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Analyzing the Multiverse with Bayesianism

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Abstract. Multiverse is a popular concept embraced by many scholars, including physicists who support the many-worlds interpretation of quantum mechanics. However, the necessity of adding many extra entities to the traditional single universe is debatable. Bayesianism, which contends to utilize degrees of belief to measure our credence, is a suitable tool to be introduced in this debate. This paper discusses the reason for believing in the multiverse and utilizes Bayesianism, claiming that we should believe in the multiverse due to the fine-tuned constants. The fine-tuned universe and Bayes' Rule are introduced, then the inverse gambler's fallacy is explained to object to the reasoning of the multiverse. Subsequently, however, the paper raises examples and Bayesian calculations to argue that the multiverse is good reasoning. Finally, the paper concludes that the multiverse is good reasoning by using 'selection effects' to distinguish it from the inverse gambler's fallacy.

Keywords: Multiverse; Bayesianism; Probability; Inverse Gambler's Fallacy; Selection Effects.

1. Introduction

The multiverse theory is widely accepted by scholars for its merit in offering explanations for many dilemmas, such as the interpretation of modality and the measurement problem in quantum mechanics. These dilemmas always involve long debates and various explanations; multiverse is one alternative explanation, a radical, innovative, and persuasive theory that cannot be falsified. In addition to its radical, revolutionary nature and its ability to offer a background for many theories, the multiverse is not baseless—it is supported by 'inflationary cosmology' since the inflation that once formed our universe could happen repeatedly and create a constellation of bubble universes each with different properties and each isolated from the others.

It has been said that our universe is 'fine-tuned' since it has the right physical constants, suitable for supporting complex lives, such as speed of light c = $3\times 10^{8} m/s$, gravitational constant G = $6.67 \times 10^{-11} m^3/kg \cdot s^2$, and mass of an electron $m_e = 9.1 \times 10^{-28} g$. Scientists have calculated the possibility of having the right physical constants capable of supporting complex lives to emerge by chance as 1 in 10^{229}, which means that is almost impossible. We cannot, therefore, attribute this nearly impossible event to luck without hesitation. Some people would turn to God as an explanation, but the suggestion that God designed the world would not solve the problem because this suggestion pushes us back to a fundamental question: where did God come from in the first place? The concept of God itself is a mystery so we cannot adopt this explanation. There are only two options left: as I see it (1) There is a subtle law that the physical constants must obey but has not yet been discovered and every physical constant must be fixed and corresponding in order to obey that law. (2) There are infinitely many universes, or at least a very large number of universes, each with different fundamental constants. In a small number of these, complex lives are possible, and we live in one of those rare universes.

The first explanation gives us hope to find the subtle and definitive law, but this is not my goal in this article. This is a job for a physicist. The second explanation raises the idea of a multiverse. Common sense suggests that, if there are infinitely many universes, the fact that ours has the right constants would be more acceptable: Among these many universes, there should be some that have the 'fine-tuned physical constants' if physical constants are given to each universe at random.

The main point of Bayesianism is that our beliefs can be measured by degrees, and such degrees of belief can be used in the calculation, as explained in the following section. The main contribution of this paper is to mingle the concept of the multiverse with calculations of degrees of belief and

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defend the multiverse theory as reasonable by considering different examples and calculations, and by saving the multiverse from the inverse gambler's fallacy with the selection effects.

2. Bayes' Rule

Bayes' Rule is basically used in mathematics' conditional probability problems. However, it can also be used to calculate personal probability or other belief-type probabilities. This is because our degree of belief obeys the laws of probabilities:

(1) For each A, $0 \leq Pr\,(A) \leq 1$.

(2) If A is certain, $Pr\,(A) = 1$.

(3) If A and B cannot both be true at once, $Pr\,(A\ or\ B) = Pr\,(A) + Pr\,(B)$

Bayes' Rule is crucial in epistemology since it teaches people how to deal with new evidence and how to update their personal belief system when acquiring new evidence in a numerical way:

$$Pr\,(H|E) = Pr\,(H) \times \frac{Pr\,(E|H)}{Pr\,(E)}$$

Bayes' Rule is important in that it leads us to some surprising discoveries about our beliefs. In other words, Bayes' Rule equips us with the ability to know our beliefs more rationally, and sometimes the result derived from Bayes' Rule will be different from what we think. This point can be seen in the discussion of the multiverse that follows.

3. The Probability of Multiverse

We have already discussed why there might be a multiverse. Here, we can utilize the Bayes' Rule to discuss the probability of multiverse from our own perspective. According to Bayes' Rule, we can get:

$$Pr\,(H|E) = Pr\,(H) \times \frac{Pr\,(E|H)}{Pr\,(E)}$$

H: There is a multiverse.

