Strong Determinism

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Philosophers' Imprint, forthcoming
arXiv:2203.02886

A Snapshot of the Universe

Introduction

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- Despite its complexity, it seems to follow simple laws.

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- Despite its complexity, it seems to follow simple laws.
- To discover what they are: one of the coolest projects we have attempted.

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- What's the role of philosophy?
- Not to propose the grand unified theory.
- But to understand...
  - what kind of laws we should look for,
  - what kind of things laws are,
  - and how they fit in our system of the world.

What should we look for in the fundamental laws of nature?

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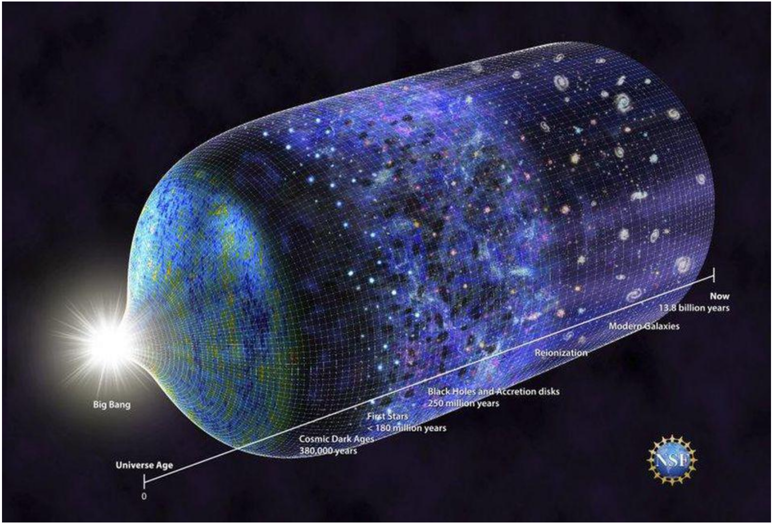
What should we look for in the fundamental laws of nature?

- An ideal of laws: determinism.
- Prediction, retrodiction, explanation.
- There is another ideal that requires more than determinism.
- It has the potential to explain why our world is this one.

The Universe



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Motivations:

- Philosophically fruitful concept
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- Perplexing consequences
- Surprisingly easy to achieve in an Everettian multiverse [but not in a way one might expect]

Speaking of multiverses...

Two upshots

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We will catch a glimpse of these...

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Strong determinism goes beyond determinism.

Starting from determinism

Let's start by defining determinism.

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- Ω^T: the set of possible worlds that satisfy the fundamental laws specified in theory T.
- Ω_α: the set of possible worlds that satisfy the actual fundamental laws obtaining in α, i.e. the set of all physically / nomologically possible worlds.

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This is sometimes called *two-way determinism*.

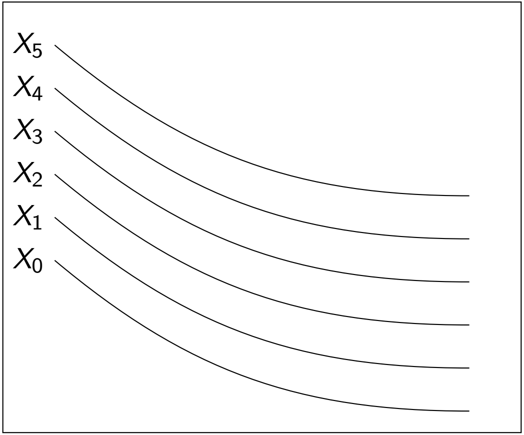

Figure: Schematic illustration of a deterministic theory T. Ω^T contains six nomologically possible worlds that do not cross in state space.

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Contrast with Penrose's definition

- Mathematical scheme vs. fundamental laws

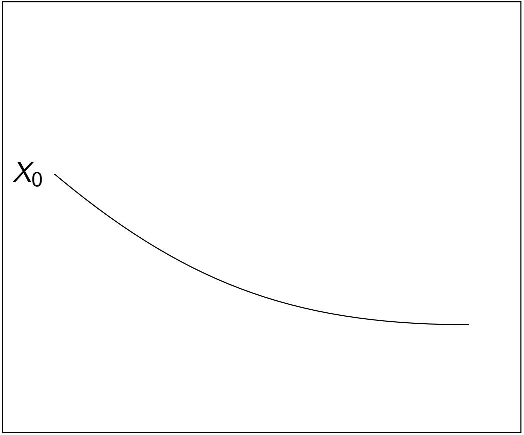

Figure: Schematic illustration of a strongly deterministic theory T. Ω^T contains exactly one nomologically possible world.

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- But not all cases of strong determinism are like that.

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- Even when there is no fundamental temporal structure, the definition of strong determinism can still apply.
- It only requires the minimal notion of the cardinality of the set of models, while defining determinism requires a notion of temporal agreement.

