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Does fine-tuning support the existence of a multiverse?

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Abstract. In the context of the probabilistic fine-tuning argument for the existence of a divine designer, appeals to the existence of a multiverse have often seemed ad hoc. The situation is rather different though if there is independent evidence from physics for a multiverse. This paper argues that the fate of the fine-tuning argument depends on open questions in fundamental physics and cosmology. It also argues that the many-worlds interpretation of quantum mechanics opens up new routes to undercutting the force of the fine-tuning argument.

1. Introduction

In the context of the probabilistic fine-tuning argument (FTA) for the existence of a divine designer, appeals to the existence of a multiverse have often seemed ad hoc. The situation is rather different though if there is independent evidence from physics for a multiverse.

This paper will argue that the fate of the FTA depends on open questions in fundamental physics and cosmology. It will also argue that Everettian (many-worlds) quantum mechanics opens up new routes to undercutting the force of the FTA.

2. The fine-tuning argument

Let us call a parameter in a cosmological theory 'fine-tuned' if there is no underlying theoretical explanation for its value and if small variations from the actual value would lead to a universe unconducive to life. According to the notorious FTA, the evidence of fine-tuning of parameters in our best cosmological theories supports the divine design hypothesis. The basic thought is that fine-tuning would be much less surprising if there is a divine designer.

Anthropic reasoning is sometimes deployed to block the FTA: if the parameters were not right for life nobody would be around to notice. But you ought to be surprised to find yourself alive after a reliable firing squad has attempted to shoot you (and may reasonably infer some unknown cause of their all missing) even if you would not have been around if they had successfully carried out their task. (This analogy is given by John Leslie [1].)

An ultra-reliable firing squad all missing their target is intrinsically unlikely: there is a very low objective chance of survival under ordinary conditions and hence survival boosts the probability of the hypothesis that some unknown factor is at work. There is a corresponding probability boost to the design hypothesis if fine-tuned parameters had a very low objective chance.

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3. Fine-tuning and multiverses

Here multiverses have often entered the story. Positing a multiverse, containing a universe for every possible combination of parameter values, seems to achieve the required result: explaining the fine-tuning of parameters *somewhere*. It is not unlikely that somewhere amongst all the universes of a suitably large and diverse multiverse there is one with life-conducive parameter values (I will say: 'a fine-tuned universe').

A problem with the multiverse response, pointed out by Ian Hacking [2] and Roger White [3]: it still seems unlikely that this very universe – the one we inhabit – should be fine-tuned. Our complete evidence tells us that this universe is fine-tuned, not merely that some universe is fine-tuned. That more specific, logically stronger evidence seems as unlikely given a multiverse cosmology as it is given a single universe cosmology. This universe, one may reason, had a tiny chance of ending up with the right parameters—so you and I still had a tiny chance of existing. In light of this objection, Hacking characterises multiverse explanations of fine-tuning as committing the 'Inverse Gambler's Fallacy'.

4. Multiverses as undercutting defeaters

The fine-tuning debate focusses on whether with no independent evidence for a multiverse fine-tuning is evidence for a multiverse. The question of what fine-tuning evidence supports if there is independent evidence for a multiverse has not been as much explored. An exception is Roger White:

"*…the Multiple Universe hypothesis screens off the probabilistic link between the Design hypothesis and the fine-tuning data. Hence if we happened to know, on independent grounds, that there are many universes, the fine-tuning facts would give us little reason to question whether the big bang was an accident, and hence our knowledge of the existence of many universes would render the fine-tuning of our universe unsurprising*." [3: 273-274]

To use a term of contemporary epistemology, the existence of a multiverse is an *undercutting defeater* for beliefs in divine design based on fine-tuning. Evidence of a multiverse is evidence that fine-tuning evidence does not support the divine design hypothesis.

Consider the familiar analogy of misleading lighting: an object looks red to us so we conclude that it is red (figure 1). Once we find out object is being lit with red light, we recognise that we ought to revert to our prior expectations about the object's colour. Information about the misleading lighting screens off the evidential relevance of our perceptual experience to the object's colour.

Figure 1. Red lighting: is the post white or red? Image: Lucas Zimmerman.

Which multiverses can undercut? Consider Max Tegmark's classification of multiverses [4]:

- Level 1: Multiplicity of regions of a single spacetime, spatio-temporally distant from one another. All regions share the same physical parameters.

Theories of cosmic inflation seem to predict a Level 1 multiverse. But all regions of such a multiverse have the same parameters. Hence the fine-tuning evidence remains highly surprising even on the supposition that we live in a Level 1 multiverse and such a multiverse is not an undercutting defeater for the FTA.

- Level 2: Multiplicity of regions of a single spacetime with varying parameters.

