Deriving Physics from the Set of All Computations

A Survey of Testable Predictions from Computational Ensemble Theories

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> *"the laws of physics will be reinterpreted as statements about information and its transformations."*
> — Frank Wilczek [1]

Abstract

This paper surveys Big World ideas—where reality is large enough that every possible observation is made by someone, somewhere—built on one simple assumption: *all computations exist*. At first glance, an "everything exists" view looks untestable. But Big World theories become testable once they also say which observer-moments are typical. Under program-prefix counting, short descriptions tend to dominate: computations determined by short program prefixes have many more completions than long, ad hoc descriptions. This creates a built-in simplicity bias and turns broad philosophical claims into concrete constraints.

We collect **98** distinct predictions and constraints from the literature. Many match well-tested facts; others remain open or speculative. Our main contribution is a consolidated table of predictions (full list in the appendix), plus a thematic atlas that explains why these claims follow from the all-computations assumption, what evidence already supports them, and what future tests could strengthen or weaken them.

Keywords: all computations exist, algorithmic information theory, algorithmic probability, Solomonoff induction, Kolmogorov complexity, Occam's razor, minimum description length, typicality, measure problem, self-locating uncertainty, observer moments, observer conditioning, Big World cosmology, computational ensemble, computationalism, functionalism, multiple realizability, arithmetical realism, mathematical realism, Ruliad, Wolfram model, multiway systems, universal dovetailer, universal computation, Church–Turing–Deutsch principle, Gandy's argument, computability of physics, information density, Bekenstein bound, discrete vs continuous, continuum emergence, quantum mechanics, Born rule, interference, Bell inequality, many-worlds interpretation, many-minds interpretation, decoherence, top-down cosmology, no-boundary proposal, Hawking–Hertog measure, participatory universe, it from bit, fine-tuning, anthropic reasoning, cosmological initial conditions, arrow of time, Bayesian model comparison, Bayes factors, computational plenitude, ensemble theory, ontology, Diophantine equations, digital physics

Contents

1 Introduction

Across physics, philosophy, and computer science, one idea keeps resurfacing:

> *All computations exist.*

We will refer to this core assumption as the *All Computations Exist* hypothesis, or **ACE** for short.

Different authors describe ACE in different ways—for example: "all programs", "all mathematical structures", "all rewriting rules", "all observer-states", "the Ruliad", and so on. But the empirical question is always the same. If every possible computation (and therefore every possible observation) occurs somewhere in a huge ensemble, why is our world so regular? Why do we see stable laws at all? Why are those laws simple enough to discover? And why do our best theories have the structure they do (quantum constraints, relativistic symmetries, and a very specific cosmological history)?

A familiar objection is that "theories that explain everything explain nothing." The literature reviewed here answers with one key move: even if everything happens somewhere, a theory can still be testable if it says which observations are *typical* for observers like us. A theory that says only that "everything happens" provides no insight as to what will happen next. This is why such theories "predict nothing". A prediction requires a rule that turns the total ensemble into first-person expectations.

What this paper contributes. Work in this area is spread across many fields and many styles of writing. To compare claims, we first need a shared inventory. This survey therefore has a concrete core: Table 3, a consolidated list of **98** distinct predictions and constraints drawn from the literature. Each row states an observable consequence (in plain language), gives an evidence label, and cites the source(s) that propose it.

We then provide a Prediction Atlas that groups the table into a small set of recurring themes. For each theme we explain why it is nontrivial in a Big World setting, how it is motivated under ACE-style reasoning, and what evidence would strengthen or weaken it. The goal is not to insist that all authors agree on one final theory. The goal is to make the empirical and methodological pressure points visible.

How to read the paper. Section 2 clarifies what "all computations exist" means in practice, and why many different formalisms fall into the same universality class. Section 3 explains how Big World theories can still have observational consequences, emphasizing typicality and measure. Section 4 highlights a short list of key predictions and points to the full list in the appendix. Section 5 is the thematic atlas. Section 6 adds a conservative Bayesian analysis, and Sections 7–8 synthesize the main lessons and outline open problems and next steps. Finally, the appendices collect definitions, methods, and annotated source notes.

2 What we mean by "all computations exist"

Different authors describe the same core idea in different words. Some talk about "all programs", some about "all mathematical structures", some about "all rewriting rules", and some about "all observer-states". For prediction-making, most versions share three parts:

(A) a very large set of possibilities,

(B) a way to connect possibilities to observers, and

(C) a rule for weighting observers.

2.1 A history of "all possibilities" ideas

Ideas that look like "everything exists" did not start with computation. Philosophers and physicists have proposed many versions of a *plenitude* or *ensemble* view, where reality is not a single world but a very large collection of possibilities.

A few well-known examples are:

- **Plato:** a realm of Forms or ideal possibilities that are more fundamental than changing physical things [2].
- **Epicurus:** an atomistic picture with infinitely many worlds in an infinite void [3].
- **Spinoza:** a view in which "infinitely many things" follow from the necessity of the divine nature [4].
- **Gödel:** a strong form of mathematical realism, treating mathematical objects as objectively real [5].
- **Nozick:** the "principle of fecundity" (roughly: all possible worlds obtain) [6].
- **Lewis:** modal realism, where possible worlds are as concrete as the actual world [7].
- **Parfit:** the "All Worlds" hypothesis as one candidate answer to why anything exists [8].

Our focus is a computational version of this tradition: we ask what follows if *all computations* exist, and if we weight observer-moments using rules inspired by algorithmic information theory. For historical context, Lovejoy's classic study traces many versions of the "principle of plenitude" through Western philosophy [9].

Later, in the discussion and appendices, we return to the deeper question of which ontology is most natural. Here, we focus on the predictions that follow once a weighting rule is chosen.

2.2 Why the choice of computational model usually does not matter

A practical concern is that "all computations" can be described in many different ways: Turing machines, lambda calculus, recursive functions, combinator calculus, cellular automata, graph-rewriting systems, register machines, billiard-ball computers, and so on. The Church–Turing Thesis says that these form an *equivalence class*: if a system is computationally universal, then it can emulate any other effective computation [10, 11, 12].

This matters for two reasons.

First, if reality's "base layer" were any one of these universal models, then the corresponding ensemble (all programs, all rewrite rules, all effective procedures, etc.) is complete in essentially the same sense.

