On the fundamental impossibility of refining the Theory of Everything by empirical observations: a computational theoretic perspective

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Abstract

Over centuries, physicists have been striving to unveil the most fundamental physical rules of the universe, known as the "Theory of Everything," which usually requires the heavy use of experimental observations to inspire or validate physical assertions. We herein show, however, that under very modest physical, philosophical and mathematical assumptions, such empirical observations of our universe are completely ineffective in the study of the Theory of Everything, in the sense that the Bayesian posterior probability that a certain candidate Theory of Everything is true is the same regardless of what we empirically observe about the universe. Implications of this conclusion are briefly discussed. In particular, we advise to defund expensive physics projects such as large colliders, and instead raise the funding in the field of computational theory, which is (provably) a more efficient strategy for encouraging really useful research on the Theory of Everything.

1 Introduction

As is known to all, the quest for the "ultimate truth" of our universe – notably, the most basic, "bottom-level" physical rules, known as the "Theory of Everything" (ToE)[1], and the initial conditions of our universe – has been viewed by many reductionist scientists as the most important, or even ultimate mission of science. It is an ancient and still widespread belief that once the ToE and the initial conditions of the universe are known, one can at least in principle calculate everything about the universe and therefore come to know every single knowledge of the world. However, despite the remarkable success of e.g. the Standard Model, there are still quite many aspects of the universe that cannot yet be explained by contemporary physics. The size of the gap between our current understanding of physics and the true ToE is still largely unknown, especially given that even if we think we have found the ToE, the theory may well be just an effective theory (a very good approximation to the true ToE, but not equivalent to the ToE), and some ultra-precise experiments or experiments carried out under previously unreachable energy scales may eventually disprove that theory and ruin our day in the far future, just like how measurements of light speed under different reference frames disproved Newtonian mechanics and how certain quantum effects disproved classical mechanics.

While some philosophers may disagree, the consensus among scientists is that any attempt to formulate the ToE should rely on empirical observations (including passive observations and experiments) of our universe, such as the evolution of the universe and the interactions of particles. Either a candidate ToE is directly inspired by observations of the universe, or it is first proposed on the ground of mathematical, aesthetic and/or philosophical considerations and then verified by actual observations. It is widely agreed that sufficient experimental and observational evidence, especially under extreme conditions (e.g. observations of the very early history of the universe, black holes, or the collisions of very high-energy particles), must be gathered so as to provide new insights into the ToE, and enough evidence to falsify some of the current candidates of the ToE. This has led to a number of extremely costly projects, such as space telescopes, ground-based large radio telescopes, and large particle colliders. However these endeavors have not yet been rigorously proved to be worthwhile for those who are only interested in the ultimate theory; while occasional discovery of new particles or refined measurements of the large scale structures of the universe do provide new insights that seemingly push us further towards the ToE, it is always a theoretical possibility that they may only help to clarify some aspects of the phenomenological effective theories, but are completely useless for refining the bottom level theory, i.e. the ToE.

In this work, we prove that if one is only interested in the ToE but not the effective theories derived from it, then one should not pay anything on the Big Science stuffs mentioned above. The argument is very simple: the ToE must be able to give birth to the human civilization in order to be consistent with our universe, and that means the ToE must be Turing complete. But a Turing complete system can emulate any other Turing complete system, and given a sufficiently complex initial condition, many of such emulations will actually occur, and there will be many regions in the universe that behave like other universes with complete different physical rules than the ToE. The latter universes will have regions that behave like still other universes, etc. (Figure 1). Eventually, the details of the ToE do not really matter: if we look up from the bottom of the tree in Figure 1, it may be that many vastly different candidate ToEs will converge to a very similar set of leaf nodes. If this is the case, then it will be a very inefficient strategy to deduce the form of the ToE from what we empirically observe, since no matter what the ToE is, we tend to observe similar facts about the universe. The remaining parts of the article make this claim rigorous, and in fact prove that, the only observational evidence that can be used to derive or constrain the form of the ToE is that we ourselves exist in the universe, which are indeed useful in refining the ToE by use of the Anthropic Principle[2]; any other observations, whatever energy or space scale they are

