actual evidence, we have epistemic justification to make inferences about regions that will not be observed – the entire mosaic, ξ , can be summarized by a simple law that happens to be deterministic.

Related to determinism is the concept of superdeterminism in quantum foundations. A superdeterministic theory is a deterministic one that has to violate statistical independence (Hossenfelder and Palmer 2020). Roughly speaking, a theory violates statistical independence just in case the probability distribution of the fundamental physical variables is not independent of the detector settings. The motivation is to evade Bell’s theorem of non-locality. It is not metaphysically impossible, on BSA or MinP, that the actual laws are superdeterministic. PNS offers a principled objection to superdeterminism. The constraints on empirical frequencies are so severe that it is hard to see how it can be written down in any simple formula. Unlike the Past Hypothesis, which can be given a reasonably simple description of the matter distribution or spacetime structure of the initial condition, we have no reason to think that the superdeterministic laws can be simple at all. Given simpler alternatives such as Bohmian mechanics and objective collapse theories, PNS allows us to be epistemically justified in assigning low credences in superdeterministic theories. See Chen (2021) for a critical overview of superdeterminism and more discussion about the relevance of nomic simplicity.

4.5 Explanation

There is a strong connection between nomic realism and scientific explanation. The point of postulating laws, on BSA and on MinP, is to provide scientific explanations. However, not all candidate laws provide the same quality of explanation or same kind of explanation. Hence, on both versions of nomic realism, we may wonder if there is a principled reason to think that we will have a successful scientific explanation for all phenomena.

On MinP, laws provide good explanations only when they are sufficiently simple, which means that constraints, in and of themselves, do not always provide satisfying explanations (Chen and Goldstein 2022, p.45). Many constraints are complicated and thus insufficient for understanding nature. For example, the constraint given by just $\Omega^L = \{\xi_M\}$, which requires a complete specification of the mosaic, is insufficient for understanding the Mandelbrot world. Knowing why there is a pattern requires more than knowing the exact distribution of matter.

On MinP, many candidate laws can constrain the mosaic. But not all have the level of simplicity to provide illumination about the mosaic. With PNS, we expect the actual constraint to be relatively simple. The constraint given by the Mandelbrot law should be preferred to that given by $\Omega^L = \{\xi_M\}$. The simple law provides a successful

explanation while the more complicated one does not.³²

On BSA, it is built in the notion of laws that they systematize the mosaic. However, whether there is a systematization that is simpler than the mosaic is a contingent matter, depending on the detailed, microscopic, and global structures of the mosaic. Not every mosaic supports a systematization that provides illumination in the sense of unifying the diverse phenomena in the mosaic (Loewer 2023). BSA only entails that the best system is no more complex than the exact specification of the mosaic. For example, some mosaics may support no better optimal summary than the exact specification of the mosaic itself. Hence, on BSA, having successful explanations is not automatic. It requires the mosaic to be favorable.

On BSA, some mosaics are favorable: they support optimal summaries that are simpler than themselves and provide “Humean explanations” about the mosaic. In fact, most mosaics may not be favorable (Lazarovici 2020). There exist mosaics underdetermined by actual evidence that do not support any good summaries. Given the actual evidence, with PNS, we are epistemically justified in inferring that the actual best system is relatively simple such that it can provide a “Humean explanation” about the actual mosaic. In effect, we are expecting that the actual Humean mosaic is a favorable one that completely cooperates with our scientific methodology and is such that it can be unified in a reasonably simple best system.

On both MinP and BSA, the viability of scientific explanation can be traced to PNS.

5 Epistemic Fundamentality

I have argued that PNS yields substantive theoretical benefits. For that reason, I regard it as a fundamental epistemic principle. In this section, I discuss three issues: the problem of justification, the problem of precision, and the epistemology of laws on Humeanism and non-Humeanism.