So when different authors describe a universal dovetailer, enumerable sets, cellular automata, or rewriting systems, they are typically pointing at the same underlying space of computable processes. There is no computation, nor any computationally generated observer state, that would exist under one framework, but not another.

Second, in algorithmic information theory, changing the reference universal machine mostly changes description lengths by an *additive constant*. That is, the shortest description of an object can shift by a fixed amount when we swap one universal machine for another, but it does not change the overall picture of which descriptions are "short" versus "long" [13, 14]. So the broad simplicity-biased conclusions used in this literature (for example, that simpler rules tend to be weighted more heavily under universal priors) are robust to the choice of a particular universal computational language.

In short: the details of the ontology may matter for fine points of measure, but the core claim "all computations exist" and the main algorithmic-information arguments do not depend on whether we write those computations as Turing-machine tapes, lambda terms, graph rewrites, or anything else in the same universality class.

3 How an "everything exists" idea can still make predictions

We use the term *Big World* to mean a setting where reality is large enough that every observation-type occurs somewhere (often many times). In a Big World, the statement "somebody sees X" is almost always true for many different X. So a theory becomes testable only if it can say what an observer like us should *expect* to see—usually by showing that some observations are more typical than others.

A common worry is that a theory with such a huge space of possibilities cannot be tested. Victor Stenger summed up the worry with the line: "Theories that explain everything explain nothing." [15]

Bostrom puts the key requirement in simple terms: even in a Big World where all observation types occur somewhere, we still need a notion of typicality.

> *"To be able to derive any observational consequences from our scientific theories in a Big World, we need to be able to say that certain types of observations are more typical than others."* [16]

The key point is that science does not only ask whether an observation exists somewhere. It asks how likely it is that *we* would see it. Bostrom explains this using self-locating evidence: not just "an observation occurs," but "this is what we observe." [17, 16] Once you take that step, Big World theories can disagree about what we should expect to see, and they become testable again.

There is also a second issue: in infinite sets, "counting" can depend on how you count. Tegmark explains this as the measure problem. Different ways of ordering or encoding the same infinite set can give different fractions, so any prediction needs a clear rule for how observers (or observer-moments) are weighted. [18, 19]

4 Key Predictions

Table 3 contains the full consolidated list of **98** predictions and constraints gathered from the literature. Most entries are short, and many overlap in assumptions, so the table is best read as an index: it tells you what claim is being made and where it appears.

In this section we highlight a small set of high-impact items that are either already strongly supported by evidence or are clear, near-term targets for tests. These are examples of the kinds of empirical consequences ACE-style reasoning aims to explain. The complete list appears in Appendix A.

Columns. Each row lists (i) an ID, (ii) a plain-language prediction, (iii) an evidence status label, and (iv) the source(s) that propose it.

Table 1: Selected high-impact predictions and constraints (illustrative). The complete list of 98 items appears in Appendix A (Table 3).

ID	Prediction (plain language)	Status	Sources
P003	We should usually observe stable, simple regularities that can be summarized as “laws”, rather than constant chaos. In an all-computations picture, that means typical observers should land in worlds with compressible patterns.	Accepted	[20]
P006	We should almost never see wild, law-breaking events that come out of nowhere. A workable “all computations” theory must make such bizarre outcomes extremely rare for typical observers.	Observed	[21, 22, 23, 24]
P008	Some yes/no questions about the world should be incompatible: you cannot get definite answers to both at the same time, and measuring one can spoil information about the other.	Established	[21, 23]
P009	At large scales, the effective laws we observe should not depend on arbitrary choices like the order we update a model or the coordinates we use. This can show up as relativity-like symmetry (general covariance).	Observed	[25, 26]
P013	Experiments that test Bell inequalities should show the same non-classical correlations that standard quantum mechanics predicts, even if the underlying model is deterministic.	Observed	[25, 26]
P014	Some tasks should be much faster on a quantum computer than on any classical computer (a real quantum speedup).	Observed	[27]
P025	Quantum states should evolve in a linear, probability-preserving way between measurements (the standard unitary evolution of quantum mechanics).	Observed	[22]
P032	True, irreducible randomness should not be fundamental. What looks random should come from not knowing which copy/branch of an observer one will become, or from self-location uncertainty in a large ensemble.	Plausible	[19, 28, 26]
P097	Observers need an ordering of distinguishable states (an experienced “before/after”) to register differences and therefore to have information; thus any observer-containing world should exhibit an effective time (or time-like ordering) and stable records.	Accepted	[29, 30]

Continued on next page

ID	Prediction (plain language)	Status	Sources
P098	The universe's effective initial conditions should be describable by a very short specification (low algorithmic complexity) rather than arbitrary complexity; typical observers should therefore see simple, highly regular early-universe conditions.	Plausible	[29, 22]

5 Prediction Atlas

This atlas is a guide to Table 3. The table aims to be complete; the atlas is selective. Each theme explains what is being claimed, why it is not automatic in a Big World, why ACE-style reasoning suggests it, and what evidence would support or weaken it.

5.1 Simplicity

In a huge ensemble there are far more complicated rule-sets than simple ones, and far more ways for a regularity to fail than to hold. So it is not obvious why our world is compressible into short equations, or why those equations keep working in new regimes. [8, 31, 32]

Computational-ensemble approaches try to make simplicity typical rather than lucky. Under ACE-style counting, many bit strings represent the same effective computation because only a finite prefix is ever read. If a system's behavior is fixed by a short prefix, it has exponentially many completions, and therefore higher induced weight. When we also condition on being observers, high-weight observer-producing computations dominate. The result is a built-in bias toward stable, compact "laws". [33, 34, 22]

Representative predictions

P006 (Observed). We should almost never see wild, law-breaking events that come out of nowhere. A workable "all computations" theory must make such bizarre outcomes extremely rare for typical observers. [21, 22, 23, 24] Under ACE, if observers are sampled from the induced distribution over computations, then long, ad hoc rule-breaks are strongly suppressed. A single bizarre deviation typically requires extra descriptive information (it must be specified as an exception), so it gets less weight than a continuation that keeps following a short rule. So far, the strongest support is simply that in both daily life and precision physics we do not encounter persistent, macroscopic "miracles" that violate established regularities. This picture would be challenged by a reproducible class of large-scale law violations that cannot be explained by a shorter underlying rule.

