The Theory of Everything and the future of life*

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Abstract

This paper is a philosophical essay on metaphysics, in which we develop a justification for Algorithmic Communication with Extraterrestrial Intelligence by considering the relationship between the Theory of Everything and the future of life or physical eschatology.

Although Algorithmic Communication with Extraterrestrial Intelligence[37, Part III] is usually assumed to be a valid form of communication with alien intelligence, it is not necessarily self-evident why it must be so. Is it a 'complete' form of communication? Would alien intelligence understand computation of algorithms as we do? What is intelligent life? To answer these questions and more, we begin simply by asking, "What is the *justification* for Algorithmic Communication with Extraterrestrial Intelligence?" Is it capable of describing *Everything*? Even if it is, what would we communicate?

But first... what do we mean by Everything anyway? What would a physical Theory of Everything tell us about life and its future?

1 The Theory of Everything

Usually, the Theory of Everything is defined to be the unified theory of the four known basic physical forces. We shall denote it as the Theory of Something.

Definition 1.1 (The Theory of Something) *A grand unified theory of the four known basic physical forces: strong force, electromagnetism, weak force, gravity.*

However, we will use the following formal, general definition of the Simulation of Everything to explain why the Theory of Something cannot be the Theory of Everything.

Definition 1.2 (The Simulation of Everything) *The simulation of the Multiverse corresponding to the set of all computations in the repertoire of a universal model computing machine U operating by finite means that can perfectly simulate every finitely realizable physical system.*

The simple reason why the Theory of Something cannot be the Theory of Everything is because there is no explicitly defined mechanism in the former by which one can reliably produce (and reproduce) the Simulation of Everything.

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Suppose we do obtain the Theory of Something: how would we decode it anyway? Hence, we will investigate a few candidates for the Theory of Everything, of which the Theory of Something will necessarily be a subset. (We are not trying to undermine the *colossal* importance of the rich field of the Theory of Something; we are merely trying to point out its incompleteness in computing Reality.)

The critic might also note that our definition of the Simulation of Everything relies heavily on the Theory of Computation and thus fails to consider other alternatives (such as hypercomputation and so on). We will justify the reliance of the Simulation of Everything on the universal computer by showing that the universal computer might be able to simulate all physical processes. Hence, all possible candidates that rely on digital computation for the Theory of Everything must be logically equivalent since their output, the Simulation of Everything, must be identical. To greatly simplify, *the universal computer is anything that can simulate everything.* This is the most complete definition for a Simulation of Everything that can possibly exist. Hence, to stop belaboring the point, this is what we mean by the Theory of Everything unless stated otherwise.

Although our definition of the Simulation of Everything is partly based on the Church-Turing principle(1.7), it is by no means bound by chains to the Quantum Theory of Computation. We will also observe that the aforementioned principle is an emergent one, as opposed to being a fundamental law of nature. This observation will prove to have important implications.

We will develop the outline of a Theory of Everything — if such a theory is possible — and justify Algorithmic Communication with Extraterrestrial Intelligence this way. Why would the justification work? We inspect one of the central methods of Algorithmic Communication with Extraterrestrial Intelligence: the *algorithm*. Let us assume for the rest of the paper that hypercomputers are impossible. It follows that if there is an algorithm for simulating Everything, then Algorithmic Communication with Extraterrestrial Intelligence could be used by two intelligent entities or more to communicate about Everything. Otherwise, we are forced to conclude that Algorithmic Communication with Extraterrestrial Intelligence, and consequently the Theory of Everything, are limited to something and not everything (which we would be forced to denote as the Theory of Almost Everything). One of the objectives of this paper is to see why we might not need to subscribe to such a pessimistic point of view after all.

1.1 The Classical Theory of Computation

The classical theory of computation[49, 29], defined shortly, has been alleged to perfectly describe the universal computer U. Turing himself hinted at the conjectural nature of the Church-Turing thesis, a temporary axiom made in order to make scientific progress[55, pp. 57]. Unfortunately, it has mostly been taken for granted to be a self-evident truth. Fortunately, we will see that is not entirely true since the Classical Theory of Computation is a special case (in terms of complexity and *not* computability) of a more general, physically-provable theory of computation, the Quantum Constructor Theory(1.2).

For decades, the most commonly-accepted definition of an algorithm has been addressed by the Church-Turing thesis, mostly via the ingenious physical implementation that is the Turing machine[49, Chapter 3]. All our definitions of the Church-Turing thesis and its variants are from Nielsen and Chuang[38, Chapter 1].

Definition 1.3 (The Church-Turing thesis) Any *algorithmic process can be simulated using a Turing machine.*

When it became clear that the various alternative models of computation did not significantly outperform the Turing machine, the strong Church-Turing thesis was invented to claim that every model of computation — lambda calculus, cellular automata[57], neural networks, register machines, to name a few — is ultimately similar to that of the Turing machine; that is, they are computationally equivalent to each other. In fact, this is partly what Wolfram[57, Chapter 12] means by the "Principle of Computational Equivalence".

Definition 1.4 (The strong Church-Turing thesis, or, The Principle of Computational Equivalence) *Any algorithmic process can be simulated* efficiently *using a Turing machine.*

The strong Church-Turing thesis remained reasonable, until it was discovered that randomized algorithms, such as the Solovay-Strassen test for primality of an integer, may efficiently solve problems which cannot be efficiently solved on a deterministic Turing machine[38, pp. 6]. Thus, an *ad hoc* modification was made to the strong Church-Turing thesis:

Definition 1.5 (The probabilistic strong Church-Turing thesis) *Any algorithmic process can be simulated efficiently using a* probabilistic *Turing machine.*

As Nielsen and Chuang[38, pp. 6] have emphasized, these *ad hoc* modifications to the Church-Turing thesis leave it questionable. Does there exist a method for *proving* the real Church-Turing thesis once and for all?

Besides, what does it mean for physics? Can classical computation adequately simulate Reality? If it can, then there must exist a classical algorithm, a Theory of Everything, of Reality itself. The Theory of Everything would be a *universal algorithm*, in which every possible algorithm, including itself, is a logical entailment; every algorithm is a description of a physical system. (One such universal algorithm is the simple algorithm which enumerates every possible computable bitstring, which can be fed to a universal Turing machine.) So, is Reality computable with the Classical Theory of Computation?

1.2 The Quantum Constructor Theory

> "Nature isn't classical, dammit, and if you want to make a simulation of nature, you'd better make it quantum mechanical."
>
> – Richard P. Feynman[23]

In short, no, Reality is not computable with the Classical Theory of Computation. (This is not to say that classical physics is completely wrong — it is just not universally right. If Bohr's Correspondence Principle is correct, then at a certain correspondence or classical limit (it is not clear what this must be[27]), classical physics should be a good approximation to quantum physics; decoherence theory[48, Chapter 9] appears to be a much better solution. We are not trying to undermine the *immense* importance of the Classical Theory of Computation; we are merely trying to point out its incompleteness in computing Reality.) Nevertheless, it does turn out that Reality might be computable with the Quantum Constructor Theory. We stress again that it does not logically entail from this that Reality is a computer. Reality is computable but it is not necessarily a computer(1.3.3)[16]. We will now proceed with our investigation of the nature of the Quantum Constructor Theory.

Definition 1.6 (The Quantum Constructor Theory) *The physical theory of the virtual reality Simulation of Everything via the Quantum Theory of Computation under the constraints of the Theory of Something; the theory of metaphysics; the Theory of Everything.*

As we have seen, the Quantum Constructor Theory consists at least of:

- The Theory of Something
- The Quantum Theory of Computation

Hence, the Quantum Constructor Theory, when completed, is an *emergent* theory, as opposed to being an axiom/principle of Reality.

1.2.1 The Theory of Something

The Theory of Something is traditionally proposed to be a unified theory of at least the two best theories or explanations we have of Reality: the two theories of relativity and quantum physics (perhaps together with a theory of initial conditions and other related information to provide a complete description of Reality[12, pp. 105]). It might be possible that the Theory of Something would lead us to even more powerful theories of computation than the Quantum Constructor Theory, thanks to some effects of quantum field (for an interesting alternative, please see the qubit field theory[18]) or string theory[38, pp. 6], in which case then the Quantum Constructor Theory might become a special case of a superior Theory of Computation and the results of this paper might apply in a limited case. We will not delve into the details of the Theory of Something since they are beyond the scope of this paper.