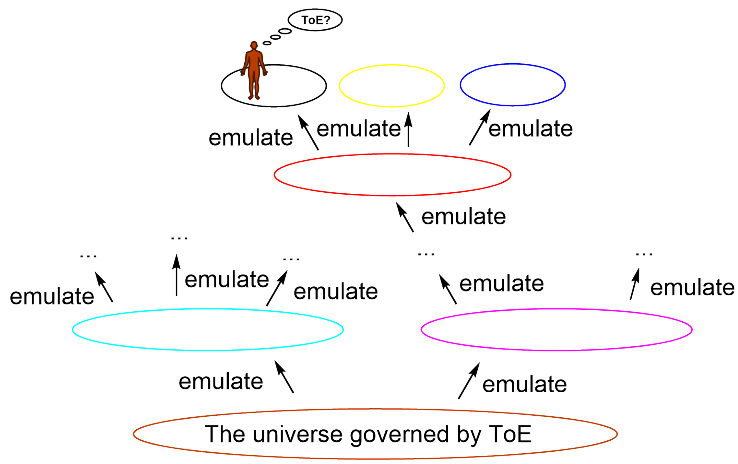

Figure 1: Illustration of the hierarchical emulation of universes by the ToE.

probing and however inspiring they may seem, are absolutely useless, without lending even a single additional hint to the ToE. However, we *can* understand the ToE better by studying how a random Turing complete system emulates other Turing complete systems, which are in the realm of computational theory. A natural corollary is that particle colliders and deep space telescopes are a waste of money for ToE research, and the money should be invested into computational theory research instead!

2 Results

We start by making the following innoculous assumption.

Assumption 1. *Our universe is simulated by a cellular automaton (CA).*

This idea is of course not new[3, 4], but is unfalsifiable as we know it, so we must treat it as an assumption. As most discrete physical models of our universe can be reformulated as CAs, and the physical models that cannot be exactly formulated as CAs can be approximated to arbitrary precision by CAs, this assumption is actually a very reasonable one. Given this assumption, we may define the ToE as the rule of the CA. Of course, it may be that the CA simulates another CA, which then simulates the universe that we actually see. In this case we still say that our universe is simulated by the first CA, not the second one (since by definition the ToE refers to the most basic rules of the universe, not apparent rules that are the result of other deeper rules); we however say that the second CA "emulates" our universe (Figure 2). In other words, when we talk about simulating a universe with a CA, we always assume that the CA is a "real thing," i.e. the CA is not simulated by something else, and the simulation can be indirect, i.e. simulating something else and let that thing simulate the universe;

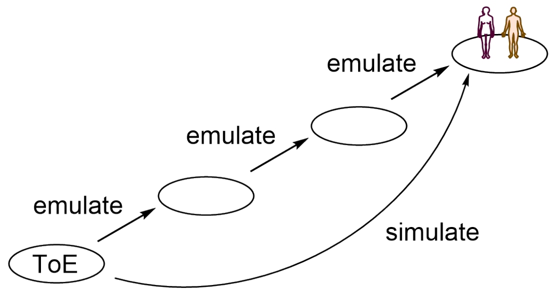

Figure 2: The difference between simulating something and emulating something.

when the CA may be simulated by something else, and the CA simulation gives rise to the universe or another CA simulation directly, without first simulating an intermediate CA, we use the word "emulate." Note also the difference between a CA simulation and a CA that simulates the universe; only the latter requires that the CA is a real thing, but the former can be used in any context, for example we can say that a CA simulation emulates another CA simulation.

The second assumption is

Assumption 2. *The CA that is simulating our universe is Turing complete.*

Quantum mechanics, as we know it, is Turing complete; if this is indeed the case, the CA that is simulating it must be Turing complete as well. But the quantum mechanics as we know it is an approximation, and we cannot rigorously rule out the possibility that the true underlying rules of the universe are not Turing complete. So we leave this as an assumption, although it is a very reasonable one.

Definition 1 (The Emulation Matrix)**.** Suppose we combine all possible *Turing complete* CA rules $\{\mathcal{R}\}$ and all possible initial states $\{\mathcal{I}\}$ into tuples $\{(\mathcal{R},\mathcal{I})\}$. Then the emulation matrix $\mathbf{E}$ is defined as

$$\mathbf{E}_{(\mathcal{R}_2,\mathcal{I}_2)(\mathcal{R}_1,\mathcal{I}_1)} = N \tag{1}$$

iff a simulation of the Turing complete CA rule $\mathcal{R}_1$ starting from initial state $\mathcal{I}_1$ emulates N instances of simulations of the Turing complete CA rule $\mathcal{R}_2$ starting from initial state $\mathcal{I}_2$. For brevity, if there is a simulation of a CA rule $\mathcal{R}$ starting from initial state $\mathcal{I}$, we may refer to the CA simulation as "the CA simulation $(\mathcal{R},\mathcal{I})$" (which makes sense since $\mathcal{R}$ and $\mathcal{I}$ uniquely determine the whole simulation). We can also use a variable to label the simulation and do not write out the tuple explicitly (e.g. "the CA simulation i").