5.1 The Problem of Justification

Unlike logical consistency and probabilistic coherence, PNS is a non-structural epistemic principle. It is neither analytic nor empirically discoverable. Moreover, it does not follow from metaphysical realism that laws are relatively simple. On both BSA and MinP, laws *can* be extremely complicated.³³ (Roberts 2008, p.158) suggests that something like PNS would be a “synthetic *a priori*” principle concerning metaphysically contingent truths that is much stronger than what even Kant would affirm.

We might wonder what could possibly justify such a strong principle. It is natural to worry:

Problem of Justification There is no plausible epistemic justification for the principle of (nomic) simplicity.

³²PNS and other epistemic guides may be regarded as responses to questions about primitivism raised by Hildebrand (2013).

³³If the best system is too bad, Humeans can say that there isn’t anything that deserves the title of lawhood.

We may consider an argument from reflective equilibrium for PNS as an epistemic principle. There are many cases of empirical equivalence where the salient difference between the empirical equivalents is their relative complexity. For example, if we are epistemically justified in accepting T_{M1} over T_{M2} because the former has simpler laws, or in accepting GR over GR^+ because the former has simpler laws, simplicity has to be an epistemic guide to lawhood, in the sense that a simpler equation has a higher epistemic prior probability of being a law.³⁴ The applications of PNS to a wider range of cases in §4 give further support to that idea.

Reflecting on our judgments over those cases, we may conclude that simplicity as a guide to lawhood is one posit we should make to justify epistemic realism about laws. It is what we presuppose when we set aside (or give less credence to) those empirical equivalents as epistemically irrelevant. For our preferences in the cases of empirical equivalence to be epistemically justified, the principle of simplicity should be an epistemic guide. As such, *it is not merely a pragmatic principle, although it may have pragmatic benefits*. Simpler laws may be easier to conceive, manipulate, falsify, and the like. But if it is an epistemic guide, it is ultimately aiming at certain truths about lawhood and providing epistemic justifications for our believing in such truths. There is, to be sure, the option of retreating from epistemic realism. But it is not open to nomic realists.

Why think it is a *fundamental* epistemic guide that is not justified further? I think a compelling argument can be made by its vindication of induction (§4.1). The rationality of inductively learning about physical reality is indispensable to scientific practice and nomic realism. We can make a transcendental argument: science presupposes induction, so we have to believe in the epistemic rationality of induction. If Hume is right, induction has no non-circular epistemic justification. Deductive and probabilistic justifications of induction require premises that can be learnt only through induction. Therefore, whatever justification we offer for induction cannot completely satisfy the skeptic. We have to start somewhere by postulating fundamental epistemic principles that clarify how and why induction works.

I suggest that PNS is a good candidate for such a fundamental posit. (However, it need not be the only one; see footnote #24.) If we are rational in believing that physical laws are reasonably simple, we can assume that they are completely uniform in space and time or else provide a simple rule that specifies how they change over space or time. We can discover, using standard scientific methodology, physical laws and natural phenomena that follow from them. PNS is at the correct level of generality and makes the right connections to symmetries, determinism, and explanation. Accepting PNS as a fundamental epistemic principle may seem too bold. But it is worth remembering that we already accept many similar principles, regarding the veridicality of perception, the absence of evil demons, and so on. PNS is just another foundational principle that we need to succeed in our epistemic lives.³⁵

³⁴For a similar argument, see Lycan (2002).

³⁵ An astute referee observes that my formulation of PNS is non-veritistic, in the sense that it is supposed to hold even when physical laws are not simple. As such, it differs from another strategy where we postulate a veritistic epistemic norm that depends on what the world is like. If physical laws are simple, then the norm holds and we ought to believe laws are probably simple; if they are complex, then the norm does not hold and we don't have to believe laws are probably simple. Assuming the veritistic epistemic norm, if we do not independently know that the physical laws are simple, we do not