Any universal computer U, then, must obey the fundamental laws of Reality; that is, it must work by the constraints set by the Theory of Something. As Deutsch[15, 17, pp. 5, pp. 11-15] has pointed out, the Quantum Theory of Computation is incomplete because it does not yet do so; hence the need for the Quantum Constructor Theory. For example, the present incarnation of the Quantum Theory of Computation does not recognize *the laws of thermodynamics* and thus incorrectly predicts the possibility for a perpetual motion machine of the second kind[15, pp. 5]; among other things, it must also work by Landauer's principle, where if a computer erases a single bit of information, the entropy of the environment increases by at least $k_B \ln 2$, where k_B is Boltzmann's constant[38]. *Communication* too must be taken seriously in the theory of computing: computations which consider the limits of communication, such as classical parallel programs, are not exceptions but rather the rule (even quantum information[38, Part III] must adhere to them). Any Theory of Computation which fails to acknowledge communication is not general. For example, no information should be able to travel at a speed faster than that of light, as this would violate one of the postulates of the theories of relativity. Eventually, any advanced civilization will have to deal with these problems; as an instance, when one builds a deep space analogue of the Internet. And last but not least, *space, time and energy* must be taken into any consideration[12, pp. 348] of computational universality. These questions can only be answered via the correct cosmological theory of Reality that ultimately depends on the Theory of Something; the specifications for infinite memory and time in a closed universe[53] are very different from those in an open one[16].

Quantum Constructor Theory makes some interesting predictions: time travel[12, Chapter 12]; parallel universes/Multiverse[12, Chapter 2] (a theory of the structure of the Multiverse can be found in [14]). As an added bonus, the Quantum Constructor Theory may be used to verify the Theory of Something: a universal quantum computer may be used to simulate black holes (or wormholes) and explore the possibility of creating new universes[15, pp. 6-7].

We pose an open problem to the scientific community: can they derive a *physically correct* Theory of Computation superior to the Quantum Constructor Theory? How would, for example, the possibility of time travel and wormholes affect the ultimate Theory of Computation? We believe this problem is of the utmost significance to the development of science.

1.2.2 The Quantum Theory of Computation

This component of the Quantum Constructor Theory is an extremely rich field on its own with an intriguing history. The Universal Quantum Computer is a machine with many incredible properties, such as the generation of true random (in the nondeterministic but computable sense, not algorithmically incompressible sense[3]) numbers and quantum correlations, the perfect simulation of arbitrary finite physical systems including discrete finite stochastic systems (crucial for our case), parallel processing on serial computers (akin to classical vector parallel machines), faster computations[11] and even the ability to perform experiments to detect parallel universes[10] (which is an excellent refutation of the conventional idea that the Multiverse hypothesis is not experimentally falsifiable). We cannot do the Quantum Theory of Computation any justice with a summary given our limited space. For an excellent scientific treatment of quantum computation and information, please see the wonderful textbook by Nielsen and Chuang[38]. Instead of a summary, we will use established results of the Quantum Theory of Computation to derive new ones. Our results only assume that the reader has a basic knowledge of the Quantum Theory of Computation. Let us first define the Church-Turing principle[11, pp. 3] for reference.

Definition 1.7 (The Church-Turing principle) *Every finitely realizable physical system can be perfectly simulated by a universal model computing machine operating by finite means.*

We may also use the following definition by Deutsch[12, pp. 135]:

Definition 1.8 (The Church-Turing principle) *It is possible to build a virtual reality generator whose repertoire includes every physically possible environment.*

The Church-Turing principle is only a principle, or axiom, at the moment because it remains a conjecture. Nobody has yet proven that it can actually be built[38, Chapter 7]; when the proof comes though, it will be elevated to the status of a theorem. (What physicists call a principle, the mathematicians call it an axiom. It is time for them to realize they are both working on the same Reality and focus on creating the Theory of Everything, which will of course benefit both sides. The term 'mathematical physics', as we will see later(1.4.1), is redundant.) Once again, we wish to highlight this interesting open problem to the scientific community.

As we mentioned earlier, the Classical Theory of Computation is a special case of the Quantum Theory of Computation; the Quantum Theory of Computation can do everything the Classical Theory of Computation can do and sometimes do it more efficiently (but it cannot, we believe, do hypercomputation). Let us now analyze some interesting fundamental properties of the Quantum Theory of Computation.

We will subscribe to the explanation that quantum physics is a theory of parallel universes[52] or the Multiverse (a Level III Multiverse, in Tegmark's terms). As we have mentioned, this hypothesis is perfectly experimentally falsifiable[52]. For those who doubt the hypothesis, we invite them to answer Deutsch's challenge: explain how Shor's quantum algorithm for factorization[38, Chapter 5] works. When Shor's algorithm is factorizing a 250-digit number, the number of interfering universes (for parallel processing on the quantum computer) will be of the order 10^{500}. When the number of atoms in the entire visible universe is estimated to be around 10^{80}, how was the factorization of this number performed? *Where was it computed?*[12, pp. 216-217]

Conjecture 1.1 (The Theorem of Physical Impossibility) *If program X is uncomputable with the Quantum Constructor Theory, then the corresponding physical system Y, its simulation program being X, is physically impossible and can never exist as a part of the Multiverse.*

Argument For practical purposes, we would require a programming language like QCL[39] to enumerate all possible computations of the Quantum Constructor Theory. However, since theoretically the Quantum Constructor Theory assumes to compute only what the Universal Turing Machine can, we can define Simulation of Everything to be the computation of every member of the Kleene set $\{0, 1\}^*$. We claim that the Quantum Constructor Theory is able to produce the Simulation of Everything; this conjecture is explored in [11]. Assuming that the Church-Turing principle is true, if X is uncomputable with the Quantum Constructor Theory, then $X \notin$ Simulation of Everything. ∎

To rephrase Fredkin[26], we say, "What cannot be programmed, cannot be physical." We will demonstrate a few more uncomputable/physically impossible things.

Conjecture 1.2 *The halting probability, Ω, can never be physically realized.*

Argument The halting probability, Ω, is uncomputable[6]. By Conjecture 1.1, Ω is physically impossible. ∎

Conjecture 1.2 should prove that all hypercomputers[41] that depend on the physical realization of the Ω can never be built. (Recently, Tsirelson has proven that Kieu's quantum algorithm does not solve Hilbert's tenth problem[54].) It also follows that other uncomputable reals, such as the general solution to Post's Correspondence Problem and so on, are physically impossible. As Chaitin has noted[7], however, the computational enumeration of all of the uncountably many uncomputable reals is impossible.

Conjecture 1.3 *It is impossible to transform an $\aleph_0$ number of qubits into the Hadamard state.*

Argument An impossible algorithm in QCL, assuming the constant `ALEPHZERO` (where `ALEPHZERO` $= \aleph_0$):

```
procedure godel()
{
qureg x[ALEPHZERO]; //allocate ALEPHZERO number of qubits from heap
int m; //allocate 1 large integer with the size of ALEPHZERO
H(x); //put qubit register x into Hadamard state
measure x,m; //measure x and put it into m
print "random number = ",m; //print m
reset; //reset computer memory
}

//call procedure
godel();
```

If *godel*() is computable, tben at the moment of the Hadamard superposition of the $\aleph_0$-sized quantum register x (however long it takes), our impossible quantum algorithm would have access to memory capable of storing $2^{\aleph_0} = \aleph_1$ number of bits. But that is physically impossible by Conjecture 1.1 since that would mean contradicting the definition of a computer, which has access to $\aleph_0$-sized memory but not $\aleph_1$-sized (uncountably big) memory. Even if *godel*() is Quantum Theory of Computation computable, it is not Classical Theory of Computation computable. ∎

We call the procedure above *godel*() to demonstrate that the mathematical concept of "incompleteness" does not necessarily entail the impossibility of universality (in the sense of knowledge); on the contrary, it might be a strong indicator of physical impossibility (hence, perhaps the implications of Gödel's Incompleteness Theorem are widely misunderstood). Gödel, Turing and Chaitin[6] are among the few who have paved the path towards this understanding. Conjecture 1.3 should qualify as a constraint by the Quantum Constructor Theory on the Quantum Theory of Computation.

