Governing without a Fundamental Direction of Time: Minimal Primitivism about Laws of Nature

Eddy Keming Chen* Sheldon Goldstein†

*Department of Philosophy, University of California San Diego

†Departments of Mathematics, Physics, and Philosophy, Rutgers University

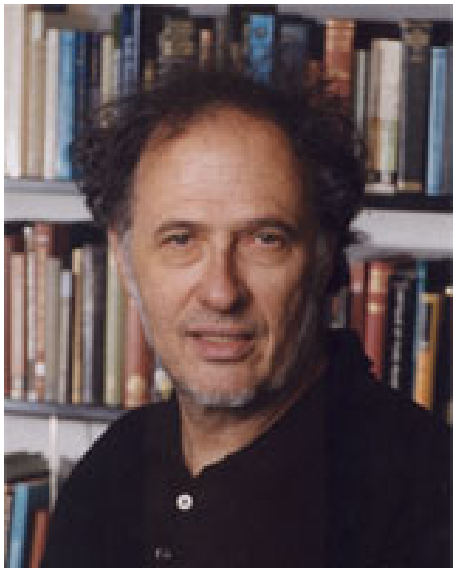
Paper version: arXiv 2109.09226

Introduction

Even if there is only one possible unified theory, it is just a set of rules and equations. What is it that breathes fire into the equations and makes a universe for them to describe?

–Stephen Hawking, *A Brief History of Time*

Introduction



While physicists have been busy proposing, elaborating, and testing systems of laws, scientifically minded philosophers have engaged in discussions and disputes about the metaphysics of laws. The metaphysical question is "in virtue of what does a generalization or an equation express a law?"

–Barry Loewer, "What Breathes Fire into the Equations"

Introduction

- Much work in physics has been devoted to the discovery of its true fundamental laws: the basic principles that govern the world.
- The collection of all such laws may be called the axioms of the final theory of physics or the Theory of Everything (TOE). The fundamental laws cannot be explained in terms of deeper principles (Weinberg 1992).
- We use them to explain observed phenomena, including the formation of galaxies, the collisions of black holes, the stability of matter, the tidal periods of ocean waves, and the melting of ice cubes.

Introduction

- Laws are intimately connected to many long-standing philosophical issues, such as modality, explanation, causation, counterfactuals, time, induction, and determinism.
- For example, physical possibility and necessity can be defined in terms of laws;
- laws contribute to scientific explanations of natural phenomena;
- laws support counterfactuals, predictions, and retrodictions;
- laws are linked to the direction of time; determinism and indeterminism are properties of laws; and so on.

Anyone interested in those issues would benefit from some understanding of laws.

Introduction

There are interesting puzzles about laws themselves:

Metaphysical issues:

- What kind of things are laws?
- Most people believe that laws are different from material entities such as particles and fields, because, for one thing, laws seem to *govern* the material entities.
- But what is this governing relation? What makes material entities respect such laws?

Introduction

Epistemological issues:

- How do we have epistemic access to laws?
- Many different candidate laws can yield the same data, a phenomenon known as empirical equivalence.
- How should we decide which one to accept?
- Many people believe that laws apply not just in our local region but everywhere in spacetime.
- Are we justified in holding such beliefs given our finite and limited evidence?

Introduction

The marks of the nomic:

- There are certain features, such as simplicity, universality, exactness, and objectivity, that we normally associate with laws (the nomic elements of reality).
- How should we understand those hallmarks, in light of the metaphysics and epistemology of laws?

Such questions do not have straightforward answers, and they cannot be directly tested in empirical experiments. They fall in the domain of philosophy.

Let us focus on the metaphysical issues in this talk.

Introduction

The Great Divide in metaphysical debates about laws is between Humeans, who think that laws are merely descriptions, and non-Humeans, who think that laws govern.

- Humeans maintain that laws merely describe how matter is distributed in the universe.
- In Lewis's version, laws are just certain efficient summaries of the distribution of matter in the universe, also known as the *Humean mosaic*, an example of which is a four-dimensional spacetime occupied by particles and fields.
- All there is in fundamental reality is the Humean mosaic; nothing enforces patterns or moves particles or fields around.
- On the face of it, Humeanism is highly revisionary; it regards patterns in nature as ultimately unexplained.

Introduction

- A common theme in non-Humean views is that laws govern the distribution of matter.
- By appealing to the governing laws, the patterns are explained.
- How laws perform such a role is a matter of debate, and there are differences of opinion between reductionist non-Humeans such as Armstrong and primitivist non-Humeans such as Maudlin.