P024 (Accepted). When we compare different explanations for the same data, the ones with shorter descriptions should get much higher weight (roughly exponentially higher). [22, 28] Under ACE, if shorter descriptions have exponentially higher induced weight, then among explanations consistent with the same data, the shorter one should generally be the better bet for new predictions. This is the intuition behind minimum description length (MDL) and related Bayesian model-selection results. In practice, across science and statistics, simpler models often generalize better when they fit comparably well, and compression-based priors are a workhorse in practical inference. A useful place to test this is in domains where two models fit the current data equally well but differ greatly in description length; ACE-style reasoning predicts a systematic advantage for the shorter model.

P094 (Plausible). Among all universes (or computations) that can produce observers, we should typically find ourselves in one with the *least* information content (shortest description) consistent with our existence. [22, 35] Under ACE, if we condition on being observers, then we should not expect to land in a random element of the ensemble; we should expect to land in a high-weight element that still supports observers. Under a simplicity-weighted measure, that means "as simple as possible, but not simpler than observerhood allows". This is not a settled empirical claim, but it is consistent with the historical pattern that features once thought like optional "frills" often turn out to be needed for complex structure (chemistry, long-lived stars, stable records). A sharper test would be to identify concrete simplifications of known physics that leave all other evidence intact; if such simplifications reliably destroy life-permitting structure, that would support the claim.

Simplicity is the first pressure point, but it immediately raises a second question: if many computations instantiate the same observer-state, what does probability mean for first-person prediction? That leads to self-location and duplication.

5.2 Self-location and duplication

In ordinary uncertainty, we do not know which external situation is true. In a Big World, there can be many physical instantiations of what is, from the inside, "the same observer so far". The uncertainty is then indexical: which copy, branch, or continuation am I? [17]

Computational ensemble theories often treat observer-states as the starting point and then derive transition probabilities from the weighted set of continuations that realize each possible next experience. This is where typicality rules do real work. Without a principled way to weight observer-moments, "everything happens" cannot turn into a forecast about what we should expect to see. [29, 21]

Representative predictions

P004 (Plausible). We should expect that deterministic duplication implies unavoidable first-person self-location uncertainty; its quantification is invariant under reconstitution delays, spatial translation, and (at the substitution level) whether the implementation is physical, simulated, or arithmetical. [21, 36, 23] Under ACE, if the same observer-state can occur in many computations, then first-person probabilities must be computed over those occurrences. The result is a family of "self-locating" update rules (closely related to anthropic reasoning, but not limited to survival constraints). The reasoning is mathematically coherent and widely used in philosophy of probability; its empirical bite depends on how a theory maps physical states to observer-states.

P032 (Plausible). True, irreducible randomness should not be fundamental. What looks random should come from not knowing which copy/branch of an observer one will become, or from self-location uncertainty in a large ensemble. [19, 28, 26] Under ACE, with only deterministic micro-laws, randomness can arise because an observer does not know which continuation they will find themselves in after branching-like events. Several interpretations of quantum mechanics treat probabilities in exactly this self-location way. Quantum experiments strongly support Born-rule statistics; the open question is whether those statistics are best understood as fundamental stochasticity or as emergent self-location uncertainty. A key discriminator would be credible evidence for irreducible stochasticity that cannot be modeled as branching and indexical uncertainty.

P084 (Established). In Big World reasoning, if theory T1 makes our kind of observation much more typical than theory T2, then after conditioning on our observation we should favor T1 over T2. [17] Under ACE, once we accept that we are one observer among many, ordinary Bayesian conditioning must be extended to include indexical information (what we observe about "where/which" we are). This is the core of how Big World theories escape the critique that they are unfalsifiable: different Big World theories can imply different distributions over observer-moments, and we can prefer the one that makes our observation more typical. This is a methodological constraint rather than a new physical discovery, but it is widely recognized as necessary in Big World reasoning.

P096 (Speculative). Changing an observer's state (memory, body, or interpretive "point of view") can change which histories and effective laws are compatible with producing that observer; in this sense, different observer-states select different "worlds" within the same underlying ensemble. [37, 24, 38] Under ACE, if an observer-state is what selects the compatible histories, then changing the observer-state (memory, embodiment, or effective point of view) can change the class of worlds in which that observer-state is typical. This generalizes anthropic selection beyond "survival" to selection by arbitrary observer properties. At present this is a synthesis across different authors" intuitions rather than a single confirmed physical effect. Its value is that it unifies several observer-dependence ideas and suggests a direction for making observer-conditioning more precise.

Self-location becomes especially important in quantum physics, where our best-tested theory is explicitly probabilistic and where measurement-like events naturally look like branching into multiple compatible continuations. That is why computational ensemble programs often target quantum structure next.

5.3 Quantum structure

Quantum mechanics works extremely well, but it still feels strange: superposition, interference, entanglement, and Bell-type correlations clash with classical intuitions. If computational ensemble theories can reproduce key quantum constraints from deeper typicality principles, that would be a sharp success because quantum structure is rigid and highly constrained. [26]

Several ACE-style approaches start from observer-states and treat quantum probabilities as first-person transition chances across many compatible continuations. The shared hope is that linearity, Born-rule weighting, and nonclassical correlations emerge as consistency conditions for typical observers in a multi-history ensemble. [29, 21, 25]

Representative predictions

P010 (Observed). When we repeat the same quantum measurement many times, the long-run outcome frequencies should follow the usual quantum probability rule (outcomes with larger wave strength happen more often). [25, 26] This prediction is simply the empirically observed Born-rule pattern. ACE-style accounts aim to explain why typical observers should see these frequencies, often by arguing that alternative weighting rules are unstable or atypical under branching. The evidential status is strong because the frequencies are confirmed across many experimental platforms. A genuine anomaly—systematic, reproducible deviation from Born statistics—would immediately constrain many versions of the program.

P011 (Observed). Quantum behavior should look like a combination of many alternative histories: different possible paths can add together or cancel out (interfere). [25, 26] Interference is the signature that “many paths” contribute to an outcome. In a computational ensemble view, interference is not an optional extra; it is the kind of phenomenon you expect if multiple compatible micro-histories contribute to the same observer-level event. The evidence is overwhelming (double-slit and its modern variants), and the key explanatory task is to show why interference disappears exactly when decoherence predicts it should.