1.2.3 Hypercomputation and Physics

> "Why should I believe in a real number if I can't calculate it, if I can't prove what its bits are, and if I can't even refer to it? And each of these things happens with probability one! The real line from 0 to 1 looks more and more like a Swiss cheese, more and more like a stunningly black high-mountain sky studded with pin-pricks of light."
>
> – Gregory Chaitin[7]

If uncomputability implies physical impossibility, then there are some truly frightening consequences for the present incarnation of physics and mathematics. We face these problems partly because we assume quantum computers cannot provide hypercomputation but only better computational complexity. If this assumption is wrong, then of course this "crisis" would not matter. Ord[41] presents some fascinating discussions on the physical plausibility of hypercomputation, including wise observations of the conflicts between theories of hypercomputation and our present best theories of physics — such as accelerating machines to work faster than the speed of light or probing at distances smaller than the Planck length. Hypercomputation, if it is physically possible, will provide such terrible conflicts with our best theories of physics that we are extremely tempted to doubt their plausibility in the first place. We ask proponents of hypercomputers to answer our question: if hypercomputers are possible, what does it *mean* to realize the Halting Paradox, or equivalently, to be able to build a machine $H(M)$, where M is the string encoding of a Turing machine $\langle M \rangle$, in which $\langle M \rangle$ accepts M if and only if $\langle M \rangle$ rejects M?[49, Chapter 4] Surely this would warrant a revolutionary revision of physics! Until this question is answered satisfactorily, we are unfortunately not inclined to consider hypercomputation in this paper.

So do fundamental constants of physics like π, e and $\sqrt{2}$ actually exist? *Yes, they do.* These numbers are perfectly computable[3]; by Conjecture 1.4, they must exist. This fact would provide tremendous comfort to all physicists and mathematicians, we are sure, but we repeat our caveat: if Conjecture 1.1 holds true, then hypercomputational physical/mathematical theories simply cannot correspond to Reality.

1.2.4 The Quantum Constructor Theory as the Theory of Everything

We have explored the possibilities of nominating the Quantum Constructor Theory as the Theory of Everything. We must caution that the nomination remains tentative for as long as the claim that the Quantum Constructor Theory is universal (i.e. it is able to produce the Simulation of Everything) remains a conjecture. If the Quantum Constructor Theory is correct, though, it implies that knowledge of everything is compressible, given tools such as the algorithmic information theory[28, Chapter 8].

From the Quantum Constructor Theory as a Theory of Everything, it might be possible to derive every physical theorem, including the theory of computation (this self-similar nature of Reality will be explored in (1.3.2)), from the axioms of physics[29, 53-54].

1.3 The Applications of the Theory of Everything

We will now explore some interesting applications of the Theory of Everything.

1.3.1 Relativistic Computing

It is usually thought that computational complexity theory conclusively proves that the time complexity of an algorithm cannot improve beyond certain limits[49, Chapter 7]. While this is true, it is *not* true that we cannot do better. What happens, for example, when we consider *time travel* as a component of the Theory of Computation, as it must be with any complete one? We will only consider computations with future-directed time travel as governed by the two theories of relativity. As we have said earlier, we leave the open problem of a Theory of Computation better than or equal to the Quantum Constructor Theory with a consideration of the Theory of Something (which would provide conclusive results about time travel) to the reader.

Before we begin, we reflect that we are worried about "reasonable" computing time because of the mortality and finite time span of our present lives. *But what if we were immortal?* Intractability would still make a difference mathematically/physically, but we wonder, what would an arbitrarily advanced civilization be able to do to alleviate the problem, besides conjuring time travel and constructing ultimate kinds of computers?

Our basic idea is simple: while the computer calculates at rest, we travel "to the future" (relative to and necessarily without the computer). We shall consider two relativistic means of performing future-directed time travel: *velocity time dilation* and *gravitational time dilation.*

Velocity time dilation[5, Chapter 4] is governed by:

$$t_{life} = t_{computer} \times LORENTZ \tag{1}$$

$$LORENTZ = \sqrt{1 - \frac{u^2}{c^2}} \tag{2}$$

where c is the speed of light, t_{life} is the amount of time an observer spends travelling at a relativistic speed u (we note that the savings in time is greater as u^2/c^2 approaches arbitrarily close, but never, to 1), $t_{computer}$ is the running time of a program on a computer at rest and $LORENTZ$ is the denominator of the Lorentz factor.

Gravitational time dilation[5, Chapter 16] is approximated by:

$$t_{life} = t_{computer} - [t_{computer} \times (1 - SCHWARZSCHILD)] \tag{3}$$

$$SCHWARZSCHILD = \sqrt{1 - \frac{2GM}{r_o c^2}} \tag{4}$$

where c is the speed of light and G is the gravitational constant, t_{life} is the amount of time an observer spends at position r_o outside a spherical mass M, $t_{computer}$ is the running time of a program on a computer at rest and $SCHWARZSCHILD$ is a factor of the Schwarzschild metric.

The equations indicate, for example, that an observer travelling at $u = 99.999999\% \times c$ on a roundabout trip for 1 year from and back to a computer on Earth (neglecting the tiny effects of gravitational time dilation on our own planet) will find that around 7,000 years would have passed on Earth. We conclude our equations with the note that there can be a significant amount of savings in time if we are allowed to, say, travel arbitrarily close to the speed of light or position ourselves in an immensely strong gravitational field (our idea should apply to black holes as well). Please see Appendix A for a computational version of our results with the software Mathematica.

Of course, we have ignored several important caveats from our results. One such caveat is the energy expenditure of relativistic future-directed time travel.

Is it worth spending that much energy for a particular computation with its own energy requirements? Another caveat is the question of the safety of life during relativistic future-directed time travel. But perhaps these problems are solvable. A critic might also argue that we're "cheating". We wish to strongly emphasize that our results have nothing to do with hypercomputation[41]. Relativistic future-directed time travel, as far as we know, is perfectly physically permissible. An interesting discussion of time travel can be found in [33, Part III].

1.3.2 The Self-Replicating Multiverse

We suggest that the Multiverse self-replicates for an infinite number of times (see Figure 1). To rephrase a familiar analogy, the universal computer is the Multiverse's way of simulating another Multiverse (itself).

We begin by introducing the seemingly trivial converse of Conjecture 1.1:

Conjecture 1.4 (The Theorem of Physical Possibility) *If X is computable with the Quantum Constructor Theory, then X is physically possible and must exist as a part of the Multiverse.*

Argument We claim that the Quantum Constructor Theory is able to produce the Simulation of Everything. If X is computable with the Quantum Constructor Theory, then $X \in$ Simulation of Everything (see Conjecture 1.1). If the 'quantum artificial intelligence experiment'[10] decides that the Multiverse interpretation of quantum physics is correct, then the Simulation of Everything should represent the Multiverse. ∎

Conjecture 1.4 depends on the quantum theory of the Multiverse[14], where the Multiverse is the realization of all physical possibilities (lately, quantum cosmology too has been a proponent of this theory[33, Chapter 12]).

We claim that Figure 1 represents the logical structure of the Multiverse. The size of the Multiverse is taken to be $\aleph_0 = \infty$, which is the smallest infinity in the Generalized Continuum Hypothesis[31], with $2^{\aleph_\alpha} = \aleph_{\alpha+1}$ (where α is a member of a set of ordinals).