Introduction

- Many physicists and philosophers have non-Humean intuitions.
- However, when they first encounter the philosophical literature on laws, they face a dilemma.
- They reject Humeanism, but they find traditional non-Humeanism unattractive.
- For example, some accounts explain laws in terms of other entities, such as Platonic universals or Aristotelian dispositions, which are foreign to scientific practice.
- Other accounts severely limit the forms of laws one is allowed to consider.
- It is sometimes assumed that the governing view requires that laws must be *dynamical* laws that *produce* later states of the world from earlier ones, in accord with the direction of time that makes a fundamental distinction between past and future.
- Call this conception of governing *dynamic production*.

Introduction

- This conception of laws may be natural to start out with.
- But it runs into problems in modern physics.
- It is overly restrictive.
- It goes beyond the core idea about laws.

Introduction

Paradigm examples of candidate fundamental laws of physics

- Newton's laws of motion
- The Schrödinger equation
- The Dirac equation

Dynamical laws of a particular form: laws of temporal evolution

Introduction

Consider these examples:

- The Einstein equation (of general relativity)
- The Wheeler-DeWitt equation
- Conservation laws
- Symmetry principles
- The principle of least action
- The Past Hypothesis (of a low-entropy boundary condition of the universe)
- Equations of motion in Wheeler-Feynman electrodynamics

Do they have the right form to be fundamental laws?

Controversial!

Related to one's metaphysical views about laws and time.

Introduction

Our goal:

- To articulate *minimal primitivism about laws of nature* (MinP), a minimalist and primitivist view about laws
- To contrast it with some leading alternatives

Focus: laws of physics, and particularly those suitable for being **fundamental laws**.

Introduction

- Note: we use "fundamental laws" and "laws" interchangeably unless noted otherwise.
- Complicated topic; need to be selective and need to simplify
- A more personal note

Introduction

MinP captures our conviction that the universe is governed by laws of nature in a way that does not presuppose a fundamental direction of time.

Flexible about the forms of the laws

Introduction

In the philosophical literature, and perhaps in many people's minds, the two are tightly linked:

- Governing conception of laws [laws govern in a metaphysically robust sense]
- Fundamental direction of time [a fundamental distinction between past and future]

For laws to really govern the world, they must produce the later states of the universe from the earlier ones, in accord with a fundamental direction of time.

Made explicit by Maudlin (2007), discussed at length by Loewer (2012).

Introduction

"Time-directed governing"

- Laws are not merely summaries of what actually happens
- Laws really govern, via time-asymmetric dynamic production
- A fundamental direction of time

Dynamic production

- metaphysics
- explanation
- intuitive (?)
- also attractive to many non-Humeans (Aristotelian reductionists) who don't think that laws govern

Introduction

Restrictions on the form of laws

- Dynamical laws in a narrow sense
- Fundamental laws of temporal evolution (FLOTEs) [Maudlin, 2007]

Compatibility with the block universe?

Introduction

Our motivations:

- Reflect upon the variety of kinds of laws physicists present as fundamental
- Many do not have the form of FLOTEs
- Even for FLOTEs, dynamic production is not essential to how they govern or explain

Introduction

MinP:

- Breaks the link between the governing conception and dynamic production
- Fundamental laws govern by constraining the physical possibilities of the entire spacetime and its contents
- They need not exclusively be dynamical laws (in the narrow sense of FLOTEs)
- Other forms: global constraints, boundary condition constraints
- Compatible with atemporal world, block universe, temporal loops

MinP captures the essence of the governing view without taking on extraneous commitments about the direction of time or dynamic production.

Introduction

MinP:

- A version of primitivism about laws
- Laws are not reducible to or analyzable in terms of anything else

Flexibility of MinP:

- FLOTEs
- principles of least action
- the Einstein equation of GR
- Past Hypothesis
- Wheeler-Feynman electrodynamics
- retrocausal QM

Brief Survey of Alternative Views

1. Humean Reductionism
2. Platonic Reductionism
3. Aristotelian Reductionism
4. Maudlinian Primitivism

Brief Survey 1: Humean Reductionism

[Draw]

- Ultimately, no laws
- At the metaphysically fundamental level, nothing is enforcing the patterns
- Laws are metaphysically derivative
- Laws are merely efficient summaries of the Humean mosaic
- The Humean mosaic is whatever it happens to be
- The direction of time