E: Some universe is fine tuned.

$Pr\,(some\ universe\ is\ fine\ tuned|there\ is\ a\ multiverse)$ is quite large, possibly 0.8, since if there is a multiverse that contains many or possibly infinite universes, we are more inclined to believe some will be fine-tuned universes. Our degree of belief in the probability of some fine-tuned universe would increase given the confirmation of a multiverse. $Pr\,(some\ universe\ is\ fine\ tuned)$, reversely, is small enough. Before we are told that our universe has very rare physical constants that can support complex lives, a 'fine-tuned universe' is a shocking statement that most of us would assign la ow degree of belief. The exact numbers here do not matter; let us, therefore, assume $Pr\,(some\ universe\ is\ fine\ tuned)$ is 0.001, a very small number. In this way, we can put the numbers back into the equation:

$$Pr\,(H|E) = Pr\,(H) \times \frac{0.8}{0.001} = Pr\,(H) \times 800$$

H: There is a multiverse.

E: Some universe is fine tuned.

Again, exact numbers do not matter here; the characteristic of the value is what counts. As shown, our belief in the existence of a multiverse increases dramatically (by 800 times) after we understand that our universe is fine-tuned. The fact that we see a fine-tuned universe increases our degree of belief in the multiverse hypothesis. We can conclude that anybody that knows the fact that some universe is fine-tuned should be somewhat convinced about a multiverse, according to

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Bayes' Rule, and that degree of their belief varies and depends on their initial belief, $Pr\,(H)$. The validity of such belief needs the following discussion.

4. The Gambler's Fallacy and the Inverse Gambler's Fallacy

Briefly, the gambler's fallacy describes an easily-made mistaken assumption that something is more likely to occur because it seldom or never has occurred but other possible things occurred many times alternatively. This is a mistaken conclusion since how often an event has occurred in the past will not necessarily affect the future. In the casino, for example, seeing the results of 12 rolls of dice in a sequence of 12 numbers, '1,3,5,4,2,5,3…,3,2', not including '6' does not mean the next roll will more likely be a '6'. This can be illustrated by putting the scenario into Bayes' Rule:

$$Pr\,(H|E) = \, Pr\,(H) \times \frac{Pr\,(E|H)}{Pr\,(E)}$$

H: The next result is '6'.

E: Past result is the sequency of 12 numbers, '1,3,5,4,2,5,3…,3,2', not including '6'.

Since H is a future event, the probability of past results '1,3,5,4,2,5,3…,3,2' should not be influenced given that the next result is '6'. In this way,

$$Pr\,(E|H) = Pr\,(E) = (\frac{1}{6})^{12}$$

and

$$Pr\,(H|E) = Pr\,(H) = \frac{1}{6}$$

The probability of the next result being '6' is still $\frac{1}{6}$, as we can see. In this way, the assumption that the next number more likely would be '6' given past results is an example of gambler's fallacy.

The inverse gambler's fallacy is another wrong but common consideration. It describes the following: if we see a rare event, we may believe there have been many attempts that failed to achieve this event. Take the case of the casino, where we see the only two dice on a table, showing two '6's in a single toss the moment we approach that table. This is rare since '6' is the largest number on a die and there are two '6's in a single toss, which is even more rare. We might think that before we approached the table in the casino, there must have been many attempts that failed to get two '6's, and the game must have gone on for a while to get this result, two '6's. This is also a misconception, as we can see in the following analysis using Bayesianism:

$$Pr\,(H|E) = \, Pr\,(H) \times \frac{Pr\,(E|H)}{Pr\,(E)}$$

H: There have been many attempts before.

E: I see two '6's in a single toss the moment I approach the table.

Here, given that there have been many attempts before, the probability of seeing two '6's still should not be influenced by past attempts, so:

$$Pr\,(E|H) = Pr\,(E) = \frac{1}{6} \times \frac{1}{6} = \frac{1}{36}$$

and

$$Pr\,(H|E) = Pr\,(H)$$

We can conclude that the fact that we see two '6's in a single toss the moment we approach the casino table has nothing to do with there having been many tossing attempts. The mistaken conclusion that there must have been a lot of attempts is completely wrong; we call this the inverse gambler's fallacy.

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5. Multiverse is Bad Reasoning

We have already discussed the inverse gambler's fallacy in the casino, which I have named the 'two dice casino' example. Let us now reflect: should we believe that many other universes have other random physical constants since we see a fine-tuned universe where we live? Let us clarify this point in another scenario.