Argument Let us denote a perfect simulation of the Multiverse with the ordinal i as Sim_i and the infinite series of simulations as Sim. The size of this series is given by:

$$\begin{aligned} |Sim| &= \sum_{i=1}^{\aleph_0} |Sim_i| && (5) \\ &= \sum_{i=1}^{\aleph_0} \aleph_0 && (6) \\ &= \aleph_0 \times \aleph_0 && (7) \\ &= \aleph_0 && (8) \end{aligned}$$

The size of the entire Multiverse is then given by:

$$\begin{aligned} |Multiverse| &= \aleph_0 + |Sim| && (9) \\ &= \aleph_0 + \aleph_0 && (10) \\ &= 2 \times \aleph_0 && (11) \\ &= \aleph_0 && (12) \end{aligned}$$

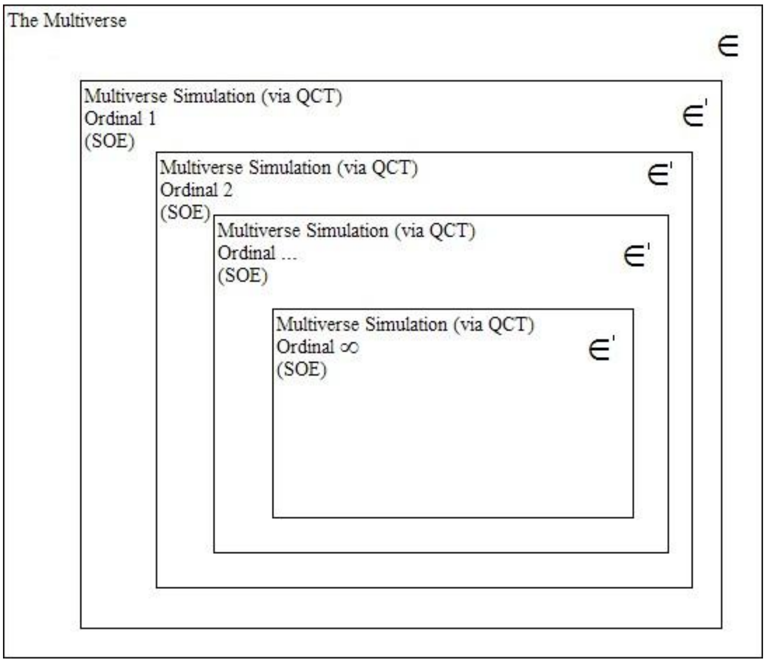

Figure 1: The Self-Replicating Multiverse (interpreted as the smaller the "box", the deeper the nesting of the simulation)

Equations (7) and (11) are respectively proven by Cantor's one-to-one correspondence between the set of natural numbers and the set of positive rational numbers, and, the one-to-one correspondence between the set of natural numbers and the set of even natural numbers. $\blacksquare$

Sim, of course, is the Simulation of Everything.

As Equation (11) and Conjecture 1.4 show, the notion of the self-replicating Multiverse is perfectly compatible with the Church-Turing principle, where cardinals from $\aleph_1$ (e.g. the cardinality of the set of all real numbers, or equivalently, all complex numbers) and beyond are uncomputable. We observe that $\aleph_0 = \infty$ has the curious property of being seemingly immutable.

One of the problems with the view above is that the infinite number of perfect simulations of the Multiverse within the Multiverse require an infinite amount of computational resources. However, we have shown that the size of these computational resources cannot exceed $\aleph_0$. It should at least be possible to create a simulation of the self-replicating Multiverse arbitrarily close to the ideal, infinite one (*Sim*).

We also propose the Principle of Indistinguishability: it should be impossible, with *Sim*, for an observer in any of the simulated Multiverses to distinguish the observer's simulated Multiverse from any other simulated Multiverse in *Sim*. If *Sim* can never be attained perfectly but only arbitrarily closely, then the principle might not hold true. *Sim* depends on whether the universality as defined by the Church-Turing principle is physically possible. We do *not* claim that the "original/host" Multiverse is indistinguishable from any of the simulated Multiverse in *Sim* (or that the observer cannot detect the presence of the "original/host" Multiverse[12, pp. 137-138]).

One of the implications of the self-replicating Multiverse is that mathematicians should take seriously the uncomputability of $\aleph_1$ and beyond. It would mean that infinite cardinals from $\aleph_1$ and beyond simply cannot physically exist as part of the Multiverse. One way to prove this physically is by showing that *Sim*, or the Simulation of Everything, cannot include itself more than once at a time; the Multiverse nor its simulations cannot exponentiate its number of simulations of itself — in other words, it must adhere to the unary tree. Calculations with the tree data structure show that the Simulation of Everything can only include itself once indefinitely in order for the cardinality of *Sim* to remain at $\aleph_0$. (For example, a binary tree of height $\aleph_0$ would have $2^{(\aleph_0+1)} - 1 = 2^{\aleph_0} - 1 = \aleph_1 - 1 = \aleph_1$ nodes. Finitely-deep exponential tree structures might work, but we think we can rule this out mathematically on the conjecture that the Simulation of Everything cannot include itself more than once and must include itself indefinitely.) If this is true, then the self-replicating Multiverse might be a good physical embodiment of the Continuum Hypothesis (with an incorporation of uncomputability). Mathematically, this reflects the fact that the Simulation of Everything must contain itself; physically, this reflects the fact that the Multiverse is able to simulate itself. The fact is that both of these descriptions are *identical*. If the Church-Turing priciple is true, then Reality has a fractal, self-similar nature[15, pp. 1-3]. It is also worth stressing that the self-replicating Multiverse is compatible with the notion of Reality as not a computer.

1.3.3 Why Reality is Most Likely Not a Computer

We argue that Reality is most likely not a computer. The digital physics/philosophy movement[57, 7, 26, 25, pp. 1026-1027], which believes that the Universe is *built* out of digital information and is a giant information-processing machine, should reconsider its axioms. It is an easy conclusion to derive, but it is not necessarily correct. *While Reality is computable, it is not necessarily a computer*[16].

We will use Deutsch's arguments[15, pp. 3-5] as a basis for our own. The methodological argument is that if Reality is a computer, then computational universality implies that we cannot understand its hardware. There is no reason to claim that the Über-Computer which is simulating Reality is made out of plastic bottles rather than billiard balls or semiconductors or tinkertoys[19] or whatever, unless experiments can somehow be devised specifically for this question. This is an extremely self-defeating view of physics.

The technical argument is that it is a mistake to assume, without justification, that the Über-Computer "somewhere else" simulating Reality must obey the same laws of computation as the computers in our Multiverse. Why must it? Why must we assume that the Turing machine is the most powerful type of computer ever possible? To do so is to assume that even the Reality (or the "host") of the Über-Computer is no more powerful than our Multiverse. Why not assume that the Über-Computer is a hypercomputer? We must also remember that there is no notion of computation prior to Reality. We have already seen that our best Theory of Computation at the moment, the Quantum Constructor Theory(1.2), is an emergent theory of Reality rather than an axiom or a fundamental law of Reality. In addition, if we assume the existence of the

Über-Computer, why not assume another Über-Computer simulating the former Über-Computer? It leads to infinite (or beyond?) regress for no good reason because it does not *necessarily* figure in the explanation of Reality. Finally, we ask, why simply assume the existence of the Über-Computer? Why not prove it, if possible? What is the experiment that could detect the presence of an Über-Computer? If there is none, then the Über-Computer theory of Reality is unscientific because it is not falsifiable.

We would like to offer an analogy for how natural it is to mistake Reality for an Über-Computer (even the author was guilty of it). Suppose someone proved the existence of a Universal Mirror and also built it. This was no ordinary Universal Mirror: this mirror could perfectly reflect (simulate, in computational terms) any physically possible system in Reality; why, this Universal Mirror could even reflect a Universal Mirror — in other words, itself! But it would be a mistake to assume that just because we can see a reflection of Reality in the Universal Mirror, then Reality itself must be some sort of an Über-Mirror. It is far more likely that the laws of Reality allow for the construction of a Universal Mirror, which in turn allows us to understand Reality (by finite means) by reflection (simulation).

With Ockham's Razor, one may say that the simpler (in terms of information) hypothesis is that the "original/host" Multiverse itself is not a simulation on an Über-Computer; it seems perfectly sufficient at the moment to say that the Multiverse is all the Reality there is. Some may use Ockham's Razor to argue that the Multiverse hypothesis itself is not simpler than the Universe hypothesis and thus the former must be discarded in favour of the latter, but this is a mistake. Tegmark[52, pp. 17] has argued that the Multiverse theory can actually be simpler (in terms of information) than the Universe theory (under the Copenhagen interpretation of quantum physics, for example), which must explain why it is the only one in existence among an infinite number of possibilities.

As a note of interest, Deutsch[17] conjectured how quantum physics accomodates the notions of both the discrete and the continuous.