Brief Survey 2: Platonic Reductionism

Universals

- repeatable
- explain the genuine similarity of material objects
- over and above the Humean mosaic

Example: every massive particle obeys the law $F = ma$

- universals: *having mass m*, *being under total force F*, *having acceleration F/m*
- unity: many particles that share such universals
- explanation: the universal *having mass m* and the universal *being under total force F* necessitate the universal *having acceleration F/m*
- every particle has to obey $F = ma$

Perhaps best paired with a fundamental direction of time

Brief Survey 3: Aristotelian Reductionism

- Ultimately, no laws
- Not a Humean mosaic, but a world that is "active and reactive" (Ellis, 2001)
- Fundamental "dispositions," also sometimes called "powers," "capacities," "potentialities," and "potencies."
- Examples: a glass has a disposition to shatter when struck; negatively charged particles have a disposition to attract positively charged particles
- Bird (2007): "According to this view laws are not thrust upon properties, irrespective, as it were, of what those properties are. Rather the laws spring from within the properties themselves."

Aristotelian Reductionism: (1) the metaphysical powers, necessity, and oomph reside in the fundamental dispositions; (2) laws are metaphysically derivative of the dispositions; (3) laws are metaphysically necessary.

Brief Survey 3: Aristotelian Reductionism

Regarding explanation, Demarest (2017) says:

> *I think the most promising solution is to appeal to production—dynamic, metaphysical dependence. According to my view, the fundamental ground includes spacetime and an initial arrangement of particles and potencies. And the subsequent behavior of the particles (further potency instantiations as well as trajectories through spacetime) is dynamically, metaphysically dependent upon that base. (p.51)*

1. dynamic production / dependence
2. manifestations, stimuli of dispositions
3. fundamental direction of time

Brief Survey 4: Maudlinian Primitivism

Maudlin, *The Metaphysics Within Physics*:

> *My analysis of laws is no analysis at all. Rather I suggest we accept laws as fundamental entities in our ontology. Or, speaking at the conceptual level, the notion of a law cannot be reduced to other more primitive notions. (p.18)*

- primitivism about laws
- scientific practice

Brief Survey 4: Maudlinian Primitivism

> *Let's call the idea that both the laws of physics (as laws of temporal evolution) and the direction of time are ontological primitives Maudlin's Non-Humean Package. According to this package, the total state of the universe is, in a certain sense, derivative: it is the product of the operation of the laws on the initial state. (p.182)*

- Maudlin's package: primitivism about both laws and the direction of time
- laws produce or generate later states of the world from earlier ones
- productive explanation: via the productive power of the laws, subsequent states of the world (and its parts) are explained by earlier ones and ultimately by the initial state of the universe
- Production is closely related to causation, and just like (paradigm cases of) causation it is time asymmetric
- Attraction: closer to the intuitive picture of the world