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Some differences between super-Det and strong Det:

- While typical histories according to super-Det violate statistical independence, such a violation is not required on strong Det.
- While there is exactly one physically possible world according to strong Det, super-Det is compatible with having (infinitely) many.

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Penrose has a specific way of thinking about the connection among the mathematical, the physical, and the mental realms.

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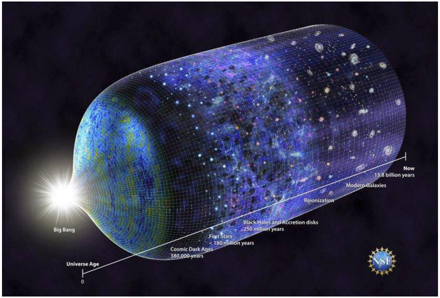
- it is closer to satisfy the PSR.
- it has perplexing consequences for counterfactuals and causation.
- it enables a strong type of prediction.

Strong Explanation

Let's start with explanations.

Strong Explanation



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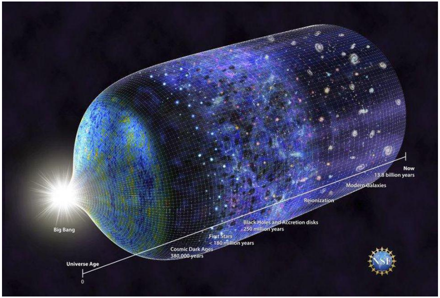

Conditional Explanation Given the state of the universe at some time (or some interval of time), the fundamental laws entail the state of the universe at any time.

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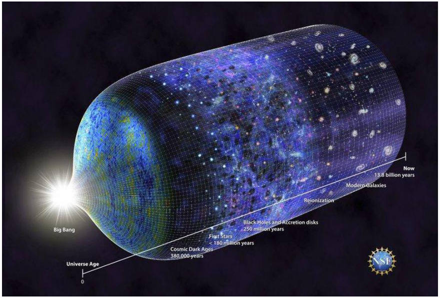

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Leaving nothing unexplained, strong explanation can be the most satisfying.

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PSR

The roots of the notion of determinism surely lie in a very common philosophical idea: the idea that everything can, in principle, be explained, or that everything that is, has a sufficient reason for being and being as it is, and not otherwise. In other words, the roots of determinism lie in what Leibniz named the Principle of Sufficient Reason. (Hoefer, 2016)

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- Of course, the full version of PSR is stronger, requiring a sufficient reason for the laws themselves.
- That requires an even stronger form of determinism. (open question)

Causation and Counterfactuals

Strong determinism leads to perplexing consequences for causation and counterfactuals.

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- Counterfactual dependence: $(A \mathrel{\Box\!\!\rightarrow} C) \wedge (\neg A \mathrel{\Box\!\!\rightarrow} \neg C)$

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- Surprising triviality thesis: every event causes every other event.
- Causality disappears?

Causation and Counterfactuals

I suggest three options:

- Option 1: Causality still exists because the counterfactuals are still true. The world is more causally connected than we are used to. In fact, it is maximally causally connected.

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Many open questions here for philosophers to work on.

Strong Prediction

Let's turn to predictions.

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- We may have epistemic limitations.
- There can still be meaningful notions of uncertainty (e.g. of self-location).

Other Philosophical Implications

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Bonus slides.

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Now you know what strong determinism is.

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You start to wonder: what it might look like.

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- Can we find out by doing experiments or observations?
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Let's think through some examples.

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- This is a strongly deterministic world.
- Definitely not our world!
- Not much explanation by the law, because there is not much to be explained.

Toy Example 2: the Mandelbrot world

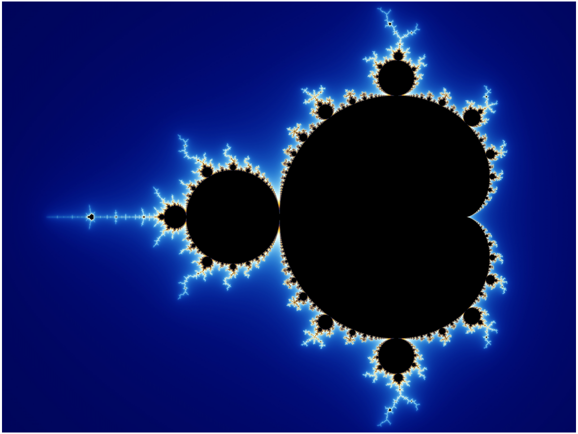

Figure: The Mandelbrot set with continuously colored environment. Picture created by Wolfgang Beyer with the program Ultra Fractal 3, CC BY-SA 3.0, https://creativecommons.org/licenses/by-sa/3.0, via Wikimedia Commons

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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.