1.4 The Implications of the Theory of Everything

Finally, we consider the implications of the Theory of Everything on, to rephrase Douglas Adams (author of the hilarious science fiction series, *The Hitchhiker's Guide to the Galaxy*) slightly, "Life, the Universe and Everything (else)" (where "Everything" includes "Life, the Universe and Everything (else)").

1.4.1 Mathematics and Physics

We wish to support Deutsch's heretical, but *correct*, view that *mathematics is a branch of physics*. This is illustrated with Figure 2, where physics is shown to allow the existence of a universal computer that is able to produce the Simulation of Everything and mathematics is conventionally seen to be the study of the Simulation of Everything or all possible physical processes. Physics describes the fundamental laws of Reality (the Theory of Something) which lead to the theory of computation (the Quantum Constructor Theory), with which all mathematics is described in terms of computation alone. "Mathematical physics" is not optional: it is mandatory for a description of Reality. With the universal computer, we are using Reality to describe itself; information is physical[38, Chapter 1]. The axioms of Reality are the fundamental laws of physics, the Theory of Something, which are special because they allow universal computation in some, if not all, possible Universes in the Multiverse[12, pp. 353-354]. We happen to live in one such Universe and use the "weak" anthropic principle to reason about these things.

Mathematics is the study of the Simulation of Everything with a universal computer (a physical machine). Physics is, at least, the study of how to copy Reality perfectly (universality) using mathematics in order to understand and explain it. Therefore, mathematics is a branch of physics. If mathematics (computation) was impossible, then universal physics (life trying to understand the whole of Reality) cannot exist. This explains how the Classical Theory of Computation explained Reality quite well (with the human brains of scientists/mathematicians and other incomplete, not universal, machines) for ages until physicists discovered the realm of the quantum relatively recently. Feynman observed, for example, that classical computers couldn't simulate quantum systems as efficiently as quantum computers can[12, Chapter 9]. Mathematics has to incorporate it and form the Quantum Constructor Theory in order to have a complete description of Reality. Of course there will be the human inertia to the change (maybe it is part of the physics of the human civilization) that is the Quantum Constructor Theory but eventually it will be accepted when the Classical Theory of Computation is generally perceived to fail to provide a complete explanation of Reality (due to incomplete mathematics). This is no disrespect to the Church-Turing thesis: in fact, Church, Turing, Post and others would have been happy to see a proof of their thesis — it is a testament to their sheer genius that their proposed machines are theoretically capable of simulating Everything.

From this formal definition of mathematics, we can see why we live in Tegmark's[52] Level III Multiverse and why a Level IV Multiverse is not likely to exist. The only kind of mathematics that is physically permissible is precisely the one that the Quantum Constructor Theory can compute. Mathematics originates from the Multiverse and not the other way around; mathematics is not external to physics, it is a part of it[9]. We live in a Level III Multiverse, where all mathematical/physical possibilities are realized; Tegmark's "mathematical democracy" already exists. It is not likely there is mathematics external to the Multiverse, essentially for the same reasons why it is not likely there is an Über-Computer external to the Multiverse(1.3.3). If there is a Theory of Everything, we can answer Wheeler's question[pp. 13][52] ("Why these particular equations, not others?") with the answer: because it is the only physical structure that is able to simulate the Multiverse since its mathematical description show that it is able to produce the Simulation of Everything. Our pitch for the Theory of Everything, of course, is the Quantum Constructor Theory.

It is interesting how there have always been hints of physical assertions in mathematics. For example, proof by construction shows the physical possibility of something, whereas proof by contradiction implies physical impossibility (perhaps by a violation of some axiom or theorem of physics) and proof by induction asserts that all elements of an infinite (physically possible) set possess a certain physical property.

Computationally speaking, the human mind is probably not capable of quantum computation[51]. But it is not necessarily bad news if the human mind is

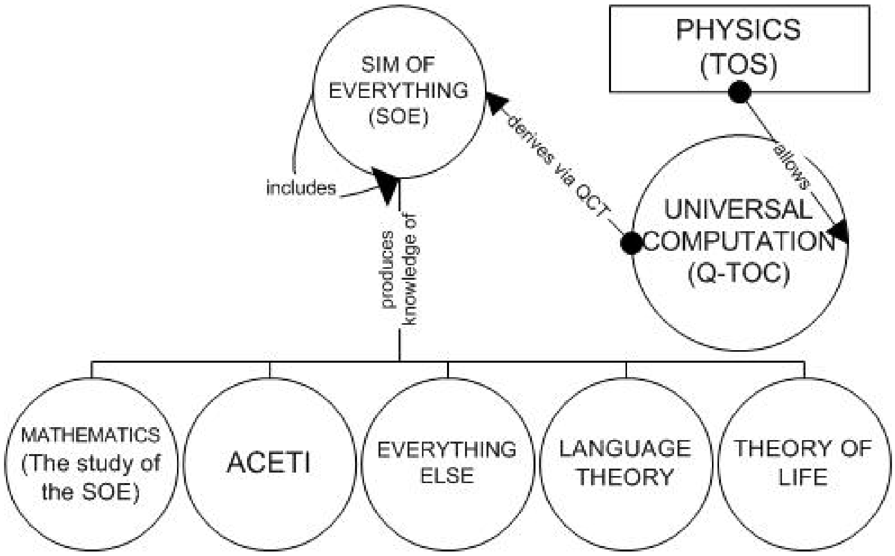

Figure 2: A map of Everything

not a quantum computer; if classical computation is sufficient to describe the human brain, then the task of artificial intelligence may not be as difficult as it could have been otherwise. Suppose that the human mind *per se* is limited to classical computation and yet, amazingly, we are able to understand everything via the Quantum Constructor Theory, then perhaps the human civilization works like a hybrid QCL program[39]. The human civilization could then be a universal constructor[15, pp. 7]. Whether the human brain is a classical or a quantum computer remains to be seen, but that does not matter. What does matter is the conjecture that the brain is not capable of hypercomputation. That the brain is computable is terrific for artificial intelligence, because then a (quantum, just to be complete) computer can simulate the human mind. If the Church-Turing principle is correct, then there should no longer be any arguments about whether the human mind is "special" or not. (Of course we're special, but we're not superior to Reality. Reality keeps reproducing us again and again every time a human baby is born.) The human mind is perfectly computable, maybe even classically, as we have speculated. Penrose's theory[42] of the human mind is intriguing, but we do not think the brain, even if it is a quantum computer, can hypercompute if Reality does not permit it. A simple experiment to test this is to require human mathematicians to produce the complete value of Ω and then physically realize the Halting Paradox with it, thereby proving that contradictions are not physically impossible after all. The nature of mathematics can now be explored securely with a proper physical foundation instead of intuition.

If our case is right, then Everything that can exist is inherently interesting and computable[24]. An uncomputable problem might not be very interesting since the answer can never physically exist. Therefore, to answer Hilbert's question, yes, it is possible to capture the set of all mathematics...and this set is *identical* to the Simulation of Everything. This, of course, goes against the conventional mathematical view that the universal computer cannot capture the whole of mathematics. The simple reason why this counter-conventional view must be true is that the Quantum Constructor Theory can produce the Simulation of Everything. It might be unproductive to study physically impossible things, except to understand Reality better. The solution to the Halting Problem (the Ω) and every uncomputable problem can never be found, and certainly not by human mathematicians, if Reality itself cannot do it. We have not found it too depressing to not be able to travel faster than light, so why should we worry about the impossibility of hypercomputation?

Chaitin and Deutsch are correct when they say that mathematics must be treated as a study of physical processes that is otherwise known as computation. One of the consequences is that even proofs of mathematics must be treated as computation[9, pp. 17]. For example, no human mathematician could hope to understand the proof for a factorization of a large enough number with Shor's algorithm since our Universe would not have enough space to contain it! It is also not possible to measure a quantum system while it is performing a computation without interfering with the computation. While this may seem deeply unfortunate, it is not necessarily so. For one thing, certainly there will always be axioms: physicists have it with their postulates and mathematicians do with their formal systems. But perhaps more importantly, every aspect of Reality can be understood via computation, so the process of proving the factorization of a number must be left to the quantum computer[9]. Consider the Haken-Appel Four-Color Map Theorem.