In this scenario, a monkey is typing poems; the action of witnessing the monkey typing poems is comparable to the action of finding evidence of a fine-tuned universe. What would be your reaction to the typing monkey? On the one hand, this monkey seems very intelligent and special; On the other hand, millions of other monkeys are typing nonsense. This second notion is the inverse gambler's fallacy, which should be rejected; most people would believe the first monkey to be special and they would research this 'special' monkey. Similarly, we see a fine-tuned universe in which we live. Should we choose to believe that our universe is a special one, designed by God or made possible by great luck, or might we assume that there are infinitely many universes without the right constants? The latter thought is an example of the inverse gambler's fallacy, and in this sense, the fine-tuned reasoning of a multiverse also suffers from the inverse gambler's fallacy.

However, this analogy is, perhaps, fallacious. There is a subtle difference between the monkey case and the multiverse case: we can observe monkeys not typing poems, by putting a typewriter in front of a random monkey that can never type, but we are unable to witness a universe without fine-tuned physical constants. One reason is that complex life would never exist in those universes, and the other reason is that we cannot detect the properties of other universes.

But does that difference make a difference? Consider another closer example and eliminate the difference between the above example and the fine-tuned universe, by imitating the multiverse with more similarities. Now we add a *bad guy* in the monkey example. You wake up in a room, in which there is a bad guy and a monkey typing poems. The bad guy tells you that you wake up and survive because the monkey types poems, and if it does not type poems, you would have already been killed and would never wake up. Just like you can never detect a universe without fine-tuned constants, you can never witness a monkey that cannot type poems. Again, it would be the inverse gambler's fallacy if you choose to believe your survival can be explained by assuming that many other people have been killed by the bad guy at times that the monkey does not type poems, and your corresponding monkey happens to type poems so that you survive. The assumption of many other monkeys and victims, which is similar to the idea of a multiverse, is still fallacious even if the example has imitated the fine-tuned universe further. Now it seems confirmed that a multiverse is still bad reasoning.

6. Multiverse is Good Reasoning

The inverse gambler's fallacy tackles the reasoning of the multiverse that uses fine-tuned constants as evidence. It suggests that there should be no difference in our degree of belief after we get the evidence of fine-tuned physical constants in our universe. Otherwise, we commit the inverse gambler's fallacy. However, the previous analysis of the revised monkey case (the example that imitates multiverse by adding a *bad guy* to make sure that you would not see the monkey's typing nonsense) omits a crucial point called 'selection effects'. The circumstances of the monkey case and its revised version are different. The emergence of the bad guy in the revised version leads to the necessity of considering 'selection effects'. We can witness the physical constants, just like being able to survive in the revised monkey case, because our universe was selected by a biased process, and such a process can be seen in the following analysis of a die example and the multiverse example.

Let us consider a '100 dice example.' If you are waiting outside a room where 100 dice are being tossed, when all 100 dice come up '6' at the same time, you will be called into the room, which means you can only witness the situation where all dice show '6'. Now you are called in and see a 100 dice that came up '6'. You do not know how many tosses there have been. Would you believe

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this is the only toss? No! At this moment, it is reasonable to believe this is probably not the first toss, as we can see in the following:

$$Pr\,(H_1|E) = 1 - Pr\,(H_2|E)$$

H_1: There has been at least one more toss prior to now.
H_2: There has been no toss prior to now.
E: This is the first toss with a hundred '6's.

Since

$$Pr\,(H_2|E) = Pr\,(H_2) \times \frac{Pr\,(E|H_2)}{Pr\,(E)}$$

You do not know how many tosses there have been, and you would be called in only when there are a hundred '6's, so let us first not consider $Pr\,(H_2)$, but we are sure it will be a number between 0 and 1, according to the laws of probabilities as mentioned.

Now let us consider $Pr\,(E|H_2)$ and $Pr\,(E)$. $Pr\,(E|H_2)$ is your degree of belief in this is the first toss given that there has been no toss prior to now. $Pr\,(E|H_2)$ equals to $(\frac{1}{6})^{100}$, which is a very small number. $Pr\,(E)$is surely much larger than $Pr\,(E|H_2)$. In this way, we can conclude:

$$\frac{Pr\,(E|H_2)}{Pr\,(E)} is\ a\ very\ small\ number$$

As mentioned, $Pr\,(H_2)$is a number between 0 and 1, so we get:

$$Pr\,(H_2) \times \frac{Pr\,(E|H_2)}{Pr\,(E)} is\ a\ very\ small\ number$$

And

$$Pr\,(H_2|E)\ is\ a\ very\ small\ number$$

Since $Pr\,(H_1|E) = 1 - Pr\,(H_2|E)$, we get:

$$Pr\,(H_1|E) \approx 1$$

As we can see, we have strong reason to be sure that there has been at least one more toss prior to now. In this case, I can substitute H_1 with 'there is at least one universe other than ours', H_2 with 'there is only one universe', and E with 'our universe has fine-tuned physical constants'. Likewise, we were born in this universe given that our universe has fine-tuned physical constants, just like being called into the room when there are a hundred '6's shown. We have good reason to believe there has been at least one toss prior to 'now' in the given example. Similarly, we have good reason to believe that there are other universes or at least one universe other than ours, which means we should have a high degree of belief in the existence of multiverse. This point can be further supported by the following analysis:
We have rules:

$$Pr\,(H_1|E) = 1 - Pr\,(H_2|E)$$
$$Pr\,(H|E) = Pr\,(H) \times \frac{Pr\,(E|H)}{Pr\,(E)}$$