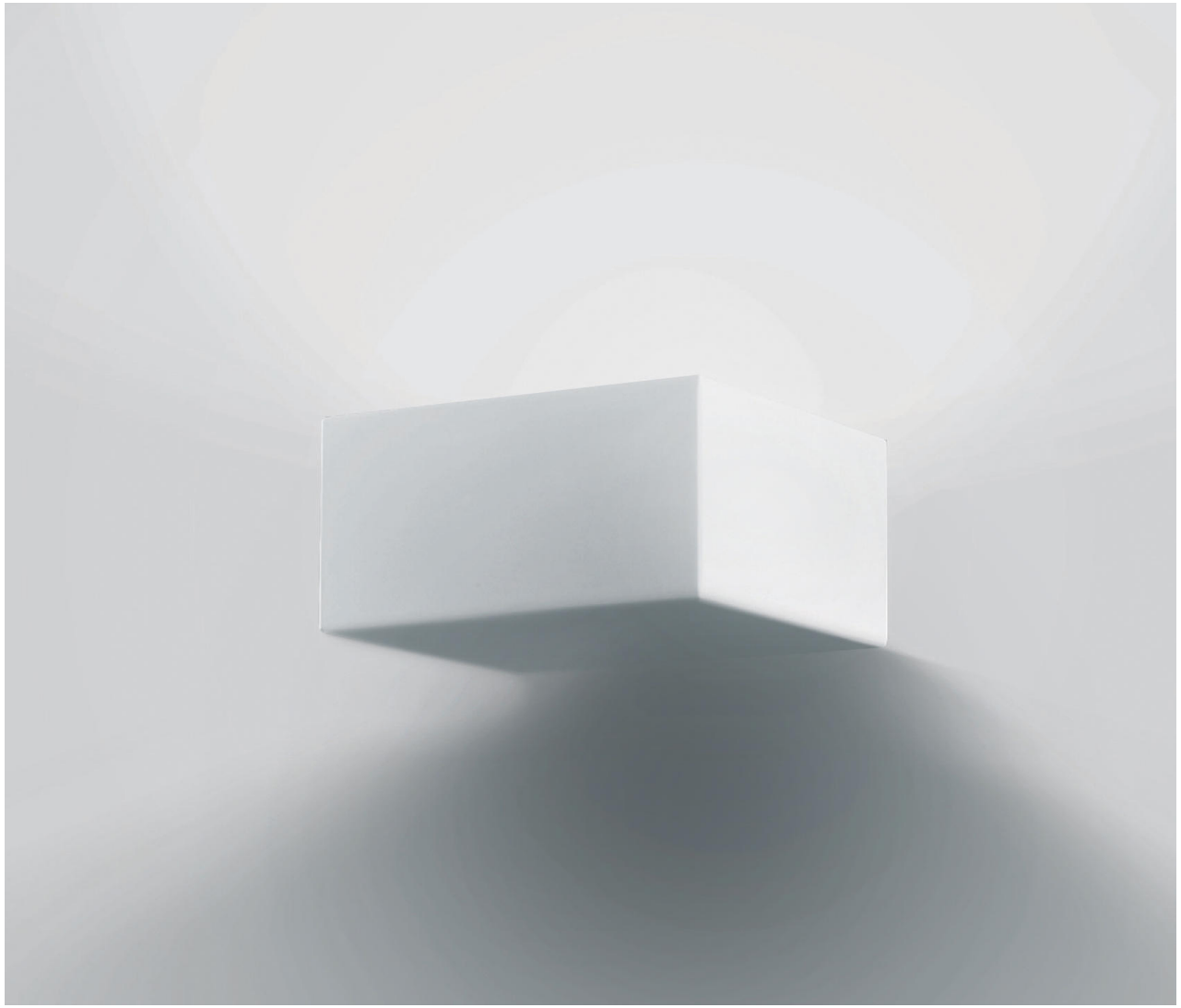
Brief Survey 4: Maudlinian Primitivism

Maudlinian Primitivism

Fundamental laws are certain ontological primitives in the world. Only dynamical laws (in the narrow sense of laws of temporal evolution) can be fundamental laws. They operate on the universe by producing later states of the universe from earlier ones, in accord with the fundamental direction of time.

- restriction to FLOTEs
- dynamic production in a block universe; intuitive?
- relativity
- first moment in time
- relata of dynamic production

Minimal Primitivism (MinP)



Minimal Primitivism (MinP)

Two theses: a metaphysical one and an epistemic one.

Minimal Primitivism

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.

Primitivism about laws, but does not require primitivism about the direction of time.

Minimal Primitivism (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 Humean Reductionism, those features are metaphysically constitutive of laws, but on our view they are merely epistemic guides for discovering and evaluating the laws.

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.

Clarifications: Primitive Facts

- Fundamental laws of nature are certain primitive facts about the world, in the sense that they are not metaphysically dependent on, reducible to, or analyzable in terms of anything else.

Clarifications: The Governing Relation

- laws govern by limiting the physical possibilities and constraining the actual world (history) to be one of them
- This notion of a constraint does not require a fundamental distinction between past and future, or one between earlier states and later ones.
- What the laws constrain is the entire spacetime and its contents.
- Sometimes, expressible as differential equations that permit a productive interpretation; sometimes not.

Clarifications: The Governing Relation

Example: consider Hamilton's equations of motion for N point particles with Newtonian masses $(m_1, ..., m_N)$ moving in a 3-dimensional Euclidean space, whose positions and momenta are $(\boldsymbol{q_1}, ..., \boldsymbol{q_N}; \boldsymbol{p_1}, ..., \boldsymbol{p_N})$:

$$\frac{d\boldsymbol{q_i}(t)}{dt} = \frac{\partial H}{\partial \boldsymbol{p_i}} \, , \, \frac{d\boldsymbol{p_i}(t)}{dt} = -\frac{\partial H}{\partial \boldsymbol{q_i}} \tag{1}$$

where $H = H(\boldsymbol{q_1}, ..., \boldsymbol{q_N}; \boldsymbol{p_1}, ..., \boldsymbol{p_N})$ is specified in accord with Newtonian gravitation:

$$H = \sum_{i}^{N} \frac{\boldsymbol{p_i}^2}{2m_i} - \sum_{1 \leq j < k \leq N} \frac{G m_j m_k}{|\boldsymbol{q_j} - \boldsymbol{q_k}|} \tag{2}$$