In a Level 2 multiverse, then there are infinitely many different regions of spacetime with suitable parameter values for life, and it is no surprise that as living beings we observe such a region.

While Level 1 multiverses are relatively mainstream, the theories that generate Level 2 multiverses are much more speculative. They include:

- Andrei Linde's chaotic inflation model [5], figure 2 (also known as eternal inflation).
- Lee Smolin's cosmological natural selection model [6].

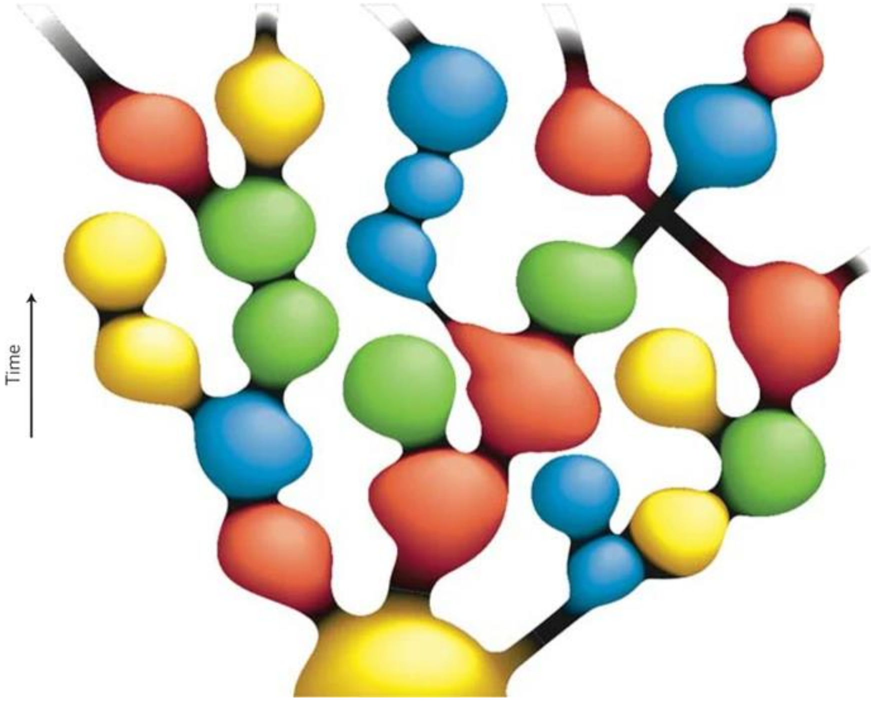

Figure 2. Chaotic inflation. Image: Andrei Linde.

If we take a Level 2 multiverse seriously, then to that extent the fine-tuning argument is undercut. Our situation is like someone who has seen an object that looks red but knows that misleading lighting is a serious possibility. The more confident we are in a Level 2 multiverse, the more confident we should be that the fine-tuning evidence is undercut.

- Level 3: Multiplicity of quantum-mechanical worlds.

The Level 3 multiverse is the multiverse of Everettian quantum mechanics, otherwise known as the many-worlds interpretation. There is a quantum world for each physically possible course of events. Unlike Levels 1 and 2, the universes of the Level 3 multiverse are not different regions within a single spacetime. Rather, each inhabits its own spacetime. Quantum worlds can be thought of as superimposed,

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rather than as laid out in a mosaic pattern. There is a quantum world corresponding to all physically possible outcomes of indeterministic quantum processes.

The million-dollar question: are there processes that assign non-zero chances to life-permitting combinations of parameter values?

5. A toy model of fine-tuning

Suppose just one parameter is involved—call it Z—and suppose that Z may take any integer value from 1 to 100. Only if Z = 77 is life possible. Z = 77 is observed.

Suppose that Everettian quantum mechanics is correct and that a quantum-mechanically indeterministic process determines the value of Z. There will then be quantum worlds with each physically possible value of Z.

Consider four hypotheses about the quantum process that fixes the value of Z:

- Process A: The quantum probability of Z value 77 is 100%. All other values get zero probability.
- Process B: The quantum probability of Z taking value n is 0.01% for each integer n from 1 to 100 except for n = 77; the quantum probability of Z taking value 77 is 99.01%.
- Process C: The quantum probability of Z taking value n is 1% for each integer n from 1 to 100.
- Process D: The quantum probability of Z taking value n is (n/50.5)% for each integer n from 1 to 100.

How do each of these probability distributions bear on the fine-tuning reasoning?

- Process A does not give rise to a multiverse that undercuts fine-tuning.