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- The fundamental law for the Mandelbrot world is given by (1). [note]

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The Mandelbrot world is strongly deterministic.

- The distribution of matter in spacetime is completely specified by (1).
- Nothing is left to choice, chance, or contingency.

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Explaining the patterns:

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- 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

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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.
4. Strongly deterministic laws may offer an especially strong kind of explanation, when there is a significant contrast between the complexity of the patterns and the simplicity of the laws.

More details on this conception of laws and explanation (MinP)

Eddy Keming Chen and Sheldon Goldstein, “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

arXiv: 2109.09226

A more realistic example

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Is it possible?

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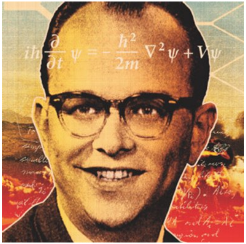
Penrose's example



Penrose's example of strong determinism: the many-worlds interpretation of Everett.

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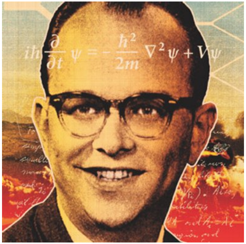

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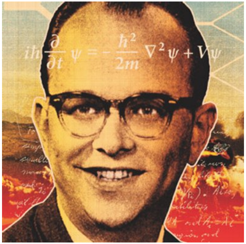

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The theory permits infinitely many microscopic initial conditions, and hence infinitely many histories of the multiverse.

The Everettian Wentaculus

However, there is another Everettian theory that is strongly deterministic.

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It is the Everettian Wentaculus.

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For more info on the Wentaculus, see Chen (2019, 2020, 2022a, 2022b, 2023)

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2. **The Past Hypothesis (PH)**: at a temporal boundary of the universe, the wave function Ψ_0 of the universe lies inside a low-entropy macrostate that, given a choice of C-parameters, corresponds to $\mathscr{H}_{PH}$, a low-dimensional subspace of the total Hilbert space.

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3. **The Statistical Postulate (SP)**: given the subspace $\mathscr{H}_{PH}$, we postulate a uniform probability distribution over the wave functions compatible with $\mathscr{H}_{PH}$.

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Can we do better?

The Everettian Mentaculus admits many choices of the initial quantum states.

Can we do better?

Can we narrow down the initial choices to exactly one?

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- There is a natural density matrix in $\mathscr{H}_{PH}$—the normalized projection operator:

$$\frac{I_{PH}}{dim \mathscr{H}_{PH}},$$

where I_{PH} is the identity / projection operator on $\mathscr{H}_{PH}$.

1. **Fundamental Dynamical Laws (FDL):** the quantum state of the universe is represented by a density matrix $\hat{W}(t)$ that obeys the von Neumann equation.

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2. **The Initial Projection Hypothesis (IPH)**: at a temporal boundary of the universe, the density matrix is (must be) the normalized projection onto $\mathscr{H}_{PH}$, a low-dimensional subspace of the total Hilbert space.

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No accompanying statistical postulate!

Figure: End of equations.

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The Everettian Wentaculus

Given the fundamental laws (deterministic dynamics + IPH), there is exactly one possible history of the Everettian multiverse — the actual one.

Therefore, the Everettian Wentaculus is strongly deterministic.

What does the world look like according to this theory?

The Everettian Wentaculus

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Depending on how to be a realist about the quantum state

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Depending on how to be a realist about the quantum state

- Material ontology
- A law of nature

For more details, see the options surveyed in Chen, E. K. (2019). "Realism about the wave function." *Philosophy Compass*, 14(7): e12611. **arXiv:1810.07010**

The Everettian Wentaculus

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Chen and Chua (in preparation) "Branching and the Born Rule in a Mixed-State Everettian Multiverse"

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Compare:

- Albert's conjecture of GRW quantum shuffling
- Wallace's conjecture of the Simple Past Hypothesis

The Everettian Wentaculus

Other payoffs of the Wentaculus:

- Nature of the quantum state. (Chen, *BJPS* 2021)
- Fundamentality of space-time. (Chen, *JPhil* 2017)
- Compatibility with Humean Supervenience. (Chen, *Noûs* 2022)
- Narratability and Lorentz invariance. (Chen, *Noûs* 2022)
- Vagueness in the laws of nature. (Chen, *Phil Review* 2022)
- Unification of universe-level and subsystem-level descriptions. (Chen, 2023)

So, a strongly deterministic theory is not difficult to find.

- The Everettian Wentaculus is a realistic example.
- It has several theoretical virtues (in virtue of being a Wentaculus theory).

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However, in general, the two strategies will make very complicated laws; they do not underwrite satisfactory explanations.

Empirical Adequacy

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- I assume so.
- But it is a subtle issue.