P013 (Observed). Experiments that test Bell inequalities should show the same non-classical correlations that standard quantum mechanics predicts, even if the underlying model is deterministic. [25, 26] Bell-inequality violations are a sharp constraint: they rule out a large class of local hidden-variable stories. Computational ensemble theories often take this as support for a picture where the observer’s effective state is not determined by a single classical history. The evidence is strong; what remains open is whether ACE provides a distinctive explanation beyond what standard quantum interpretations already offer.

P025 (Observed). Quantum states should evolve in a linear, probability-preserving way between measurements (the standard unitary evolution of quantum mechanics). [22] Linearity and unitarity are deep structural features of quantum theory. ACE-style reasoning would like these to fall out as consistency conditions for typical observers: probability conservation and stable composition rules in a multi-history setting. Experimentally, quantum control has repeatedly confirmed unitary evolution to high precision; this makes any proposed deviation a highly sensitive test.

P005 (Established). It should be impossible to make a perfect copy of an unknown quantum state. Any attempt to copy it must introduce noise or disturbance. [21] No-cloning is a clean theorem-level consequence of linear quantum mechanics and is foundational in quantum information. Within an ensemble story, it also functions as a “stability” constraint: if arbitrary state copying were possible, observer statistics and typicality updates would behave very differently. The prediction is established in the sense that no-cloning is built into the experimentally validated structure of the theory.

If quantum phenomena reflect multi-history structure, another natural question is whether physical law itself fits inside the universality class of computation. This motivates the computability theme.

5.4 Computability of laws

Physics is often written using real numbers and continua, which can suggest infinite information and, in principle, uncomputable behavior. If the world required essential hypercomputation in finitely realizable systems, “all computations” would not be a good foundation. [39, 40]

A common reply is that finite physics is limited by finite information density and finite signal speed, so universal computation should suffice to simulate any finitely realizable physical process to any desired precision. If that is right, many computational formalisms (Turing machines, lambda calculus, cellular automata, rewrite systems, and so on) are interchangeable at the level of what they can represent, and ACE can be stated in many equivalent ways. [41, 42]

Representative predictions

P017 (Established). We should expect that different computational bases converge to equivalent ruliad structure (via computational equivalence). [43] This is the standard robustness result: many models of computation are equivalent in power. In the present context it matters because it reduces ontology-dependence: an "all computations" ensemble defined over one universal model is, up to constants, equivalent to an ensemble defined over another. That supports the paper's strategy of treating different authors' formalisms as variations on a shared core.

P095 (Accepted). Every finitely realizable physical process should be perfectly simulable by a universal computer using finite resources (up to any desired precision). [39, 40, 44, 41, 42] This captures the physical Church–Turing–Deutsch style claim. It is not a triviality: it asserts that there are no physically realizable finite devices that compute functions beyond universal computation. The current evidence is indirect (no known counterexamples; physical constraints like finite speed and finite entropy bounds are consistent with it), but a single credible demonstration of finite-resource hypercomputation would be decisive.

P050 (Established). There exist fixed polynomial equations with whole numbers such that, by changing a parameter, the equation can represent any computable, listable set. This shows that universal computation can be encoded inside basic number theory. [45, 46] Universal Diophantine representation is a mathematical bridge: it shows how arithmetic can encode the entire class of recursively enumerable computations. This is relevant because it supports "arithmetical realism" programs that claim computation follows from number theory alone, without additional physical postulates.

If the underlying substrate is computable and possibly discrete, we still need to explain why internal observers often model the world using smooth continua. That motivates the discrete-to-continuum theme.

5.5 Discrete and continuous

Much of classical physics is written in the language of smooth continua. A discrete computational substrate can therefore look, at first glance, like a poor match.

The usual response is that observers have finite resolution and access only to coarse-grained summaries. Many discrete systems show "universality": at large scales the behavior becomes insensitive to micro-details, and continuous-looking effective laws can emerge as approximations. On this view, the continuum is an effective description, not necessarily the base layer.

Representative predictions

P036 (Accepted). Even if the underlying world has discrete states, it can still look continuous from the inside, because many discrete steps can approximate smooth change, and because observers may sample across many closely related variants. [47, 19, 48, 26] This is the general claim of continuum emergence: discrete microdynamics can yield smooth effective behavior. Evidence comes from effective field theory, lattice models, and the success of numerical simulation in approximating continuous dynamics.

P065 (Accepted). We should expect that physical processes can be modeled as computations over a discrete substrate (calculating space), anticipating cellular-automaton universe proposals. [48] Deutsch's point is that internal observers in discrete systems can still experience apparent continua, because their measurements and records are finite and because stable large-scale regularities can exist even in discrete substrates. The important open problem is to recover the specific symmetries we observe (especially Lorentz invariance) without fine tuning.

Once we accept that effective laws can emerge for internal observers, we can ask which effective laws and parameter ranges are compatible with observers at all. That leads naturally to fine-tuning.

5.6 Fine-tuning

Many physical parameters appear to lie in narrow ranges that allow long-lived stars, stable chemistry, and complex structure. Without selection effects, it is unclear why we should expect those values rather than the vastly larger range of values that seem sterile. [49]

In an ensemble, the theory does not predict one fixed value for each constant. Instead it predicts that typical observers will find themselves in regions of parameter space that support observers—and, under a simplicity-weighted measure, possibly near the simplest such regions. The hard part is to turn this into quantitative, discriminating predictions rather than post hoc compatibility arguments. [22]

Representative predictions

P058 (Accepted). We should expect that relatively small changes in some constants/parameters can block stages from big bang → atoms → stars → planets → biospheres → intelligence. [49] This is the general anthropic-selection prediction: constants observed by observers will be biased toward observer-compatible ranges. Evidence is mixed because the width of life-permitting ranges is debated and because different multiverse measures yield different expectations.

P061 (Accepted). We should expect that matter-antimatter imbalance (~1 in 3 billion) is required; without it, annihilation leaves only radiation (no atoms/galaxies/life). [49] The matter–antimatter asymmetry is an empirically established fact and is plausibly necessary for the existence of stable matter. Ensemble reasoning treats it as part of the observer-conditioning filter; the hard part is to predict its magnitude rather than merely its sign.