It guarantees that there will be a quantum world with a life-conducive value of Z, but this is not enough to fully undercut the support that fine-tuning provides for the divine designer hypothesis. Fine-tuned parameter values continue to play an unexplained dynamically-distinguished role in the underlying theory. So there would still be a significant boost in this toy scenario for the divine design hypothesis.

- Process B does not give rise to a multiverse that undercuts fine-tuning.

Although all values of n are physically possible, there is still something dynamically-distinguished about the life-supporting value of Z: it is nearly 10000 times more likely than any other value of Z and there is no explanation for this fact within the underlying theory. So there would still be a significant boost in this toy scenario for the divine design hypothesis.

- Process C does give rise to a multiverse that undercuts fine-tuning.

The particular Z value that is conducive to life does not play any special role in the theory. It is not dynamically distinguished in any way from other possible parameter values, so there is no basis for the hypothesis that a divine designer had any hand in distinguishing it.

- Process D does give rise to a multiverse that undercuts fine-tuning.

As with Process C, the particular Z value that is conducive to life does not play any dynamically-distinguished role in the theory. The probability distribution over Z values is not uniform, but nor is it especially tilted towards life-conducive Z values. What makes a quantum world more likely to be the outcome of the initial chance process in this scenario is just higher Z value; this fact by itself is not suggestive of divine design.

For Process A and B a divine designer is not necessary to explain why the actual quantum world we observe has suitable parameters. Rather, Processes A and B invite the hypothesis of a divine designer to explain why the theory itself has certain properties that are correlated with life-conduciveness. The evidence for a divine designer is not based on the observed parameter values being unlikely, but instead is based on the way in which these observed parameter values are selected being unlikely. That alters the nature of the FTA, but it does not change the upshot.

Which of these scenarios is actual if many-worlds quantum mechanics is correct? It is simply too early to tell for sure. Not enough is known about the physics of the very early Universe to know whether there were suitable quantum-mechanically indeterministic dynamical processes in the early Universe.

6. String landscape models

Many-worlds quantum mechanics, while not itself undercutting the FTA, does at least provide a cosmological framework suitable to host dynamical processes by which the FTA might be undercut.

String landscape models as proposed by e.g. [7], following [8], provide one possible form that these dynamical processes could take. In the string landscape scenario, it would be a matter of quantum chance which vacuum was formed by compactification of a Calabi-Yau manifold (figure 3). In a many-worlds implementation of this quantum-mechanically chancy compactification process, there would exist a quantum world corresponding to each possible compactification.

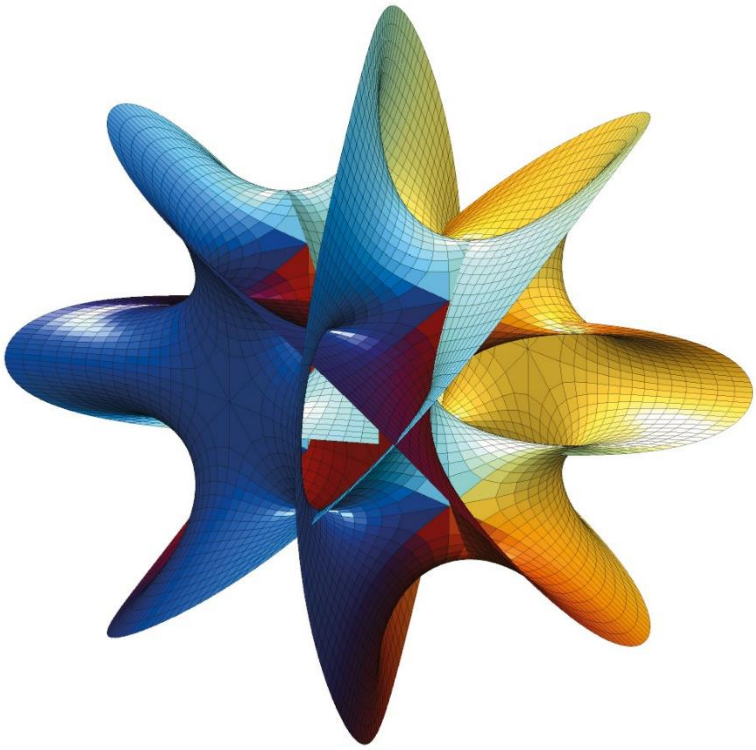

Figure 3. Compactification of a Calabi-Yau manifold. Image: Z. Zhang.

7. Conclusions

Better cosmological theories are needed to settle the status of the FTA - in particular of candidate dynamical processes that might give rise to variation in parameter value in the early Universe.

However, there is an evidential route to undercutting the FTA that is available in many-world quantum mechanics but not in one-world quantum mechanics. The interpretation of quantum mechanics thus turns out to be potentially evidentially relevant to the question of divine design.

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