We now define the *emulation depth* in a recursive fashion.

Definition 2 (The Emulation Depth)**.** The CA simulation that is simulating our universe has an emulation depth of 0. If a CA simulation has an emulation depth of N and emulates another simulation, the emulation depth of the latter CA simulation is $N+1$.

Theorem 1. *The number of instances of a given simulation i that have emulation depth N is*

$$(\mathbf{E}^N \mathbf{V}^{(X)})_i \tag{2}$$

where

$$\mathbf{V}_i^{(X)} = \delta_{iX} \tag{3}$$

is a column vector that has only one non-zero element which is 1, δ is the Kronecker delta, and X is the simulation that is simulating our universe.

Proof. Trivial for $N=0$. If the theorem holds for a given N, then the number of instances of a given simulation i that have emulation depth $N+1$ is

$$\sum_j \mathbf{E}_{ij}(\mathbf{E}^N \mathbf{V}^{(X)})_j = (\mathbf{E}^{N+1}\mathbf{V}^{(X)})_i \tag{4}$$

$\square$

Corollary 2. *The total number of instances of a given simulation i is*

$$((\sum_{N=0}^{+\infty} \mathbf{E}^N)\mathbf{V}^{(X)})_i \tag{5}$$

To proceed, we get ourselves into the philosophical realm and define the following:

Definition 3 (The Observation Matrix)**.** For any CA simulation i and any kind of empirical observation α, the matrix elements of the *observation matrix* $\mathbf{O}$ are defined as

$$\mathbf{O}_{\alpha i} = N \tag{6}$$

iff the CA simulation i emulates N sentient beings that make the empirical observation α.

For example, if a Game of Life (GoL)[5] simulation from a certain initial state $\mathcal{I}$ produces 5 physicists who conclude that their universe is expanding, then $\mathbf{O}_{(\text{the universe is expanding})(\text{GoL},\mathcal{I})} = 5$.

Corollary 3. *The total number of sentient beings that make the empirical observation α is given by*

$$\mathbf{n}_{\alpha X} = (\mathbf{O}(\sum_{N=0}^{+\infty} \mathbf{E}^N)\mathbf{V}^{(X)})_\alpha \tag{7}$$

Theorem 4. *The total number of sentient beings simulated by X is*

$$n_X = \max_\alpha \mathbf{n}_{\alpha X} \tag{8}$$

Proof. A sentient being, in order to be sentient, must be able to observe at least the fact that the sentient being itself exists[6]. Therefore $n_X \leq \max_\alpha \mathbf{n}_{\alpha X}$. But a sentient being must exist before it can make any observation, so $n_X \geq \max_\alpha \mathbf{n}_{\alpha X}$. The only possibility is thus $n_X = \max_\alpha \mathbf{n}_{\alpha X}$. □

Theorem 5.

$$\frac{\mathbf{n}_{\alpha X}}{n_X} > 0 \quad \text{if} \quad n_X = +\infty \tag{9}$$

i.e. if there are an infinite number of sentient beings in a universe, then no matter how seemingly inconsistent the empirical observation α is with the physical reality of the universe, there is always a finite portion of the sentient beings that claim they observe α.

Proof. This is expected because there is always a non-zero probability that a given sentient being is hallucinated, brainwashed, confused, or simply stupid, and come to believe in a given claim about the universe, however ridiculous and/or self-contradictory the claim may be. □

Note that the theorem holds even if α is something like "I do not exist," since a finite portion of people do believe in both a proposition and its negation[7].