P094 (Plausible). Among all universes (or computations) that can produce observers, we should typically find ourselves in one with the *least* information content (shortest description) consistent with our existence. [22, 35] This is the stronger "near-minimal complexity" version of fine-tuning. It says not only that parameters must allow observers, but that typical observers should see laws and parameters that are as simple as possible while still allowing observers.

Fine-tuning concerns parameter values. Cosmology adds another layer: the large-scale history must also produce stable structures and records. That brings us to cosmology and initial conditions.

5.7 Cosmology

Modern cosmology describes a universe with a hot Big Bang origin and a long period of structure formation. Historically, even the idea of a finite-age universe was controversial, and the discovery and interpretation of the cosmic microwave background pushed the field decisively away from steady-state models. [50, 51, 52]

Ensemble approaches typically predict that observers will see early conditions that support stable records and long stretches of lawful evolution. In computational terms, the claim is that typical observer-containing histories are biased toward relatively simple effective initial conditions and toward long periods of compressible lawfulness that allow information to accumulate. [29, 22]

Representative predictions

P063 (Accepted). If dark energy had dominated much earlier than it did, galaxies would not have formed. So the observed timing of cosmic acceleration must fall in a range compatible with galaxy formation. [49] This is the claim that dark-energy-like acceleration cannot dominate too early, or galaxies and long-lived structures would not form. The evidence is that we do see galaxies and a long matter-dominated era; tighter tests come from precision constraints on the expansion history.

P064 (Accepted). We should expect many regions with different effective laws, produced by mechanisms like inflation or a large "landscape" of possible low-energy rules. [49] This entry captures the landscape/eternal-inflation style picture. It remains debated because evidence for inflation is indirect and evidence for eternal inflation is even less direct. The relevant question for ACE is whether measure choices plus observer-conditioning yield distinctive, testable predictions.

P066 (Observed). Typical observers should expect an external world with simple, computable laws and an apparent early-time origin (like a Big Bang) rather than an infinitely old, maximally irregular past. [29] This is a broad constraint tying together three facts: (i) a Big Bang-like origin, (ii) simple, stable laws, and (iii) probabilistic prediction structure. The key to moving beyond compatibility is to extract quantitative predictions—e.g., distributions for cosmological parameters—under a clearly specified measure.

Some cosmological frameworks make observer-conditioning explicit: probabilities are computed for histories consistent with what is observed now. That is the focus of the next theme.

5.8 Observer-conditioned histories

In everyday thinking, the past is fixed and the present is the result of that past. In some Big World cosmologies, probabilities are instead computed by conditioning on present observations, so the set of relevant past histories depends on what is observed.

This lines up with the observer-first stance in many computational ensemble theories: start from the observer's data and sum over compatible histories. On this view, the "history of the universe" is not one observer-independent narrative but a weighted family of histories selected by conditioning. The empirical question is whether any such conditioning rule yields predictions that differ from competing cosmological measures. [53, 54]

Representative predictions

P086 (Plausible). Cosmology may need to be "conditioned" on what we observe now: the set of past histories that matter can depend on the question asked, rather than there being a single observer-independent past. [53, 55] Hawking and Hertog provide a concrete implementation of top-down conditioning in a no-boundary setting. The framework is clear; the difficulty is extracting robust discriminators that do not depend sensitively on modeling choices.

P091 (Plausible). Under the no-boundary/top-down weighting, histories that look like a patchwork from eternal inflation should have very low weight, so we should not expect to live in a universe dominated by such mosaic structure. [53] This entry summarizes a general concern: once conditioning is allowed, patchwork histories can contribute, and one must show that the resulting measure does not become dominated by strange, contrived histories. This is the cosmological analogue of the "white rabbit" (a sudden, law-violating miracle event) problem.

The logic of simplicity-weighted conditioning is not unique to cosmology; it also appears in formal theories of learning and decision-making. Those theories provide a pragmatic bridge from "all computations" to successful prediction.

5.9 Induction and decision-making

Induction is the problem of guessing rules from past data so that we can make good predictions about future data. It is not obvious that any single method should work in general, yet science and everyday learning often do. Universal induction shows, in an idealized form, that if the environment is computable then a simplicity-weighted mixture over programs can converge toward optimal prediction. This matters here because it shows that algorithmic priors are not just aesthetic: they are the right kind of prior for learning in computable worlds. [33, 34]

Representative predictions

P020 (Plausible). Prediction methods based on Solomonoff-style induction should converge toward the true data-generating process whenever that process is computable. As evidence accumulates, observers should therefore agree more and more on stable external regularities, and short explanations should continue to outperform ad hoc ones. [33, 34]

P040 (Proposed). Universal induction implies an idealized agent called AIXI that is (in a formal sense) optimal for any computable environment. [34] AIXI is not computable, but it defines an ideal benchmark that links universal priors to rational action. Its main value here is conceptual: it shows how observer-like agents embedded in a computable world would be expected to use algorithmic priors if they were Bayes-optimal.

Finally, if observers inhabit effective spacetimes with stable laws, we should understand why those laws exhibit the symmetry structure they do. This leads to the spacetime and symmetry theme.

5.10 Spacetime and symmetry

Relativity puts symmetry principles at the center of physics: the laws look the same under translations, rotations, and changes of inertial frame. From a computational point of view, such symmetries are not guaranteed; they are strong constraints on the underlying rule-set. [56]

Computational approaches often treat observed symmetries as invariances in the effective description available to embedded observers. The challenge is to explain why typical observers see symmetries that are so clean and so wide-ranging even if the underlying substrate is discrete or rule-dependent.

Representative predictions

P009 (Observed). At large scales, the effective laws we observe should not depend on arbitrary choices like the order we update a model or the coordinates we use. This can show up as relativity-like symmetry (general covariance). [25, 26] This prediction records the empirical fact that these symmetries hold to high precision. For ACE-style programs, the task is explanatory: to show why symmetry-breaking micro-details are typically invisible at the observer scale, or why the measure favors rule-sets whose effective laws exhibit symmetry.

Taken together, these themes show how the "all computations exist" program attempts to turn what look like brute facts—lawfulness, quantum structure, computability, and cosmological history—into typicality-weighted expectations. The next section evaluates how much support this provides and where the sharpest open problems remain.

6 Analysis

This section gives a *conservative* Bayesian "scorecard" showing how the evidence shifts the odds of ACE versus its negation. The goal is *not* to claim a definitive probability from Table 3. Rather, the goal is to (i) make assumptions explicit, (ii) avoid double counting, and (iii) highlight which empirical pressure points would most strongly move the posterior odds if they became sharper and more discriminating.