Clarifications: The Governing Relation

- Saying that (1) and (2) govern our world means that (1) and (2) express fundamental facts that constrain particle trajectories in spacetime.
- No need to invoke dynamic production.
- Let Ω^H denote the set of solutions to (1) and (2).
- In this example, the dynamical equations are time-reversible.
- For every solution in Ω^H, its time reversal under $t \to -t$ and $\boldsymbol{p} \to -\boldsymbol{p}$ is also a solution in Ω^H.
- On MinP, two solutions that are time-reversal of each other can be identified as the same physical possibility.

Clarifications: The Governing Relation

- We should not think of a law as necessarily equivalent to the set of possibilities it generates.
- The two can be different.
- There are many principles and equations that can give rise to the same set of possibilities denoted by Ω^H.
- Given Epistemic Guides, we expect laws to be simple. (More on this later)
- One way to pick out the set Ω^H is by giving a complete (and infinitely) long list of possible histories contained in Ω^H.
- Another is by writing down simple equations, such as (1) and (2), which express simple laws.
- The equivalence of physical laws is not just the equivalence of their classes of models. **For two laws to be equivalent, it will require something more.**

Clarifications: The Governing Relation

Is governing a mystery? (Beebee, 2000)

- The notion of governing seems derived from the notion of government and the notion of being governed.
- But laws of nature are obviously not imposed by human (or divine) agents. So isn't it mysterious that laws can govern?
- Reply: a better analogy is not to human government, but to laws of mathematics and logic.
- Arithmetical truths such as $2 + 3 = 5$ and logical truths can also be said to constrain our world, in the sense of imposing formal constraints.
- The actual world cannot violate those mathematical or logical truths; every possible world must respect them.
- The actual world cannot violate physical laws; every physically possible world must respect them.

Clarifications: The Governing Relation

No analogy is perfect!

- Difference in epistemic access: we discover mathematical laws *a priori*, without the need for experiments or observations, but we discover physical laws *a posteriori*, empirically.
- Difference in scope: mathematical laws are more general than physical laws, in the sense that the former are compatible with "more models" than the latter.
- Still, it shows that the notion of governing does not depend on governing by agents.

On MinP, laws govern by constraining, and constraining is what they do. This provides the *oomph* behind scientific explanations. (We return to this shortly.)

However, such an oomph does not require dynamic production, and it does not require an extra process supplied by a mechanism or an agent.

Clarifications: Epistemic Access

- On MinP, even though the Humean criteria for the best system are not metaphysically constitutive for lawhood, they are nonetheless excellent epistemic guides for discovering and evaluating them.
- Lewis is right that in scientific practice, in the context of discovery, we do aim to balance simplicity and informativeness (among other things).
- Regarding Epistemic Guides, one might ask in virtue of what those theoretical virtues are good guides for finding and evaluating laws.
- This is a subtle issue.

Clarifications: Epistemic Access

- Unlike Humeans, we cannot appeal to a reductive analysis of laws.
- (By the way, what's the Humean story?)
- We can offer an empirical justification: the scientific methodology works.
- In so far as those theoretical virtues are central to scientific methodology, they are good guides for discovering and evaluating laws, and we expect them to continue to work.
- Related to the problem of induction.

Clarifications: Epistemic Access

Some other questions concerning MinP:

1. According to MinP, can laws change with time?
2. Can fundamental laws refer to non-fundamental properties, such as entropy?
3. How are fundamental laws distinguished from non-fundamental laws?
4. How do laws explain?
5. How does MinP compare to the other views?

Laws and Explanation

On MinP, laws explain, but not by accounting for the dynamic production of successive states of the universe from earlier ones.

- They explain by expressing a hidden **simplicity**, given by compelling **constraints** that lie beneath complex phenomena.
- A fundamental direction of time is not required for our notion of scientific (nomic) explanation.
- "Constraint explanation" (Ben-Menahem 2018; Lange 2016)

Laws and Explanation

To explain, fundamental laws need not be time-directed or time-dependent.