Theorem 6. *There exists a Turing complete CA simulation that emulates one instance of every possible Turing complete CA simulation.*

Proof. For any Turing complete CA rule and any computational task, it is always possible to set the initial state of a CA simulation simulated by that rule, such that the simulation implements that particular computational task. So, given a Turing complete CA rule, we can always set the initial state so that the CA simulation (hereafter denoted as i^*) emulates one instance of every possible Turing complete CA simulation. □

Definition 4 (The Principle Eigenvalue and the Principle Eigenvector)**.** Suppose we sort the eigenvectors of $\mathbf{E}$ in descending order according to the norms of their corresponding eigenvalues. The first eigenvector $\mathbf{U}$ that satisfies $\mathbf{OU} \neq \mathbf{0}$ is called the principle eigenvector (as $\mathbf{U}$ is not necessarily square-normalizable, we normalize it by its infinity norm instead of its 2-norm, i.e. we set the element with the largest absolute value to 1). The corresponding eigenvalue is called the principle eigenvalue λ.

Theorem 7. *The norm of the principle eigenvalue is $+\infty$.*

Proof. Because the simulation i^* emulates every CA simulation once, $\mathbf{EV}^{(i^*)}$ is a vector with all 1's. It then follows that $\mathbf{E}^N\mathbf{V}^{(i^*)}$ is a vector with all positive values for any $N \geq 1$, since i^* also emulates itself once, which means

$$(\mathbf{E}^N\mathbf{V}^{(i^*)})_i \geq (\mathbf{E}^{N-1}\mathbf{V}^{(i^*)})_i, \quad \forall\, i \tag{10}$$

Suppose we expand the normalized (w.r.t. the infinity norm) version of $\mathbf{E}^N\mathbf{V}^{(i^*)}$ in terms of the eigenvectors of $\mathbf{E}$, $\{\mathbf{U}^{(\mu)}\}$:

$$\frac{\mathbf{E}^N\mathbf{V}^{(i^*)}}{\max_i(\mathbf{E}^N\mathbf{V}^{(i^*)})_i} = \sum_\mu c_\mu \mathbf{U}^{(\mu)} \tag{11}$$

As is known from the properties of the power iteration[8], when N is sufficiently large, only those c_μ whose corresponding eigenvalues λ_μ have the largest norm can survive. The eigenvalues must have an infinite norm, because $\|\mathbf{V}^{(i^*)}\|_2 = 1$ and $\|\mathbf{E}\mathbf{V}^{(i^*)}\|_2 = +\infty$. On the other hand, $\mathbf{O}\mathbf{E}^N\mathbf{V}^{(i^*)} \neq \mathbf{0}$ due to the fact that some matrix elements of $\mathbf{O}$ are non-zero and the elements of $\mathbf{E}^N\mathbf{V}^{(i^*)}$ are all positive. Thus among the eigenvectors $\mathbf{U}^{(\mu)}$ whose corresponding coefficients c_μ survive when $N \to +\infty$, at least one of them must satisfy $\mathbf{O}\mathbf{U}^{(\mu)} \neq \mathbf{0}$, which implies Theorem 7 because λ_μ already have an infinite norm. □

We need one additional assumption at this point.

Assumption 3. *The principle eigenvalue λ is non-degenerate. Moreover, among the eigenvalues of $\mathbf{E}$ besides λ and λ's complex conjugate, there is no eigenvalue that has the same norm as λ does.*

This is a very reasonable assumption since the norms of two eigenvalues of a matrix, in general, can only become degenerate by coincidence, except when they are the complex conjugate of each other. As a result, the principle eigenvalue is unique up to a complex conjugate, and the principle eigenvector is unique up to a complex conjugate and constant scaling.

At this point we are ready to prove our main result:

Theorem 8. *Under the above assumptions, the success of making a certain empirical observation does not alter the posterior probability that any given ToE candidate is the true ToE.*

Proof. Suppose we are given two candidate CA simulations X_1 and X_2, such that one of them is simulating our universe. We want to decide their relative posterior probability $P^{\text{post},\alpha}_{X_1}/P^{\text{post},\alpha}_{X_2}$ based on a given relative prior probability $P^{\text{prior}}_{X_1}/P^{\text{prior}}_{X_2}$ and the fact that we successfully made a physical observation α of our universe. To be fair, we should not announce that any given ToE candidate is absolutely impossible without making even a single observation of the universe. Thus, we require that the prior probability of any CA simulation be positive.

So a sentient being that knows nothing about the universe except that the sentient being itself exists, will (according to the Anthropic Principle[2]) conclude that the relative posterior probability that the universe is simulated by X_1 rather than by X_2 is

$$\frac{P^{\text{post}}_{X_1}}{P^{\text{post}}_{X_2}} = \frac{P^{\text{prior}}_{X_1} n_{X_1}}{P^{\text{prior}}_{X_2} n_{X_2}} \tag{12}$$

where $P^{\text{post}}_{X_1}$ is the posterior probability that the universe is simulated by X_1 given only the knowledge that the sentient being exists.