6.1 Hypotheses

We compare two coarse-grained hypotheses:

- **H1 (ACE):** all computations exist. Concretely, we can index "every possible program" by a bit string (or integer) and imagine that every such description is executed an equal number of times.[1]
- **H0 (Not ACE):** everything else. This includes "small world" views (one universe with one set of dynamical laws), as well as non-ACE ensembles and/or non-algorithmic ways of selecting typical observations.

H0 is intentionally broad. We do *not* try to defend any particular alternative here; the paper's focus is H1. The cost of this choice is that H0 absorbs many explanations, which forces us to be cautious: only evidence that clearly favors H1 over a wide range of alternatives should count.

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[1] A key point—important for interpreting the rest of this paper—is that this already induces an algorithmic-information-style simplicity bias, without adding any special weighting by hand. Many different bit strings correspond to the *same effective computation* because only a finite prefix of the tape is ever read. If a computation's behavior is fully determined by an N-bit prefix p, then among all length-L strings there are 2^{L-N} extensions of p out of 2^L strings total, giving an induced weight 2^{-N} for that behavioral class (independent of L). Summing these $2^{-|p|}$ contributions over all prefixes that yield a given observation recovers the standard Solomonoff–Levin form of algorithmic probability (up to machine-dependent constants) [33, 34]. In this sense, the "AIT weighting" is not an extra axiom but a consequence of ACE plus the fact that unused suffix bits are behaviorally irrelevant.

6.2 Evidence selection rule

Although Table 3 contains **98** entries, most are not suitable for Bayes factors: many are background principles shared by almost any scientific worldview, and many are correlated. To reduce bias, we apply three conservative rules:

(a) **Discriminating:** we include only evidence that plausibly has different likelihood under H1 vs H0.

(b) **Conservative:** when uncertain, we choose the lower bound for the Bayes factor.

(c) **De-correlated:** we aggregate by themes (roughly the Atlas subsections) and apply a dependence weight $w \in (0, 1]$ to downweight overlapping assumptions.

6.3 A conservative Bayes-factor table

Let E_i denote a small set of theme-level observations. For each E_i we assign a conservative Bayes factor range $BF_i = P(E_i \mid H1)/P(E_i \mid H0)$, along with a dependence weight w_i. We then combine them in log-odds form:

$$\log O(H1 \mid E) \;=\; \log O(H1) \;+\; \sum_i w_i \log BF_i.$$

ID	Evidence E_i (theme-level)	Conservative BF_i range	w_i
E1	Big World theories require a typicality rule to yield observational consequences (some observations must be more typical than others). [17]	1.5–3	0.6
E2	Our world exhibits stable, compact (compressible) laws across many contexts; simplicity appears unusually successful. [22, 8, 31]	1.2–4	0.5
E3	Simplicity methods (Occam/MDL/compression) improve prediction in practice; universal induction formalizes why simplicity priors can succeed. [33, 34]	1.1–3	0.5
E4	Quantum phenomena are strongly non-classical and probabilistic (Born rule, interference, Bell violations). [26]	1–3	0.4
E5	Computability of finite physical processes remains viable (no known finite hypercomputers; finite-speed and finite-information constraints are consistent with physics). [39, 40]	1–2	0.4
E6	Observer-conditioning is treated seriously in cosmology (top-down/no-boundary frameworks exist). [53]	1–1.5	0.3

Combined evidence multiplier. Using the dependence-weighted combination above, these six items yield a total Bayes-factor multiplier of approximately:

$$BF_{\text{total}} \approx \begin{cases} 1.47 & \text{(conservative: all lower bounds)} \\ 4.76 & \text{(middle: geometric means)} \\ 15.49 & \text{(optimistic: all upper bounds).} \end{cases}$$

These numbers are *deliberately modest* because (i) we excluded ambiguous evidence, and (ii) we discounted dependence across themes.

6.4 Posterior under an agnostic prior

For simplicity, we report posteriors under an *agnostic* prior: $O(H1) = 1$ (50:50 odds for ACE vs Not-ACE before considering evidence). Under this choice, posterior odds are just the total Bayes factor: $O(H1 \mid E) = BF_{\text{total}}$.

Scenario	Posterior odds $O(H1 \mid E)$	Posterior probability $P(H1 \mid E)$
Conservative	1.47	0.595
Middle	4.76	0.826
Optimistic	15.49	0.939

Table 2: Posterior odds and probabilities for ACE under an agnostic prior, using the three Bayes-factor scenarios defined above.

6.5 Interpretation

This Bayesian scorecard should be read as a *map of leverage.* The numbers above assume an agnostic prior and conservative dependence discounts. It says: given conservative choices and strong dependence discounts, the current evidence provides at most modest multiplicative support for H1 over a broad H0. At the same time, it identifies clear opportunities for stronger evidence: sharper, model-discriminating predictions in quantum foundations, cosmology (measure and conditioning), and any genuinely surprising quantitative constraints on constants or law structure would increase the Bayes factors substantially.

In short, the "all computations exist" program already has many points of contact with observation, but a decisive Bayesian case will require fewer, sharper, and more discriminating predictions than most entries in Table 3 currently provide.

7 Discussion

This paper started with a simple claim: *all computations exist.* We then asked a practical question: if that were true, what should observers like us expect to see? The literature suggests a rich answer: many familiar features of our world—and many constraints a world like ours must satisfy—can be traced back to ACE plus an observer-weighted notion of typicality.

7.1 What the survey shows at a glance

The most concrete result of this review is Table 3: a list of **98** distinct predictions or constraints that appear across the literature. The table includes both (i) direct empirical claims ("we should observe X") and (ii) structural constraints that must hold if Big World theories are to have any observational consequences at all (for example, that some observation types must be more typical than others).

A simple but telling pattern is the status distribution. A nontrivial share of the items are already **Observed**, **Established**, or **Accepted** in mainstream science, and **none** are currently marked **Disfavored**. This is not a proof of the underlying assumption. Some entries are broad background principles, and many observed facts admit multiple explanations. But it is encouraging that a large collection of consequences drawn from "all computations" programs are compatible with what we already see, and in many cases line up with the best-tested parts of modern physics.