They may govern purely spatial distribution of matter.
For example, Gauss's law

$$\nabla \cdot \mathbf{E} = \rho \tag{3}$$

in classical electrodynamics—one of Maxwell's equations—governs a Maxwellian world and explains the pattern in the distribution of matter.

Laws and Explanation

Often the explanation that laws provide involves deriving striking, novel, and unexpected patterns from simple laws.

The relative contrast between the simplicity of the law and the complexity and richness of the patterns may indicate that the law is the correct explanation of the patterns.

Laws and Explanation

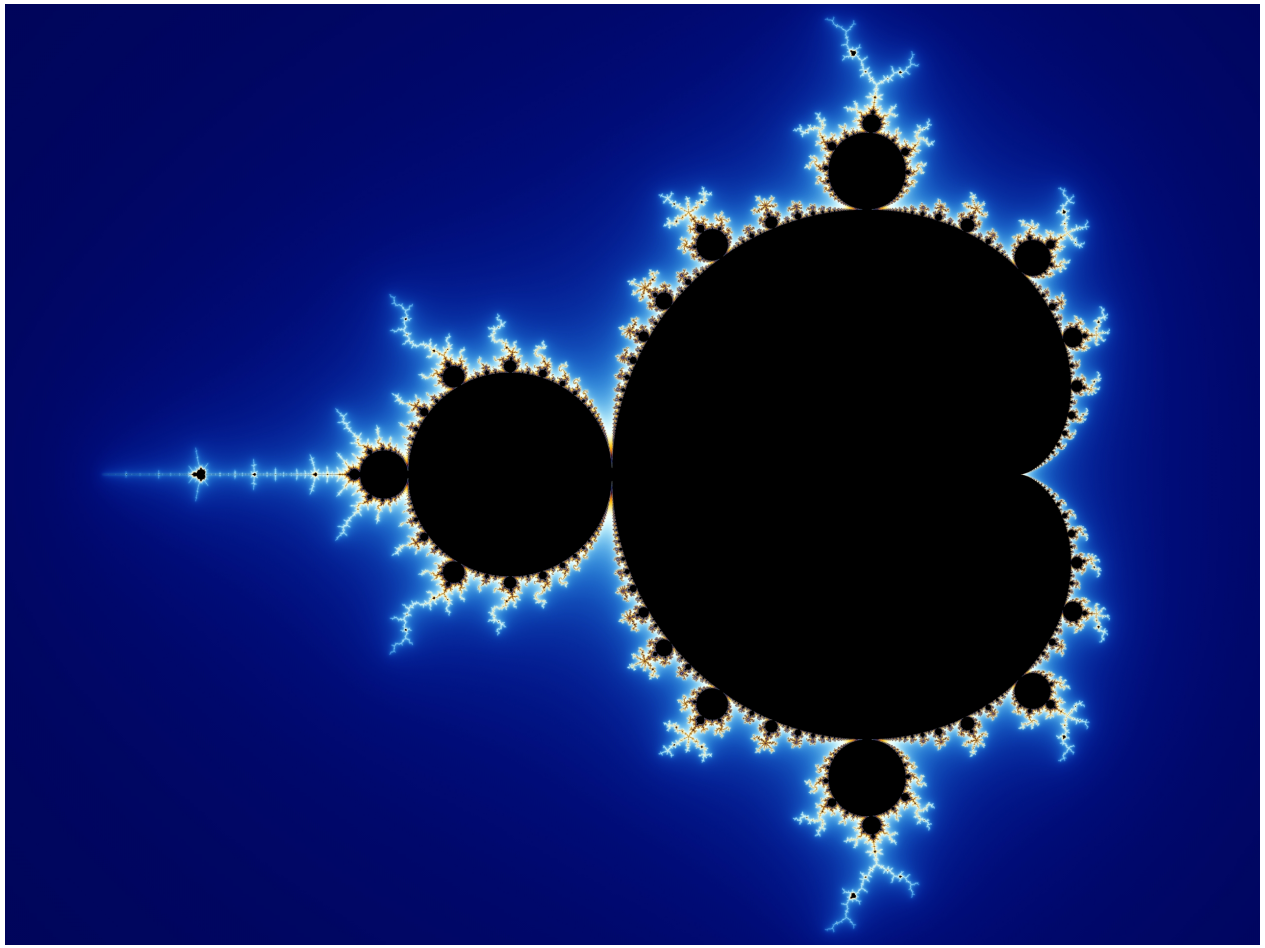


Figure: The Mandelbrot set with continuously colored environment. Picture created by Wolfgang Beyer with the program Ultra Fractal 3, CC BY-SA 3.0, https://creativecommons.org/licenses/by-sa/3.0, via Wikimedia Commons

For a more interesting example, 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

$$f_c(z) = z^2 + c \tag{4}$$

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 $(0, -1, 0, -1, 0, -1, ...)$ is bounded but $(0, 1, 2, 5, 26, 677, 458330, ...)$ is not.