If the sentient being further makes the observation α, then the relative posterior probability will be

$$\frac{P_{X_1}^{\text{post},\alpha}}{P_{X_2}^{\text{post},\alpha}} = \frac{P_{X_1}^{\text{prior}}\mathbf{n}_{\alpha X_1}}{P_{X_2}^{\text{prior}}\mathbf{n}_{\alpha X_2}} \tag{13}$$

Now, several possibilities exist:

1. $P_{X_1}^{\text{post}}/P_{X_2}^{\text{post}} = +\infty$ (A sentient being that merely knows that itself exists will conclude that the simulation X_1 is infinitely more likely to simulate its universe than the simulation X_2).

   Since we have assumed that $P_{X_1}^{\text{prior}}$ and $P_{X_2}^{\text{prior}}$ are positive (and of course they are smaller than 1), this implies that $n_{X_1}/n_{X_2} = +\infty$. In this case, according to Eq. (9), $\mathbf{n}_{\alpha X_1}/n_{X_1} > 0$, and obviously $\mathbf{n}_{\alpha X_2}/n_{X_2} \leq 1$ due to Eq. (8). Thus $\mathbf{n}_{\alpha X_1}/\mathbf{n}_{\alpha X_2} = +\infty$, and it follows that $P_{X_1}^{\text{post},\alpha}/P_{X_2}^{\text{post},\alpha} = +\infty$. Hence, even if the sentient being observes the empirical fact α, it will still conclude that the simulation X_1 is infinitely more likely to simulate its universe than the simulation X_2, and the observation α is thus useless for gaining any insight into the relative posterior probability of X_1 being the ToE compared to X_2 being the ToE.

2. $P_{X_1}^{\text{post}}/P_{X_2}^{\text{post}} = 0$ (A sentient being that merely knows that itself exists will conclude that the simulation X_1 is infinitely less likely to simulate its universe than the simulation X_2).

   This implies $P_{X_2}^{\text{post}}/P_{X_1}^{\text{post}} = +\infty$, and by the same reasoning one concludes that $P_{X_2}^{\text{post},\alpha}/P_{X_1}^{\text{post},\alpha} = +\infty$, i.e. the Bayesian estimate of the relative posterior probability of X_1 being the ToE and X_2 being the ToE is not altered by observing α.

3. $0 < P_{X_1}^{\text{post}}/P_{X_2}^{\text{post}} < +\infty$ (A sentient being that merely knows that itself exists will conclude that the simulation X_1 is neither infinitely less likely nor infinitely more likely to simulate its universe than the simulation X_2).

   This is the most interesting case. At the first glance, substituting $P_{X_1}^{\text{post}}/P_{X_2}^{\text{post}}$ by $P_{X_1}^{\text{post},\alpha}/P_{X_2}^{\text{post},\alpha}$ may indeed change the value of the ratio. But is it the case? Let us divide this case into two sub-cases:

   (a) There exists a CA simulation Z such that $P_{Z}^{\text{post}}/P_{X_1}^{\text{post}} = +\infty$.
   In this case, Z is infinitely more likely to be the correct simulation that is simulating our universe than X_1 is, so X_1 cannot be correct and need not be considered as a candidate theory at all. Since X_2 is not infinitely more likely to be the correct simulation than X_1, we conclude that X_2 cannot be correct, either. And the observation α does not change the conclusion that neither X_1 nor X_2 can be the ToE because, following a similar line of reasoning as above, if $P_{Z}^{\text{post}}/P_{X_1}^{\text{post}} = +\infty$ ($P_{Z}^{\text{post}}/P_{X_2}^{\text{post}} = +\infty$), then $P_{Z}^{\text{post},\alpha}/P_{X_1}^{\text{post},\alpha}$ ($P_{Z}^{\text{post},\alpha}/P_{X_2}^{\text{post},\alpha}$) must also be $+\infty$.