7.2 What is most surprising (and why it matters)

Several themes stand out as especially striking because they run against what one might naively expect from a plenitude.

Simplicity. If "everything exists", then there are vastly more complicated laws than simple ones, and vastly more ways for apparent lawfulness to break down than to hold. This is why Parfit, Carroll, and Vilenkin all emphasize that simplicity is not automatic in an ensemble picture [8, 31, 57]. The computational-ensemble program tries to turn this into a prediction: under algorithmic priors and observer weighting, simpler regularities can be *typical* rather than rare. Standish's "least information content compatible with observers" claim (P094) is an especially strong version of this idea [22].

Quantum structure. Quantum mechanics is famously counterintuitive, and yet it is among the best-tested frameworks in science. Several lines in the literature argue that key quantum constraints can be understood as what typical observers should expect in a branching or multi-history computational ensemble, where first-person uncertainty plays a central role. Even if one does not accept any particular derivation, the fact that these approaches repeatedly connect "many computations" with quantum-like constraints is a major empirical target for the overall program.

Observer-conditioned histories. Hawking–Hertog top-down cosmology and Wheeler-style "participatory" views make explicit what is usually only implicit: probabilities can depend on what is observed [53, 58]. This resonates strongly with algorithmic idealism and related approaches that start from the observer-state and reason outward. The point is not that the past literally "changes", but that in a Big World one must specify which histories are *relevant and weighted* given the observer's data.

Computability. A computational ontology risks being empty if physics requires uncomputable ingredients. Deutsch's physical Church–Turing principle, Gandy-style physical constraints, and related arguments aim to justify the opposite: that any finitely realizable physical process is simulable by universal computation (P095) [39, 40]. If correct, this places computation and physical law into the same universality class and supports treating "all computations" as a candidate foundation for physics.

7.3 How much of this supports the core assumption?

It is useful to separate three questions.

(1) Is the Big World move necessary? Some topics (anthropic selection, fine-tuning, measure problems) are hard to even formulate without an ensemble. In that sense, the Big World move is already embedded in parts of modern cosmology and quantum foundations.

(2) Does "all computations exist" add explanatory power beyond other ensembles? Many ensembles exist in the literature: landscapes of effective laws, many-worlds quantum branching, mathematical realism, and the Ruliad [38, 19]. What distinguishes the computational ensemble is the attempt to put a *universal, simplicity-biased measure* on possibilities (via algorithmic information theory), and then to connect that measure to observer-moments. That is where many of the sharper predictions come from (e.g., simplicity, anti–white-rabbit constraints, and claims about the typical form of laws).

(3) Are the observed successes discriminating? Some "successes" are too generic to be strong evidence: for instance, that our world contains regularities, or that science works, are facts that many philosophies can accommodate. The most probative successes are those where the computational ensemble yields a *nontrivial quantitative constraint* or resolves a tension that is otherwise puzzling. Examples include: sharp typicality arguments in Big Worlds [17], specific algorithmic claims about simplicity bias [28, 22], and any clean derivation of quantum constraints from observer self-location assumptions.

7.4 Open problems and future directions

The literature reviewed here is energetic but not finished. Several issues recur across authors and will likely determine whether this program becomes a mature empirical framework:

- **Make the measure precise.** Many proposals depend on how we weight computations and observer-moments. Turning that into a robust, non-ad-hoc measure (and showing it avoids pathologies) is central.
- **Define observer-states carefully.** Several approaches begin from "the observer" but differ on what counts as the relevant state (raw bitstrings, knowledge states, or functional/causal organization). These choices may affect predictions.
- **Derive more specific physics.** The next benchmark is not merely reproducing existing qualitative facts, but constraining more detailed structure: constants, dimensionality, particle content, and cosmological initial conditions.
- **Seek discriminating tests.** The best evidence would be cases where this framework predicts something *different* from competing explanations, not merely something compatible with them.
- **Connect to computation in practice.** Universal induction and compression already work as tools. A promising direction is to ask whether the same algorithmic biases that make prediction work can be shown to also govern the typical form of physical laws [33, 34].

A number of popular expositions highlight a complementary point: the program earns its keep only if it continues to generate discriminating, surprising predictions rather than merely accommodating what we already know. This provides a useful "north star" for future work, and a reminder that measure choices must ultimately be judged by their predictive power. [59]

7.5 Closing perspective

At the start of this paper we quoted Wilczek's suggestion that, over the next century, "the laws of physics" may be reinterpreted as statements about information and its transformations [1]. The research surveyed here can be read as a concrete attempt to push in that direction: to treat computation and information not as tools for describing physics, but as candidates for what physics *is* at the deepest level.

8 Conclusion

Across philosophy, computer science, and physics, many authors have argued that reality may be an ensemble of possibilities. This review focused on a particularly strong version: *the set of all computations*. We found that this single assumption, combined with observer-weighted typicality and algorithmic information theory, has been used to derive many empirical and structural consequences. We distilled **98** distinct predictions or constraints from the literature, many of which align with well-established features of our world, including the existence of stable laws, the success of simplicity-based inference, quantum phenomena, and observer-conditioned reasoning in cosmology.

The agenda is not complete. The hard work ahead is to sharpen the measure, formalize observer-states, and find new predictions that clearly discriminate this framework from rival explanations. But the overall picture is suggestive: the same idea that initially seems to explain "everything" can, in fact, explain *something in particular*—and make contact with observation—once we take seriously the question of which observations are typical in a Big World.

If future work upgrades more of today's plausible or proposed items into the observed or established categories, and especially if it yields unexpected, specific predictions that later check out, that would be accumulating evidence for the deeper claim that "all computations exist".

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Appendix

A Full list of predictions

This appendix contains the complete consolidated list of **98** predictions and constraints. Status labels are defined in Section 4.

Table 3: List of predictions and constraints from the literature.