Laws and Explanation

- In this example, a relatively simple rule yields a surprisingly intricate and rich pattern in the complex plane — a fractal structure.
- Regard the Mandelbrot set as corresponding to the distribution of matter over (a two-dimensional) spacetime.
- Call it the Mandelbrot world.
- The fundamental law for the Mandelbrot world is given by (4).

Laws and Explanation

Explaining the patterns:

- Given just the pattern we may not expect it to be generated by any simple rule.
- It would be a profound discovery in that world to learn that its intricate structure is generated by the aforementioned rule based on the very simple function $f_c(z) = z^2 + c$.
- The pattern is constrained by this fundamental law.
- Big contrast between the simplicity of the law and the complexity and richness of the patterns.
- Yet it is not a dynamical law (in the narrow sense of a temporal-evolution law).

Laws and Explanation

1. Laws explain by constraining the physical possibilities in an illuminating manner.
2. Nomic explanations (explanations given by fundamental laws) need not be dynamic / productive explanations; indeed, they need not involve time at all.
3. Explanation by striking constraint can be especially illuminating when an intricate and rich pattern can be derived from a simple rule that expresses the constraint imposed by a law.

Laws and Explanation

Two ingredients of a successful scientific explanation: a metaphysical dimension and an epistemic one.

1. must refer to the objective structure in the world
2. must relate to our mind, remove puzzlement, and provide an understanding of nature.

Laws and Explanation

1. Non-Humean Precondition
   - laws should not be mere summaries of, or supervenient on, what actually happens
   - what the laws are should not depend on our actual practice or beliefs

On MinP, the precondition is fulfilled by postulating fundamental laws as primitive (metaphysically fundamental) facts that constrain the world. The constraint provides the needed *oomph* behind scientific explanations. Here lies the main difference between MinP and Humean Reductionism.

Cf. grounding explanation

2. Epistemic Dimension
   - Constraints, in and of themselves, do not always provide satisfying explanations.
   - Many constraints are complicated and thus insufficient for understanding nature.
   - What we look for: not just any constraint but simple, compelling ones that ground observed complexities of an often bewildering variety.
   - It corresponds to the insight or realization that leads us to say, "Aha! Now I understand."

Penrose 1974: "it has to do with *unexpected* simplicity, where one imagines that things are going to be complicated but suddenly they turn out to be very much simpler than expected. It is not unnatural that this should be pleasing to the mind."

Laws and Explanation

The epistemic dimension illuminates our principle of Epistemic Guides:

- It is obvious that fundamental laws should be empirically adequate and consistent with all phenomena.
- But why should we expect them to be simple?
- On our view, this can partly be answered by thinking about the nature of scientific explanations.
- If successful scientific explanations require simple laws, then laws should be simple to perform their explanatory role.
- One might press further and ask why laws should perform such roles and why scientific explanations can be successful.
- But such questions can be raised for any account of laws.

Examples

To further illustrate our view, let's go through some examples:

1. Dynamical laws
2. Non-dynamical constraint laws
3. Probabilistic laws

Dynamical Laws

We take a dynamical law to be any law that determines how objects move or things change. Thus, our notion of dynamical laws is wider than Maudlin's notion of FLOTEs.

Dynamical Laws

1. Hamilton's equations.
2. Principles of least action.

$$\delta S = 0 \tag{5}$$

3. Wheeler-Feynman electrodynamics.

$$m_j \ddot{q}_j^{\mu} = e_j \sum_{k \neq j} \frac{1}{2} ({}^{(k)}F_{ret}^{\mu\nu} + {}^{(k)}F_{adv}^{\mu\nu}) \dot{q}_{j,\nu} \tag{6}$$

4. Retrocausal quantum mechanics.

$$\frac{d\boldsymbol{Q_j}(t)}{dt} = \frac{\hbar}{m_j} \mathrm{Im} \frac{\Psi_f \nabla_j \Psi_i}{\Psi_f^* \Psi_i} (Q(t), t) \tag{7}$$

5. The Einstein equation.

$$R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} = k_0 T_{\mu\nu} + \Lambda g_{\mu\nu} \tag{8}$$

Non-Dynamical Constraint Laws

1. The Past Hypothesis.

PH At one temporal boundary of the universe, the universe is in a low-entropy state.