What about approaches that aim to reduce simplicity to structural epistemic principles (such as the likelihood principle)? As far as I can see, the reductive approaches to simplicity do not apply in the cases of empirical equivalence discussed here. For example, the AIC model-selection criterion advocated by Forster and Sober (1994) is designed for predictively inequivalent theories. In the absence of any successful reduction of simplicity to resolve cases of empirical equivalence, it is warranted to regard it as a fundamental epistemic guide. If someone presents a proof that simplicity can be reduced to something structural, we should be open to the idea and regard the principle of simplicity as derivative of some deeper principle. However, the existence of reasonable algorithms that generate empirical equivalents should cast doubt on the existence of such proofs.³⁶

5.2 The Problem of Precision

Simplicity is a vague notion. Insofar as PNS is to be regarded as a fundamental epistemic principle, its vagueness may be undesirable. It is natural to worry:

Problem of Precision There is no precise standard of simplicity.

It is unrealistic to insist that there is a single measure of simplicity regarding physical laws. There are many aspects of simplicity, as shown by recent works in computational complexity, statistical testing, and philosophy of science. Among them are: number of adjustable parameters, lengths of axioms, algorithmic simplicity, and conceptual simplicity.³⁷ Certain laws may employ more unified concepts, better achieving one dimension of simplicity, but require longer statements and hence do less well in other dimensions of simplicity. There need not be any precise way of trading off one over the other. Moreover, not all laws must take the form of differential equations; there can be boundary-condition laws and conservation laws. It is unreasonable to expect a single measure applied to all different forms of laws. I suggest that we take simplicity to be measured in a holistic (albeit vague) way, taking into account these different aspects of simplicity.³⁸

The vagueness of simplicity may appear problematic for nomic realists. However, what matters to a realist who accepts PNS, which involves simplicity comparisons, is

know whether to apply the epistemic norm. However, there is a similar consequence on PNS, which is non-veritistic. On PNS, if physical laws are simple, what we ought to believe aligns with what the world (laws) is like; if they are not simple, what we ought to believe misaligns with what the world is like. Without an independent way to know what the world is like, we do not know if the output of scientific discovery aligns with physical reality. In other words, nomic realists who rely on PNS are fallible.

³⁶Similar conclusions can be drawn about reductive approaches to IBE, such as Henderson (2014)'s proposal. Henderson suggests that it may be unnecessary to use explanatory considerations or theoretical virtues to help determine the epistemic priors. She infers from a historical case study that, for a wide range of independently-motivated priors, simpler theories will get a greater boost from evidence and receive higher posteriors. However, as Algorithms A-C show, we can generate empirical equivalents where the more complex theories always assign equal or higher likelihoods to actual evidence, where the simpler alternatives do not get a greater boost from evidence. In order to prefer those simpler theories, we have to assign them higher priors, based on simplicity considerations.

³⁷For an overview of these different measures, see Baker (2022) and Fitzpatrick (2022).

³⁸Alternatively, we may take simplicity as a family of concepts, and the principle of simplicity as a family of principles.

that there is enough consensus about paradigm cases. There are hard cases of simplicity comparisons, but there are also clearcut cases, such as T_{M1} and its empirical equivalents generated by Algorithm A, or general relativity and its empirical equivalents generated by Algorithms B and C. This is similar to Lewis's assumption that Nature is kind to us and the borderline cases do not show up in realistic comparisons. The vagueness of simplicity here is no worse than the problem in the BSA account of lawhood.

The vagueness of simplicity does not imply that there are no facts about simplicity comparisons. Let us think about an analogy with moral philosophy. Judgments about moral values are also holistic and vague. While there are moral disagreements about hard cases, there can still be facts about whether helping a neighbor in need is morally better than torturing their cat for fun. Moral realists can maintain that we have robust moral intuitions about paradigm cases, which are not threatened by the existence of borderline cases. Sometimes different moral considerations conflict, in which case we may need to trade-off one consideration against another.