(b) There is no CA simulation Z such that $P_Z^{\text{post}}/P_{X_1}^{\text{post}} = +\infty$.
Suppose we choose an arbitrary simulation Z. By virtue of Eq. (7),

$$\mathbf{n}_{\alpha Z} = (\mathbf{O}(\sum_{N=0}^{+\infty} \mathbf{E}^N)\mathbf{V}^{(Z)})_\alpha \tag{14}$$

At this point we can divide this sub-case into two sub-sub-cases:

i. The principle eigenvalue, λ, is real.
According to Assumption 3, λ is non-degenerate. Thus we conclude that[8], if $\mathbf{U}_Z \neq 0$,

$$\mathbf{n}_{\alpha Z} = \mathbf{U}_Z \sum_{N=0}^{+\infty} \lambda^N (\mathbf{OU})_\alpha \tag{15}$$

Since $\mathbf{OU}$ is by construction not the zero vector, and the prefactor $\mathbf{U}_Z \sum_{N=0}^{+\infty} \lambda^N$ has an infinite norm, we conclude that for some α, $\mathbf{n}_{\alpha Z} = +\infty$ (the positive sign is because $\mathbf{n}_{\alpha Z}$ by definition must be a non-negative integer). But according to Eq. (9), this means that $\mathbf{n}_{\alpha Z} = +\infty$ for every α.
If $\mathbf{U}_Z = 0$, however, we have

$$\mathbf{n}_{\alpha Z} < \epsilon \sum_{N=0}^{+\infty} \lambda^N (\mathbf{OU})_\alpha, \quad \forall\, \epsilon \tag{16}$$

Thus, the assumption that no Z satisfies $P_Z^{\text{post}}/P_{X_1}^{\text{post}} = +\infty$ implies that $\mathbf{U}_{X_1} \neq 0$, and also (because $0 < P_{X_1}^{\text{post}}/P_{X_2}^{\text{post}} < +\infty$) that $\mathbf{U}_{X_2} \neq 0$.
As $\sum_{N=0}^{+\infty} \lambda^N (\mathbf{OU})_\alpha$ is independent of Z, if we respectively set $Z = X_1$ and $Z = X_2$, we see that

$$\frac{\mathbf{n}_{X_1\alpha}}{\mathbf{n}_{X_2\alpha}} = \frac{\mathbf{U}_{X_1}}{\mathbf{U}_{X_2}} \tag{17}$$

Combined with Eq. (8), Eq. (12) and Eq. (13), we have

$$\frac{P_{X_1}^{\text{post},\alpha}}{P_{X_2}^{\text{post},\alpha}} = \frac{P_{X_1}^{\text{post}}}{P_{X_2}^{\text{post}}} = \frac{P_{X_1}^{\text{prior}}\mathbf{U}_{X_1}}{P_{X_2}^{\text{prior}}\mathbf{U}_{X_2}} \tag{18}$$

meaning that the observation α does not alter the aforementioned relative posterior probability.

ii. λ is complex.
In this case, we select a Z such that $\mathbf{U}_Z \neq 0$. Then, the contributions of two eigenvectors dominate $\mathbf{n}_{\alpha Z}$ after left-multiplying by $\mathbf{E}^{+\infty}$: one is $\mathbf{U}$, and the other is the eigenvector associated with $\bar{\lambda}$ (the overbar denotes complex conjugation), which is the

element-wise complex conjugate of $\mathbf{U}$, $\bar{\mathbf{U}}$, owing to the fact that $\mathbf{E}$ is a real matrix. That there are only contributions from $\mathbf{U}$ and $\bar{\mathbf{U}}$ is due to the assumption that no eigenvalue of $\mathbf{E}$ has the same norm as λ, except for λ itself and $\bar{\lambda}$ (Assumption 3). Thus the expression of $\mathbf{n}_{\alpha Z}$ now reads

$$\begin{aligned} \mathbf{n}_{\alpha Z} &= \mathbf{U}_Z \sum_{N=0}^{+\infty} \lambda^N (\mathbf{OU})_\alpha + \bar{\mathbf{U}}_Z \sum_{N=0}^{+\infty} \bar{\lambda}^N (\mathbf{O}\bar{\mathbf{U}})_\alpha \\ &= 2\Re(\mathbf{U}_Z \sum_{N=0}^{+\infty} \lambda^N (\mathbf{OU})_\alpha) \end{aligned} \tag{19}$$

Since λ is infinite, we can simplify the infinite summation over powers of λ to its "last term," $\lambda^{+\infty}$, and write

$$\mathbf{n}_{\alpha Z} = \lim_{N\to+\infty} 2\Re(\mathbf{U}_Z \lambda^N (\mathbf{OU})_\alpha) \tag{20}$$

Since the l.h.s. is a non-negative integer, and $\mathbf{U}_Z$, λ and $(\mathbf{OU})_\alpha$ are all non-zero, $\mathbf{U}_Z\lambda^N(\mathbf{OU})_\alpha$ must have a positive real part for all sufficiently large N. This requires that λ is real and positive, which means that our premise, λ is complex, is wrong.