Or: the Weyl curvature C_{abcd} vanishes at any singularity at one temporal boundary of the universe. (Penrose 1979)

Fundamental nomic vagueness $\rightarrow$ there are fundamental yet vague facts. (Chen 2022)

2. Conservation laws and symmetry principles (Wigner 1964, Weinberg 1992, Lange 2009).
If there is a symmetry principle K that a fundamental law of nature L must obey, then both K and L are fundamental facts, where K constrains L in the sense that the physical possibilities generated by L are invariant under the symmetry principle K, and any other possible fundamental laws are also constrained by K.

Probabilistic Laws

Two types of probabilistic postulates in physics:

1. stochastic dynamics (e.g. GRW, Nelson's stochastic mechanics)
2. probabilistic boundary conditions (e.g. Albert and Loewer's Statistical Postulate in the Mentaculus)

Our preference: probability $\rightarrow$ typicality

Even the GRW theory can be understood as specifying a typicality measure over histories of quantum states

Probabilistic Laws

- Probability measures and typicality measures are not straightforwardly understandable in terms of MinP
- It is not clear how they should be understood in terms of (categorical) constraints.
- The difficulty is greater for stochastic dynamics.
- Common to all non-Humean accounts
- No problem on Humeanism, if one sets aside the non-governing issue

Probabilistic Laws

Five options

1. Humeanism
2. Primitivism
3. Gradable constraint
4. Typicality constraint: typical histories are the only physically possible ones. (One circle)
5. Dual modalities: dualism between modal notions of possibility and typicality. Non-probabilistic laws govern by constraining the space of possibilities. Probabilistic laws govern by constraining which possibilities are typical. Neither is reducible to the other. Both typicality and possibility should influence our expectations, and both play roles in scientific explanations. (Two circles)

Comparisons

- MinP is a minimalist version of non-Humeanism about laws
- Naturally accommodates the diverse kinds of laws entertained in physics.
- We now turn to some differences between MinP and the alternatives.

Comparison with Humean Reductionism

- Ultimate explanation
- Non-supervenience
- Objectivity and mind-independence
- The package deal
- A sharper contrast

Comparison with Platonic Reductionism

- Requires fundamental universals
- Restrictions on the form of laws
- A fundamental direction of time?

Comparison with Aristotelian Reductionism

- Requires fundamental dispositions
- Problems specific to analyzing laws in terms of dispositions: constants, conservation laws, symmetry principles, principles of least action, multiple laws relating distinct properties
- Dynamic production
- A fundamental direction of time

Comparison with Maudlinian Primitivism

- Agreement on the status of laws
- Disagreement on the status of the direction of time, the form of laws, and the nature of nomic explanation

MinP is not committed to a fundamental direction of time; dynamic production is not essential to how laws govern or explain.

Our difficulty with dynamic production

- exclusion of certain laws
- the question of relata
- block universe
- relativity
- beginning of the universe

Conclusion

- MinP is an intelligible and attractive proposal for understanding fundamental laws of nature.
- It vindicates the non-Humean conviction that laws govern
- It is flexible enough to accommodate the variety of kinds of laws entertained in physics.
- In particular, it does not require that laws presume a fundamental direction of time
- MinP illuminates metaphysics but is not unduly constrained by it.

"Governing without a Fundamental Direction of Time: Minimal Primitivism about Laws of Nature," in Yemima Ben-Menahem (ed.), *Rethinking the Concept of Law of Nature*, Springer, 2022. Free version: arXiv 2109.09226

Thank you! The end.

Some Interesting Sociological Facts

"The PhilPapers Survey was a survey of professional philosophers and others on their philosophical views, carried out in November 2009. The Survey was taken by 3226 respondents, including 1803 philosophy faculty members and/or PhDs and 829 philosophy graduate students."

Laws of nature: Humean or non-Humean?

Accept or lean toward: non-Humean	532 / 931 (57.1%)
Accept or lean toward: Humean	230 / 931 (24.7%)
Other	169 / 931 (18.2%)

Also found were certain correlations...