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- Everettian Wentaculus is empirically equivalent to Bohmian Mentaculus, and so on
- Every quantum theory is empirically equivalent to one that is strongly deterministic. (p.c. Jeff Barrett)
- In a time-asymmetric quantum world like ours, we cannot find out whether strong determinism is true or false by experiments or observations.
- In-principle underdetermination by evidence!

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6. We can never empirically rule out strong determinism
7. Theoretical virtues may even favor certain strongly deterministic theories.

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With strong determinism,

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- the universe is what it must be;

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With strong determinism,

- the universe is what it must be;
- the universe is the way it is because that's the only way it can be.

Open questions

- The Hartle-Hawking No-Boundary Proposal
- Causation, counterfactuals, and intervention
- Relations to ideas in the history of philosophy

Some Related Papers

(1) arXiv 1712.01666, *BJPS*, 2018 [2021]
(2) arXiv 2006.05029, *Noûs*, 2020 [2022]
(3) arXiv 2006.05298, *Philosophical Review*, 2022
(4) arXiv 1902.04564, in *Statistical Mechanics and Scientific Explanation*, 2020
(5) arXiv 2110.14531, *Journal of Philosophy*, 2017
(6) arXiv 2109.09226, with Sheldon Goldstein, in *Rethinking the Concept of Laws of Nature*, 2022
(7) arXiv 2008.00611, in *The Probability Map of the Universe*, 2023
(8) *Laws of Physics*, Cambridge University Press, forthcoming

Thank you for your attention!

We face an obvious problem. Different ways to express the same content, using different vocabulary, will differ in simplicity...Given system S, let F be a predicate that applies to all and only things at worlds where S holds. Take F as primitive, and axiomatise S (or an equivalent thereof) by the single axiom $\forall x F x$. If utter simplicity is so easily attained, the ideal theory may as well be as strong as possible. Simplicity and strength needn't be traded off. Then the ideal theory will include (its simple axiom will strictly imply) all truths, and a fortiori all regularities. Then, after all, every regularity will be a law. That must be wrong. (Lewis 1983, p.367)

(F1) F applies to all and only things at worlds where S holds, which includes the actual world.

(F2) F applies to all and only things at the actual world.

Lewis initially defines F as (F1). However, he needs the logically stronger (F2) to argue that $\forall x Fx$ strictly implies all truths. Given the characterization in (F2), the deductive system S axiomatized as $\{\forall x Fx\}$ is compatible with exactly one world. That is, $|\Omega^S| = 1$. Hence, S is strongly deterministic on my definition. If S is the best system of the actual world, strong determinism is true.
To say that must be wrong is to say strong determinism is impossible, which is false.

I propose a revised argument:

> *Given system S, let F be a predicate that applies to all and only things at the actual world. Take F as primitive, and axiomatise S (or an equivalent thereof) by the single axiom ∀xFx. If utter simplicity is so easily attained, the ideal theory may as well be as strong as possible. Simplicity and strength needn't be traded off.* **This makes the actual world strongly deterministic, regardless of what the actual world is like. Then, after all, strong determinism is necessarily true (or true at least in all worlds where the BSA holds).** *That must be wrong.*

PAST I have no influence over the past state at time t: there are no alternative decisions d_1 and d_2 possible for me at t such that $d_1 \Box\!\!\rightarrow s_1$ and $d_2 \Box\!\!\rightarrow s_2$, where s_1 and s_2 are incompatible states of affairs that pertain to times prior to t.

LAWS I have no influence over the laws at time t: there are no alternative decisions d_1 and d_2 possible for me at t such that $d_1 \Box\!\!\rightarrow L_1$ and $d_2 \Box\!\!\rightarrow L_2$, where L_1 and L_2 are incompatible laws.

Lewis on Naturalness

One of Loewer's insights is based on the fact that, in the Mentaculus theory, there are distinct nomologically possible microstates compatible with the same macrostate at any time. According to Loewer, I have influence over the past state at t such that, if I had done otherwise than what I actually do, the microstate of the world at time prior to t would have been another microstate.
However, if the Mentaculus theory is false and strong determinism is true, there will be exactly one nomologically possible microstate of the universe at any time. In that case, the fundamental laws are compatible with exactly one past state at any time prior to t. If I now had influence over the past state, I would now have influence over the laws.

Wilson on Modal Realism

One place in which arbitrariness might seem to remain within quantum modal realism is in the initial quantum state of the universe. Since quantum modal realists model contingency as variation across Everett worlds, there can be no contingency in an initial state that these worlds have in common... If it were to turn out that the true initial quantum state of our universe has arbitrary-seeming features that lack any apparent theoretical explanation, that would be prima facie evidence against quantum modal realism–since it would suggest a source of contingency in reality that goes beyond quantum contingency. But at present there is no reason to believe this is how things will turn out. (Wilson 2020, p.28)