Taken together, the above results indicate that empirical observations do not change the ratio of the posterior probabilities of the correctness of any two ToEs. This means that they do not change the absolute posterior probability of any given ToE being the correct one.

□

3 Discussions

Theorem 8 shows that, under a few very reasonable assumptions, we can know nothing more about the ToE from observations of our universe than from the fact that we exist. Despite that the Anthropic Principle[2] has already been widely used in refining and justifying our physical models about the universe, our work is, to the author's best knowledge, the first work to point out that if the Anthropic Principle has already been taken into account in formulating the ToE, then all other empirical observations of our universe are completely useless. It does not matter whether our universe is expanding or contracting, how much the anisotropy of the Cosmic Microwave Background is, whether there are supersymmetric particles, or how much the spontaneous matter-antimatter symmetry breaking is; advances in these fields may help us develop better effective theories, but are absolutely useless for the quest of the most basic rules of the universe, namely the ToE. Thus, physicists who are working in these frontier directions should either admit that they are only looking for effective theories without an eye on even a slight hint of the form of the ToE, or abandon these expensive research directions altogether, sit down and study the ToE from a purely theoretical perspective.

As illustrated by the proof of Theorem 8, the likelihood that a particular theory is the ToE is completely determined by the prior probabilities P_Z^{prior} and the elements of $\mathbf{U}$; among these, P_Z^{prior} is the probability that the simulation Z simulates our universe when we do not know even a single fact about the universe, which can only be determined by aesthetic considerations (for example we can assign lower prior probabilities to theories that look ugly) rather than by science, and $\mathbf{U}$ is completely determined by the matrix elements of $\mathbf{O}$ and $\mathbf{E}$. Thus from a scientist's perspective, the only things that can enhance our understanding of the ToE are:

1. The matrix elements of $\mathbf{O}$, i.e. how many sentient beings does a given CA simulation emulate, and among these how many sentient beings make a given empirical observation.

2. The matrix elements of $\mathbf{E}$, i.e. which CA simulations are emulated by a given CA simulation, and how many copies of the former are emulated.

Both are purely logical objects that are totally unrelated to empirical observations of our universe. Moreover they are both within the realm of computational theory, at least after the concept of "sentient being" is rigorously defined (which may need quite some philosophical debate). Thus, anyone who is interested in obtaining a better understanding of the ToE should invest their effort in computational theory instead of physics.

Finally, we wish to point out some limitations of the present paper. Firstly, Theorem 8 is obtained under a number of assumptions, although they either seem very plausible empirically (Assumptions 1 and 2) or is correct with probability 1 (Assumption 3). Secondly, the proof of Theorem 8 involves extensive usage of infinities, which may make our argument not completely rigorous; but since physicists, especially particle physicists, already rely very much upon non-rigorous techniques such as subtracting infinities from infinities[9], they are not expected to be unhappy with the involvement of infinities in this paper.

4 Conclusions

In this paper, we demonstrate the fundamental uselessness of physical observations in the study of the ToE, under a few very reasonable assumptions. Anyone who is interested in finding the ultimate truth of the universe should thus neither look up to the cosmos nor look into large particle colliders. Rather, they should get their feet wet in computational theory and work out how many CA simulations and sentient beings every CA simulation emulates. When they finally tabulate the matrix elements of the infinite-dimensional matrices $\mathbf{E}$ and $\mathbf{O}$, and complete the equally formidable task of diagonalizing $\mathbf{E}$ and multiplying its eigenvectors one by one with $\mathbf{O}$, the ultimate operating rules (as well as the initial conditions) of the universe will then be easily within reach. This may seem like an infinite amount of work, but we can obtain information about **E** and **O** without calculating their matrix elements one by one, which hopefully takes only a finite amount of effort. Funding agencies interested in supporting ToE research should likewise decrease their investment in traditional Big Science projects that aim to obtain obscure empirical facts about the universe, and shift their focus towards computational theory.

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Declaration of Interest

I'm not a computational theorist, and definitely not a high-energy physicist or a cosmologist.

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