Mathematicians must take very seriously the universal computer. With it, they can prove the existence of anything that is physically possible. Computer-aided proving is not "dirty" or "wrong". There is no such thing as "pure" mathematics — every computation, every physically realizable knowledge of mathematics, describes something physical; all mathematics is "applied" mathematics. Hence, mathematics is no more certain than physics (due to the foundation of the former on the latter). Additionally, quantum computers describe the ultimate limits of physics: with it, the human mathematician can explore the limits of efficiency of computation[36]. The true nature of computational complexity may be learnt from the quantum complexity theory. Secondly, they can do things a human mathematician *per se* is not capable of even in principle (such as true random number generation and other feats probably best reserved for quantum computation). *Hilbert's program did not fail — on the contrary, it couldn't possibly be more successful!* How could mathematicians not sleep better with this knowledge?

We conclude our disccusion with a restatement of an important effect of a physical theory of mathematics: everything from mathematics describes something physical (Kaku[33, pp. 326-330], who speculates that number theory may be incorporated into string theory, among others has anticipated this principle). This is extremely interesting because, for instance, Einstein showed that force is a consequence of geometry. As another example, the theory of probability has actually traditionally (and implicitly) assumed part of the Copenhagen interpretation of Reality, long before even the interpretation was explicitly stated! Nevertheless, the theory of probability can now be correctly merged with quantum physics to form a quantum theory of probability and decisions[13, 9]. We suspect that the future of the physical theory of mathematics — as well as the teaching of it to children — is going to be very interesting, even to the most skeptical mathematicians and physicists.

1.4.2 A Theory of Life

There exists an exciting movement in biology that views life itself as computation[48, Chapter 5-7]. This is equivalent to saying that life is an information-processor. What we would like to support is that if there is a computational theory of Everything, then there is a computational theory of life.

Definition 1.9 (Life) *A physical process with the tendency to maximize the survival time of some packet of information X, which includes a self-description of the physical process, by evolution of knowledge (which may or may not affect X).*

Definition 1.10 (Knowledge) *A computable theory/description of a physical system and whose algorithmic description is a member of the Kleene set $\{0,1\}^*$ (the set of the description of all possible computations).*

Life as an information-processor is hardly a new paradigm, but our definitions of life and knowledge, or the theory of epistemology (which is Greek for "limits of knowledge"), may seem completely bogus. Allow us to justify the axioms. Of course we have missed out many details of life, but here we are only interested in a "quick and dirty", working definition of life; we have only tried to capture the essence of life and not everything about it (such as the myriad ways — say, with replication or immortality[12, Chapter 8] — of preserving the packet of information X and how well it can be done). Let us analyze just how life may compute (and consequently, how it is computable). The recursion theorem[49, Chapter 6] and cellular automata[57] indicate how knowledge (information) can replicate itself. A theory of knowledge can be formed quite well with algorithmic information theory and quantum complexity theory[28, Chapter 8] (we don't claim that life does compute as efficiently as quantum computers, but quantum complexity theory will give us at least the lower bounds of efficiency). We have also seen that the task of artificial intelligence is perfectly justified, so we may reach to an understanding of how intelligence works. Life on Earth also seems to usually use computational compression techniques to replicate itself (a genome is the compression of a life form on Earth in the form of DNA and reproduction uncompresses it back again)[29, 7, Chapter VI, Chapter III]. There is nothing in our definition of life that excludes life in the form of artificial intelligence; our mini-theory of life is also compatible with Gell-Mann's own theory[28].

Freeman Dyson once said[33, pp. 258], "As we look out into the Universe and identify the many accidents of physics and astronomy that have worked together to our benefit, it almost seems as if the Universe must in some sense have known that we were coming." He is right: the Multiverse mandates for an understanding of itself (via the Church-Turing principle and Conjecture 1.4) and knowledge seems to be a byproduct of life; life seems compulsory by the laws of the Multiverse. Not only does it produce knowledge, life itself is an embodiment of knowledge (the kinds of life that survive the best are ones that have the best knowledge of their environment). Deutsch has written about the significant and interesting effects, including the crystal-like structure of knowledge, that life must have on the structure of the Multiverse[12, Chapter 8].

A child of this theory of life is a scale of intelligence:

Definition 1.11 (Intelligence Limit) *The size, with the interval being* $(0, \aleph_0)$*, of the set of all knowledge of life* X *along with the capability to compute every member of this set.*

The intelligence of any life form can be determined in this manner. We say that a life form X has *universal intelligence* if it is capable of creating the Theory of Everything and computing the Simulation of Everything. With this new knowledge, we will show a general Turing test[55] for intelligence in the next section.

2 The Future of Life

The previous section was a lengthy justification for Algorithmic Communication with Extraterrestrial Intelligence. Now that the fundamental question of Algorithmic Communication with Extraterrestrial Intelligence has been investigated — yes, we may use algorithms to communicate about Everything! — let us turn our focus on the application of the Theory of Everything on the future of life.

2.1 Some properties of physical eschatology

First, we consider a tiny proportion of the features of a theory of the future of life or *physical eschatology*[2, 8], which we think must be included in any theory of life (biology). For the latter, we will use our mini-theory of life(1.4.2) as an approximation. Other discussions on the theory of physical eschatology, including astrobiology, may be found in [37, Part I].

2.1.1 How Intelligent can Life Be?

Suppose we discover a new life form X. We would now like to measure its intelligence. How would we do it?

We propose a crude general-purpose Turing test[55] for the intelligence of any life, which may be refined in the future. In principle, our Turing test sounds exceedingly simple: it is nothing more than a measure of the intelligence limit(1.11) we first defined in our mini-theory of life. In essence, it is basically asking the question: how much of the Simulation of Everything can life form X compute? In practice, however, the intelligence limit of a life form may be more than trivial to obtain. The intelligence limit of any life form should be more than 0 (because life itself is an embodiment of some minimum knowledge), but the upper bound of the intelligence limit of any universally intelligent life form should be $\aleph_0$ because the Theory of Everything can be decompressed to compute the Simulation of Everything. That is again a matter of convenient description; in practice, any universally intelligent life should at least be able to achieve an intelligence limit that is arbitrarily close to $\aleph_0$.

2.1.2 Life cannot Be Analog

Here, we will try to answer the question — "Is life analog or digital?" — posed by Freeman Dyson, a great thinker[21] of physical eschatology, and show why life cannot be analog, as Dyson thinks it could be[22], if our case is right.

Dyson defines life as an active information processor (a system that not only holds information in memory but also processes and uses it) and that is compatible with our mini-theory of life. He defines analog life as life that performs analog computation, or hypercomputation, on information whereas digital life is life that performs digital computation on information. He speculates that the future of life in the cold, expanding universe depends on whether it is analog or digital; the chances of life surviving forever in that cosmological model seem more likely if life is analog.

Unfortunately, we regret to recall that analog computation is perhaps physically impossible.

Argument We claim the Quantum Constructor Theory can produce the Simulation of Everything(1.2). It can be shown[49] that the universal digital computer, such as that described by the Quantum Constructor Theory, *cannot* simulate all possible computations of the analog computer. By Conjecture 1.1, the analog computer or hypercomputer is physically impossible. ∎

Of course, the argument and our version of the Theory of Computation fails if hypercomputation is physically possible after all, but we do not think that is very likely. Computations (which correspond to physical processes) that are not in the Simulation of Everything are physically impossible (such as the computation of Chaitin's constant, the Ω, which, if the constant could exist, would constitute as "analog information"). Since analog computation is most likely impossible, life is not likely to perform such computation on information. We conclude that, given our current information, life cannot be analog.

2.1.3 The Survival Time of Life

But does this necessarily mean that Dyson's critics are right and the chances of life surviving forever in the future of a cold, open universe are bleak?[22]

Not necessarily. We outline Dyson's reasoning for the indefinitely long survival of life in the future of the Universe. Let us now make only the 2 following conjectures:

1. The Church-Turing principle(1.2) is correct and thus infinitely long computation is possible.
2. Life is computable and thus capable of participating in infinitely long computations (or equivalently, virtual reality simulations).