Let us take a step back. Part of the worry about the lack of precision in PNS may be that vagueness is always a symptom of non-fundamentality; whatever fundamental epistemological principles there are, they must be exact. It is unclear why the assumption is true. I am not aware of any non-structural epistemic principle that is exact. In the case of PNS, we have principled reasons to expect that it is vague, and its vagueness is appropriate. Consider its range of applications. It partly grounds our epistemic commitments about induction, symmetries, dynamics, determinism, and explanation. The measures we use across its diverse range of applications may not agree. Moreover, if we allow vague fundamental laws (Chen 2022b), it is natural to expect that the measure of simplicity will be vague.

There is another reason to tolerate some vagueness in simplicity. Consider algorithmic randomness, an active field of research in mathematics and computer science. Mathematicians and computer scientists start with a vague pre-theoretical concept of randomness. They propose a class of mathematically precise definitions, some of which turn out to be theoretically fruitful. These include the Kolmogorov notion of incompressibility, the Martin-Löf notion of typicality, and the game-theoretic notion of fair gambling (Dasgupta 2011). Surprisingly, in idealized circumstances they are provably equivalent. The equivalence shows that the vague concept is latching onto something in mathematical reality. But such notions do not completely eliminate vagueness. For example, when we apply any notion of algorithmic randomness to finite mosaics, we see the reappearance of vagueness (Li and Vitányi 2019, p.56). Instead of drawing an exact boundary between random and non-random sequences, we need to adopt a vague criterion: a sequence is random just in case it cannot be represented by a significantly shorter algorithm. What counts as "significantly shorter" is, of course, vague. Insofar as it is legitimate to apply randomness to finite strings, we can regard its vagueness here as entirely appropriate.

In cases where we can legitimately apply the concept of algorithmic randomness, it is also a measure for complexity. A non-random sequence (satisfying certain frequency properties) may be considered simple. An example is the alternating sequence (010101.....). A non-random mosaic (of a certain type) can be captured by a suitably simple law. Hence, we may plausibly treat the two concepts as duals of each other.

Duality Simplicity and algorithmic randomness are duals of each other.

Since algorithmic randomness is appropriately vague, simplicity is too.

5.3 Humeanism vs. non-Humeanism

Does PNS follow from the metaphysical postulates of BSA? The answer is no. Unpacking the reason will shed light on a debate between Humeans and non-Humeans. To begin, let us recall the comparison between T_{M1} and T_{M2} . Following PNS, a Humean scientist living in a world with Maxwellian data should prefer T_{M1} to T_{M2} because the laws of T_{M1} are simpler. However, on BSA, it is metaphysically possible that the actual ontology does not include fields. If that is the actual mosaic, the best system will correspond to the enormously complicated laws of T_{M2} . It follows that what is the best system of the mosaic may differ from what we should accept as the best system given our evidence.

There is no inconsistency, because *what the laws are* can differ from *what we should believe the laws are*. Hence, defenders of BSA are in a similar epistemic situation as defenders of MinP. Even if the nomology of T_{M2} represents the actual governing laws, a defender of MinP would and should regard T_{M1} as more likely than T_{M2} . Humeans and non-Humeans can be mistaken about physical reality, even when they are completely rational. That is a feature and not a bug, because nomic realists should be fallible.

The observation has ramifications for an argument against non-Humeanism. According to an influential argument, Humeanism has an epistemic advantage over non-Humeanism, because the former offers better epistemic access to the laws.³⁹ The argument is that the Humean mosaic is all that we can empirically access, on which laws are supervenient, but non-Humeans postulate facts about laws that are empirically undecidable. But if the analysis in this paper is correct, such arguments are epistemically irrelevant. We never, in fact, occupy a position to observe everything in the mosaic. Our total evidence E will neither exhaust the entire mosaic ξ nor directly reveal the microscopic constituents in the region we occupy. But if both Humeans and non-Humeans need to accept an independent substantive epistemic posit in order to ensure epistemic access to physical laws, there is no real advantage on Humeanism. The reason we have epistemic access to laws is by appeal to PNS (among other things), which does not follow from the metaphysical posits of either Humeanism or non-Humeanism. Humeanism and non-Humeanism are epistemically on a par, with respect to the discovery and the evaluation of laws.