H_1: There is one universe.
H_2: There are two universes.
E: Some universe is fine tuned.

Another form of Bayes' Rule is

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$$Pr\,(H_1|E) = \frac{Pr\,(H_1) \times Pr\,(E|H_1)}{Pr\,(H_1) \times Pr\,(E|H_1) + Pr\,(H_2) \times Pr\,(E|H_2)}$$

As actual numbers do not matter here, let us assume:

$$Pr\,(H_1) = 0.5$$
$$Pr\,(H_2) = 0.5$$

Set p as the possibility that a given universe is fine-tuned.

We get:

$$Pr\,(H_1|E) = \frac{0.5p}{0.5p + 0.5(1-(1-p)^2)} = \frac{1}{3-p}$$
$$Pr\,(H_2|E) = \frac{0.5(1-(1-p)^2)}{0.5p + 0.5(1-(1-p)^2)} = \frac{2-p}{3-p}$$

As mentioned, p stands for the possibility that a given universe is fine-tuned, which is a very small number. As p approaches 0, the probability that there is one universe drops to 0.333, which is lower than 0.5. As p approaches 0, the probability that there are two universes increases to 0.667. In other words, the fact that there is a fine-tuned universe increases the probability of a multiverse.

7. Explaining the Contradiction with Selection Effects

Reviewing the analysis in the previous sections, we first reach an ambiguous outcome by using Bayes' Rule that our belief in the multiverse will increase after obtaining the evidence of fine-tuned constants in our universe. This point, along with the idea of a multiverse, is attacked by the inverse gambler's fallacy which tells us there should be no difference in the probability of fine-tuned constants in our universe given that there is a multiverse, which is supported by a two dice casino example and a monkey example. Subsequently, a similar casino example, with a hundred dice, and another multiverse example both show a different result that supports the multiverse hypothesis and contradicts the inverse gambler's fallacy. It is also written that the previous analysis of the revised *monkey cas*e omits a crucial point called, 'selection effects.' What leads to the contradiction between the inverse gambler's fallacy and the outcomes of examples obtained by Bayes' Rule that support the multiverse? This requires a close look at 'selection effects.'

Here we discuss selection effects in biased procedures, where only members with a specific property are selected for a sample. This is very different from the way we gain random members for the sample, and they differ in the way we get evidence. Let us take a closer look at the two casino examples: In the two dice casino example mentioned earlier, we walk into the casino and happen to see the two dice both showing '6's, but we could, alternatively, see other combinations of dice randomly at the moment. In the latter casino example, however, we are only called to get into the room when all 100 dice show '6', which means the only result we can see is dice showing a hundred '6's. The result of the two-dice casino example is not confirmed, which would lead us to the inverse gambler's fallacy if we assume there are many attempts that fail. The result of the latter example is confirmed, which can only be all '6's. Therefore, it is reasonable to believe there will probably be other attempts. The multiverse hypothesis is similar to the latter example of casino since the only result that we can see is the fine-tuned universe, which means the result is confirmed just like the latter casino case.

8. Conclusion and Implication

In this paper, after gaining the evidence of our fine-tuned universe, generally, our belief in the multiverse will increase significantly. This reasoning is supported by Bayesianism. Later, this reasoning is attacked by the inverse gambler's fallacy, which suggests the fine-tuned constants should not affect our belief in a multiverse. However, other examples that imitate the case of a

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multiverse suggest a contradiction with what the inverse gambler's fallacy implies; our degrees of belief are enhanced after we are exposed to the evidence of fine-tuned constants. Finally, this contradiction is explained by selection effects, which describe different ways from which we get evidence and whether the evidence we can see is confirmed. Furthermore, selection effects distinguish the case of a multiverse from the inverse gambler's fallacy, proving the validity of the reasoning for a multiverse.

Based on the evidence of the fine-tuned nature of our universe, it is reasonable to believe that there is a multiverse, according to the epistemology of Bayesianism. People should give more credence to the multiverse theory since the fine-tuned nature confirms the existence and validity of other universes.

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