If these abstract conjectures are proven to be true for some type of universes, then by Conjecture 1.4, it seems mandatory that life must be able to survive forever in that type of universes. And Dyson[22], Deutsch and Tipler[12, Chapter 14] would still be right, even if analog computation or the Omega Point is impossible. (They are correct about the problem being a cosmological one.) Recently, Krauss and Starkman (the same people who worried Dyson) have shown how these conjectures might not hold true[35]. The intriguing paper by Garriga et al.[30] suggests some extremely interesting ways that civilizations could use to preserve themselves. The final answer to this conundrum remains to be cosmologically derived. The problem is a most serious one, since we are talking about the physical feasibility of *universal* computation.

2.1.4 The Life Contingency Scale

We now introduce the Life Contingency Scale, which is a rough measure of the type of disasters any intelligent civilization would have to ward off in order to maximize survival time. We will let the Life Contigency Scale explain itself:

- **Type I Disaster: Planet** Ecological disaster; nuclear annihilation; global epidemics; asteroids[33, pp. 286-298].
- **Type II Disaster: Solar System** Death of home star[33, pp. 298-299].
- **Type III Disaster: Galaxy** Galaxy mergers[33, pp. 299-300]; supernovae; gamma-ray bursts[1].
- **Type IV Disaster: Universe** Entropy death[33, pp. 304-306]; home universe unfit for indefinite survival.
- **Type V Disaster: Multiverse** No matter what life does, there is no physically possible way of surviving indefinitely long in any type of universe.

2.1.5 Algorithmic Communication with Extraterrestrial Intelligence

Finally, we discuss an extremely important component of the theory of physical eschatology: Algorithmic Communication with Extraterrestrial Intelligence. How would we communicate with ETI (the language), should they exist in our Multiverse, and what would we say (the message)? We will not talk about 'hardware' issues, such as data transmission and so on, which are covered in other treatments[37, Part II].

The Language

There is an interesting history of the programming languages suggested for Algorithmic Communication with Extraterrestrial Intelligence[37, Part III]. We will not concern ourselves with any specific implementation of a programming language for Algorithmic Communication with Extraterrestrial Intelligence; rather, we will investigate some of the general properties such a class of programming languages must have.

Any ideal programming language for Algorithmic Communication with Extraterrestrial Intelligence must be universal, of course: it must be capable of describing any possible physical system. Such a complete programming language must be designed for the Quantum Constructor Theory; one such fine example, as we have introduced, is the QCL. Nevertheless, in practice, it is not necessary to design Algorithmic Communication with Extraterrestrial Intelligence programming languages purely for the Quantum Constructor Theory. Classical languages might serve the purpose just fine. Observe, for example, that hitherto in the human history of computing, classical computation have, for the most part, served programming of physical systems quite well. (The wise critic would point out that our history of the field is an infant.) The type of the programming language we choose ultimately depends on the Message we would like to communicate.

But what should the design of an Algorithmic Communication with Extraterrestrial Intelligence programming language look like? Fortunately, we can learn

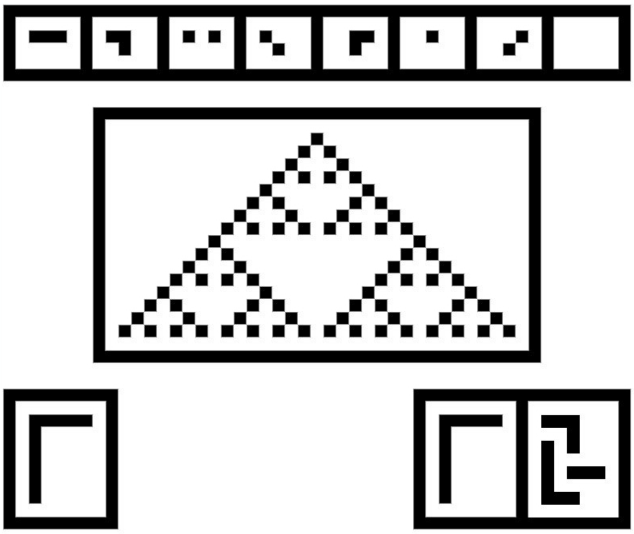

Figure 3: Example Message (continued in the next transmission)

from the existing theory of programming languages[47]. For example, one crude measure of the complexity of an Algorithmic Communication with Extraterrestrial Intelligence language might be the complexity of its grammar. The problem is that most programming languages have been designed for the purposes of human consumption (which means not only are most of them classical, they were also made to be understandable by mostly human beings; humans have a kind of bias, called the Universal Grammar, for the kinds of languages they create[43, pp. 236-240]). Besides, most of them were also not necessarily designed for the *ideal* purpose of programming in the first place: the programming of physical systems. A good heuristic for the design of an Algorithmic Communication with Extraterrestrial Intelligence language might be that it should be designed for the ease of representation of physical systems. (In fact, programming languages for humans too should be designed in this manner: all mathematics, after all, is the description of physical systems.) Since the laws of physics are universal, a Message of a collection of physical systems encoded in such a programming language might be easy to decode. What we mean is that there should be as direct as possible an isomorphism between the algorithm and the physical system in question itself; this isomorphism must be assisted by the design of the Algorithmic Communication with Extraterrestrial Intelligence language. For example, an algorithm of the Stern-Gerlach experiment[38, pp. 43-46] or quantum teleportation[38, pp. 26-28] must be as unambiguous as possible (in the parlor of language theory, there should be a single parse tree for the semantics of the program; there is no reason why even a compiler or interpreter for our Algorithmic Communication with Extraterrestrial Intelligence language cannot be devised and transmitted; the question is whether the recipient would interpret it correctly; it is even possible, though exceedingly tedious, to express this paper in such a language — say, with an extra ("natural", in linguistic terms) language designed for an artificially intelligent entity written in an Algorithmic Communication with Extraterrestrial Intelligence language).

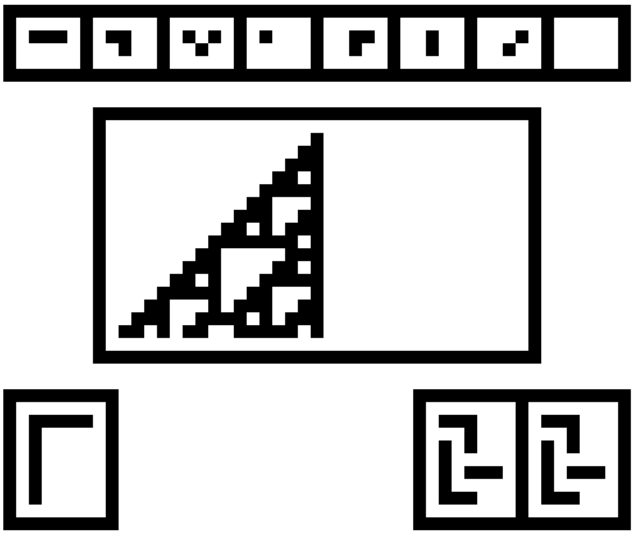

Figure 4: Example Message (End of Transmission)

We have invented an Example Message (Figure 3 and 4) for the tastebud of the curious reader; we encourage him or her to decode the semantics of the Message before consulting the answer in the next paragraph. The only external reference one would need to dechiper the Example Message is the Dutil-Dumas pictographic system[37, pp. 190-192]. We also highly recommend the reader to explore the range of programming languages that have been designed so far for Algorithmic Communication with Extraterrestrial Intelligence[37, Part III].

(Answer: The main bulk of the Example Message is the small evolution of two cellular automata[57, Chapter 2], under Rules 90 and 110 respectively, with the same particular initial condition; such a type of Message is also being invented independently elsewhere[40]. The rest of the information constitute section and page numbering. Error-checking would be a necessary feature for long enough Messages and this can be achieved, by, say, adding a checksum. One of the most interesting things about cellular automata is how Rule 110 embodies the simplicity of universal classical computation in at least 8 bits. Conway's Game of Life[57, pp. 693] cellular automata is another example of the simplicity. Perhaps universal classical computation is not too hard to evolve in Nature. We do not claim, though, that cellular automata is the best language for programming all physical systems.)

The Message

A Message between intelligent civilizations could be about any collection of physical systems whatsoever. It could be about, say, encoding altruism[40] or exchanging physical theories (even the Theory of Everything). However, we argue that there is a class of Messages that every intelligent, communicative civilization must think about. We will call such a class the Life Contingency Messages.