Taking a step back, we can see that the relation between Humeanism and PNS is somewhat indirect. PNS is an epistemic principle regarding what system we should believe given the total evidence. BSA is a metaphysical principle regarding what the best system is given the total mosaic. Since $L = BS(\xi)$, with the full mosaic the Humeans can in principle solve for L . However, the Humeans do not have access to the full mosaic, because they are macroscopically and spatiotemporally limited. Humeans are essentially solving an inverse problem. Given evidence E , what is the simplest law

³⁹For example, see Earman and Roberts (2005) and Roberts (2008). For a related argument about the epistemic inaccessibility of powers, see Schwarz (2023).

(that also balances a host of other epistemic guides) compatible with E ?⁴⁰ Suppose the epistemic guides recommend a unique candidate law given evidence E :

$$L_{\text{epistemic}} = EG(E) \quad (8)$$

with $EG(\cdot)$ the function that maps a set of evidence to a law recommended by the epistemic guides. Taking epistemic guides seriously is to have high confidence that

$$L = L_{\text{epistemic}} \quad (9)$$

Because epistemic guides do not guarantee the right answer, it is possible that

$$L \neq L_{\text{epistemic}} \quad (10)$$

In probabilistic terms, a Humean who believes in PNS and the other epistemic guides should have high prior credence in (9) and low prior credence in (10). With the high probability of (9), the Humean can solve an inverse problem to determine the actual mosaic, up to a point:

Humean Inverse Problem What is the actual mosaic like, given we have epistemic reasons to infer that it is optimally described by $L_{\text{epistemic}}$?

This can be answered by finding the following:

$$\xi_\alpha \in \Omega_{\text{BSA}}^{L_{\text{epistemic}}}, \text{ with } \Omega_{\text{BSA}}^{L_{\text{epistemic}}} = \{\xi : BS(\xi) = L_{\text{epistemic}}\}^{41} \quad (11)$$

As a last step of finding out fundamental reality, Humeans then infer that the actual mosaic is a member of $\Omega_{\text{BSA}}^{L_{\text{epistemic}}}$. But this rational reconstruction makes explicit how the Humean solution depends on epistemic guides. To know what the fundamental reality (the Humean mosaic) is, they need to (1) collect empirical data, (2) make ampliative inferences using epistemic guides such as PNS, and (3) determine what the actual mosaic is like based on the best guess about physical laws.

Let us compare that with the rational construction on the non-Humean view of MinP. Even though there is no metaphysical restriction on the form of fundamental laws, it is rational to expect them to have certain nice features, such as simplicity and informativeness. On BSA, those features are metaphysically constitutive of laws, but on MinP they are merely epistemic guides for discovering and evaluating candidate laws. At the end of the day, they are defeasible guides, and we can be wrong about the fundamental laws even if we are fully rational in scientific investigations. The second part of Chen and Goldstein (2022)'s MinP is an epistemic thesis:

Epistemic Guides Even though theoretical virtues such as simplicity, informativeness, fit, and degree of naturalness are not metaphysically constitutive of fundamental laws, they are good epistemic guides for discovering and evaluating them.

⁴⁰Recall the discussions of Hall (2009, 2015) about the Limited Oracular Perfect Physicist (LOPP). She has no inverse problem to solve, as her evidence E_{LOPP} , together with the assumption that it is indeed the complete evidence about the mosaic, pin down (L, ξ) . That is entirely different from the situation of actual Humeans.

⁴¹In general, $\Omega_{\text{BSA}}^L \neq \Omega^L$ as there are members of the latter that may not be members of the former (e.g. undermining histories).

Just as on BSA, accepting Epistemic Guides on MinP is to have high confidence in (9). A defender of MinP should be confident (though not certain) what the Epistemic Guides recommend is the governing law. They should also admit the epistemic possibility that $L \neq L_{\text{epistemic}}$. The epistemic gap on BSA is the same as that on MinP; there is no relevant epistemic advantage of Humeanism over non-Humeanism.