As the reader might have guessed by now, a Life Contingency Message is communication about a type of disaster as indicated by the Life Contingency Scale(2.1.4). The construction of such a Message, or the algorithm, depends on the type of disaster one is planning to communicate about. For example, suppose a civilization is interested in communicating about a Type IV (Universe) Disaster. Needless to say, the creators of the algorithm must have access to the correct cosmological model of the Multiverse, which would predict the future of the home universe. The future of life in a closed universe is different from that in an open or flat universe, so the creators of the Message, if they choose to be altruistic, should be able to predict the evolution of their universe in the Multiverse and provide custom solutions, if any (for example, by escaping through a higher dimension[33, pp. 306-308]), to the problem. (Speaking of cosmological models, Deutsch has suggested[12, Chapter 14] that since, at the time of writing, the omega-point cosmological model (under plausible assumptions) is the only type that allows for an infinite number of computational steps, our spacetime must have the omega-point form. However, recent cosmological surveys[4] have suggested that the Universe is actually flat. If we are to take the Church-Turing principle seriously[12, pp. 350-351] as an explanation of Reality, then we could infer that universality is possible even in an open type of universe; perhaps, say, by harnessing dark energy[16]. We would also like to strongly support the view that cosmological models must take the effects of life into account in order to form accurate predictions[12, Chapter 8].)

The design of a Life Contingency Message could be judged by an *utility function*, which must estimate the probability that the algorithm will be useful in maximizing the survival time of life in the vicinity of the disaster, regardless of interaction with any other civilization (supposing interaction is required to stave off the disaster in question or is a possibility in any other case).

Wolfram[57, pp. 822-840] has a brief, interesting discussion on Algorithmic Communication with Extraterrestrial Intelligence. (He is mistaken in conjecturing that there is no general notion of true intelligence; our general-purpose Turing test in the form of an intelligence limit for life serves as a counterexample.) He argues that random (because they are compressed) signals are surely abound and information-rich — and we presently think of them as nothing more than noise — but correctly concludes that Algorithmic Communication with Extraterrestrial Intelligence Messages are likely to have regularities. He also points out that simple physical systems can produce complex output, but we think it is possible to calculate the likelihood of a natural source having produced a 'Message'. (We would like to also add that we do not think cellular automata are any more special than universal classical computers, because they are both equivalent, but they are interesting for studying how simple classical systems can produce complexity.) A more complete work on the nature of Algorithmic Communication with Extraterrestrial Intelligence languages can be found in McConnell[37, Part III], but we wish to reinstate that a truly universal Algorithmic Communication with Extraterrestrial Intelligence language must be universal in the Quantum Constructor Theory sense.

The N_0 Message

Last but not least, we infer the N_0 Message, named after the Drake Equation solution[37, Chapter 3] for our galaxy, a Type III Life Contingency Message for the Milky Way and Andromeda galaxies. In around 3 billion years, the two galaxies are likely to collide and merge with each other over a period of 1 billion years to form an elliptical galaxy[32]. There are at least two possible fates for the Sun, depending on where it is in its galactic orbit during the time of collision: either the Sun would be thrown out of the merger as it rides on the tidal tail, or, it would be thrown right into the center of the merger, where a great starburst would be underway along with at least a few supernovae per year[20]. Whether the collision will occur remains to be seen, but if it will, then ideally the N_0 Message should describe a simulation of the merger (or include the results of the simulation itself in order to save computational time of the recipient) and, we hope, a solution to the problem, if it is one. We wonder if the merger can actually be harnessed by an advanced enough (say, Type III[33, pp. 278]) civilization for its energy needs.

3 Conclusion

We have briefly explored a logical structure of the Theory of Everything, along with its implications, and showed that the theory is necessary for an understanding of the future of life. (A quantum physicist might muse that we have only scratched Hilbert space slightly.) We hope the curious reader will tackle the open problems of this paper or extend this work with further developments.

For a good treatment of the wonders of the Theory of Everything, please see Deutsch[12], who discusses, among other things, why chaos theory is a feature of classical physics (unless, perhaps, we create a quantum chaos theory), how free will is compatible with the Multiverse theory and how past-directed time travel and a universal virtual reality generator may be possible. Also see Schmidhuber's interesting works[45, 46] on algorithmic theories of everything, which even anticipate the self-replicating Multiverse(1.3.2) but need to be more physics-based. We also now know that E.O. Wilson's "Consilience"[56], or the unity of knowledge ("the proof that everything in our world is organised in terms of a small number of fundamental natural laws which underlie every branch of learning"), is a physically possible project: art and science can finally be reconciled with each other. Everything would be amenable to Science. The Theory of Everything will be a discovery with titanic consequences for the human civilization... there is no way of overestimating (keeping physical possibility in mind) its importance.

We believe that just as much as black holes prove to be an interesting playground for testing theories of physics (even demanding new physical theories at times)[50], the same should consequently be the case for the Theory of Computation; a better Theory of Something might lead to a better Theory of Computation. Could it be, for example, that an application of the qubit field theory[18], instead of existing quantum field theories, might provide new insights into the workings of black holes? What does the Holographic Principle mean for computation? Does information loss really occur at black holes?

The theory of physical eschatology is interesting to study even if extraterrestrial intelligence does not exist: the payoff from the Theory of Everything, upon which the theory of physical eschatology depends, alone is huge. For example, there seems to no reason why, as we have seen, artificial intelligence cannot be created.

There still remains much work to be done with the theory of physical eschatology. A full-fledged theory would be quite complex, which must consider a theory of interaction between different civilizations, for example, or how to backup information (say, with time capsule crawlers[34]) or how to develop a galaxy-wide Internet. Transhumanism too must be incorporated into the science of physical eschatology; as is the case with any young field, the former is riddled with some questionable claims here and there (the future is no easy thing to predict), but over time truths will establish themselves while throwing out the falsehoods.

We must start taking physical eschatology more seriously right away, for the very future of all life in the Multiverse is at stake here[44]. What is the point of our lives if none of it will exist tomorrow? What would be most exciting and rewarding is how humanity and other life forms might be able to save themselves and continue their survival indefinitely into the future. Can and will we?

> "Wir müssen wissen. Wir werden wissen."
>
> — David Hilbert

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Appendix

A Relativistic Computing

The following are Mathematica programs for demonstrating relativistic computing. References include [5] and the Mathematica documentation (http://documents.wolfram.com/v4/).

A.1 Velocity time dilation

```
(* CONSTANTS *)
c = 2.99792458 * 10^8; (* m/sec *)
f2[x_] := f1[x] * LORENTZ;
RED = RGBColor[1, 0, 0];
GREEN = RGBColor[0, 1, 0];
```

```
(* VARIABLES *)
u = (99.999999 * c)/100; (* 99.999999% of c *)
LORENTZ = Sqrt[(1-((u^2)/(c^2)))];

(* THE DEMONSTRATION *)
f1[x_] := x; (* replace f1 with any function returning time
of running input with size x *)
Plot[f1[x], {x, 0, 10^100}, PlotStyle -> {RED}, AxesLabel
-> {"x", "f1[x]"}]
Plot[f2[x], {x, 0, 10^100}, PlotStyle -> {GREEN}, AxesLabel
-> {"x",  "f2[x]"}]
```

A.2 Gravitational time dilation

```
(* CONSTANTS *)
c = 2.99792458 * 10^8; (* m/sec *)
G = 6.6726 * 10^-11; (* m3 kg - 1 s - 2 *)
RED = RGBColor[1, 0, 0];
GREEN = RGBColor[0, 1, 0];
f2[x_] := f1[x] - ( f1[x] * (1 - SCHWARZSCHILD) );

(* VARIABLES *)
M = 10^4 * 1.98892 * 10^30; (* kg *)
R = 2.999997 * 10^7; (* m *)
SCHWARZSCHILD = Sqrt[(1-((2*G*M)/(R*c^2)))];

(* THE DEMONSTRATION *)
f1[x_] := x; (* replace f1 with any function returning time
of running input with size x *)
Plot[f1[x], {x, 0, 10^100}, PlotStyle -> {RED}, AxesLabel
-> {"x", "f1[x]"}]
Plot[f2[x], {x, 0, 10^100}, PlotStyle -> {GREEN}, AxesLabel
-> {"x",  "f2[x]"}]
```

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