Epistemic Parity Thesis Humeanism does not have an epistemic advantage over non-Humeanism regarding our epistemic access to physical laws.⁴²

The thesis does not rule out the possibility that non-Humeanism has an advantage over Humeanism regarding our epistemic access to physical laws. After all, on MinP, we should assume (by PNS) that certain fundamental facts of the world are simple. In contrast, on BSA, we should assume (by PNS) that certain superficial facts of the world (best-system laws), grounded in a complex fundamental reality, are simple. The assumption on MinP, it seems to me, is more believable than the corresponding one on BSA. It is easier to believe that nature at some deep level is simple. It is harder to believe that nature at some deep level is complicated in a certain way to give rise to a simple appearance. Of course, this will not persuade the committed Humeans, for presumably they are willing to accept the consequence. However, for many people on the fence or coming to the debate for the first time, the choice between Humeanism and non-Humeanism should be clear.⁴³

Finally, our discussion bears on a recent discussion about “ratbag idealism.” (Hall 2009, §5.6) suggests that, facing the problem that the simplicity criterion in the BSA is too subjective, Lewis and other Humeans can “perform a nifty judo move.” If non-Humeans regard simplicity as an epistemic guide to laws, it follows that “central facts of normative epistemology are *also* up to us.” Hall suggests that this is more objectionable than the ratbag idealism of BSA. A defender of BSA may reasonably embrace ratbag idealism and take laws to be pragmatic tools to structure our investigation of the world. With that viewpoint, we can expect that what laws are is somewhat up to us. However, there is no reason on non-Humeanism why fundamental epistemological and normative facts should be up to us. So the non-Humeans could face a worse problem of ratbag idealism. My analysis in this paper suggests that both Humeans and non-Humeans need to adopt fairly strong epistemological principles such as PNS.

⁴²Still, some Humeans might argue that non-Humean accounts such as MinP open up extra epistemic risks (Earman and Roberts 2005, p.280), because it is possible that we know the entire mosaic and do not know what the laws are. However, it is too idealized to be an epistemic situation relevant to actual scientists. Perhaps the Humeans would object that given any set of evidence (such as the spatiotemporally partial and macroscopic E) non-Humeanism allows “more” distinct laws than Humeanism does. Now, the number of physical laws compatible with any macroscopic and limited body of evidence is infinite. Talking about “more” in the infinite context requires a measure. Suppose this can be done rigorously. It does not follow that the set of extra laws has positive measure. One may rationally assign probabilities such that set of the extra laws has measure zero, so that:

$$P_{\text{BSA}}(L|E) = P_{\text{MinP}}(L|E) \tag{12}$$

where L is some particularly good candidate and E is our available evidence. If we characterize epistemic risks probabilistically, the Epistemic Parity Thesis can still hold. For a similar point, made in defense of Humeanism, see Loewer (2000).

⁴³See also (Chen and Goldstein 2022, pp.57-58). This argument requires more space to develop, which I leave to future work.

Humeans cannot avoid the problem that “central facts of normative epistemology” may be up to us, unless they retreat to anti-realism about the mosaic (including its microscopic structure and unexplored regions of spacetime). Insofar as they also need PNS, Humeans cannot perform the nifty judo move without undermining their own position.

6 Conclusion

Nomic realism is epistemically risky. There is an epistemic gap between metaphysical realism and epistemic realism. However, the gap is no smaller on Humeanism than on non-Humeanism. On both accounts, we need to decide what the physical laws are, in the vast space of possible candidates, based on our limited and macroscopic evidence about the universe. The principle of nomic simplicity, as a fundamental epistemic guide to lawhood, encourages us to look in the direction of simpler laws. We need to add it to both Humeanism and non-Humeanism. It vindicates epistemic realism when there is empirical equivalence (in the cases discussed here), avoids probabilistic incoherence when there are nested theories, and supports realist commitments regarding induction, symmetries, dynamics, determinism, and explanation. With many payoffs for only a small price, it is a great bargain.

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