ID	Prediction or constraint	Status	Sources
P001	When there are multiple copies of you (or multiple possible future continuations of your experience), a correct theory should still tell you the odds of what you will experience next. Any theory that cannot assign clear odds is missing something important.	Proposed	[20]
P002	Small microscopic changes should not usually change what you experience. Your experience should depend on the big-picture pattern (the information you can notice), not every atomic detail.	Accepted	[20]
P003	We should usually observe stable, simple regularities that can be summarized as "laws", rather than constant chaos. In an all-computations picture, that means typical observers should land in worlds with compressible patterns.	Accepted	[20]
P004	We should expect that deterministic duplication implies unavoidable first-person self-location uncertainty; its quantification is invariant under reconstitution delays, spatial translation, and (at the substitution level) whether the implementation is physical, simulated, or arithmetical.	Plausible	[21, 36, 23]
P005	It should be impossible to make a perfect copy of an unknown quantum state. Any attempt to copy it must introduce noise or disturbance.	Established	[21]
P006	We should almost never see wild, law-breaking events that come out of nowhere. A workable "all computations" theory must make such bizarre outcomes extremely rare for typical observers.	Observed	[21, 22, 23, 24]
P007	Very contrived "explanations" should tend to cancel out rather than add up, making bizarre outcomes rare.	Proposed	[23]
P008	Some yes/no questions about the world should be incompatible: you cannot get definite answers to both at the same time, and measuring one can spoil information about the other.	Established	[21, 23]
P009	At large scales, the effective laws we observe should not depend on arbitrary choices like the order we update a model or the coordinates we use. This can show up as relativity-like symmetry (general covariance).	Observed	[25, 26]
P010	When we repeat the same quantum measurement many times, the long-run outcome frequencies should follow the usual quantum probability rule (outcomes with larger wave strength happen more often).	Observed	[25, 26]
P011	Quantum behavior should look like a combination of many alternative histories: different possible paths can add together or cancel out (interfere).	Observed	[25, 26]
P012	The set of possible quantum states should behave like the standard quantum-state space: states act like "directions" in a high-dimensional space, and probabilities depend on how aligned those directions are.	Observed	[25]
P013	Experiments that test Bell inequalities should show the same non-classical correlations that standard quantum mechanics predicts, even if the underlying model is deterministic.	Observed	[25, 26]
P014	Some tasks should be much faster on a quantum computer than on any classical computer (a real quantum speedup).	Observed	[27]
P015	We should expect that ruliad is the entangled limit of applying all possible computational rules (all initial conditions, infinite steps).	Proposed	[43]
P016	We should expect that bounded observers sample tiny parts; coherent observers see robust regularities (effective laws).	Observed	[43]

(continued)

ID	Prediction or constraint	Status	Sources
P017	We should expect that different computational bases converge to equivalent ruliad structure (via computational equivalence).	Established	[43]
P018	We should expect that agent-moments are abstract self states; external-world embedding is not fundamental.	Plausible	[29]
P019	We should expect that transition chances between self states are governed by a universal method of induction.	Plausible	[29]
P020	Universal induction with a simplicity prior (algorithmic probability) gives a correct way to predict any computable process from data; in practice, methods that favor shorter explanations should generalize better than methods that do not.	Plausible	[29]
P021	We should not expect to be random "freak" observers (like a brain that briefly fluctuates out of chaos). Instead, we should typically see a coherent world with a consistent past.	Plausible	[29]
P022	We should expect that conscious self states exist as mathematical structures independent of physical actualization.	Plausible	[29]
P023	We should usually see simple, compressible patterns and simple-looking laws, not overwhelmingly complicated or ad-hoc ones.	Accepted	[22, 28, 19, 18]
P024	When we compare different explanations for the same data, the ones with shorter descriptions should get much higher weight (roughly exponentially higher).	Accepted	[22, 28]
P025	Quantum states should evolve in a linear, probability-preserving way between measurements (the standard unitary evolution of quantum mechanics).	Observed	[22]
P026	We should expect that for stable induction, each connected component of $O^{-1}(s)$ must be dense (nonzero weighting rule), ensuring robustness under don't care perturbations.	Plausible	[22]
P027	We should expect that the relevant TOE prior is assumed formally describable; this imposes a strong inductive bias over possible universe histories.	Plausible	[28]
P028	Any workable way of weighting "all computations" should heavily favor worlds that have short, simple generating rules, and give extremely little weight to worlds that can only be generated by very long or ad-hoc rules.	Proposed	[28]
P029	Among models that fit the past, those that can generate the data quickly should be favored over those that require huge computation.	Proposed	[28]
P030	We should expect that given long observations, likely continuations are those with minimal Levin complexity ; with probability 1 the continuation of is computable within $O(2^{K_t(x_n)})$.	Plausible	[28]
P031	We should expect that under the speed prior S, the probability that the universe lasts 2^n times longer than it has so far is at most 2^{-n}.	Plausible	[28]
P032	True, irreducible randomness should not be fundamental. What looks random should come from not knowing which copy/branch of an observer one will become, or from self-location uncertainty in a large ensemble.	Plausible	[19, 28, 26]
P033	We should expect that observer-compatible worlds should cluster near a narrow regime between frozen uniformity and chaotic boil where complex persistent structures can form (edge of chaos).	Proposed	[24]
P034	We should expect that we should observe constants just right for our functioning and long-term law stability enabling evolution and memory accumulation.	Proposed	[24]

(continued)

ID	Prediction or constraint	Status	Sources
P035	If an engineered mind could be built so that it keeps working after large changes to the surrounding physical constants, then deliberately tuning those constants could move the observer into a different set of physical laws within the larger ensemble.	Testable	[24]
P036	Even if the underlying world has discrete states, it can still look continuous from the inside, because many discrete steps can approximate smooth change, and because observers may sample across many closely related variants.	Accepted	[47, 19, 48, 26]
P037	We should expect that combining Solomonoff induction with sequential decision theory yields a parameterless universal AI (AIXI/AIXI).	Proposed	[34]
P038	A universal mixture predictor (Solomonoff-style) should converge toward the true data-generating process whenever that process is computable; this explains, in principle, why general prediction and science can work.	Testable	[34]
P039	We should expect that universal induction can be generalized to general agent-environment interaction by extending xi to conditional settings and replacing mu by xi in the rational agent model.	Proposed	[34]
P040	Universal induction implies an idealized agent called AIXI that is (in a formal sense) optimal for any computable environment; this suggests that a single simplicity-weighted prior can ground learning and decision-making without domain-specific tuning.	Proposed	[34]
P041	Among models that fit the past, those that can generate the data quickly should be favored over those that require huge computation.	Proposed	[34]
P042	If minds are computations, then (in this research program) our belief in physical laws should be derivable from arithmetic and computation alone, without assuming a particular physical world up front.	Proposed	[36]
P043	We should expect that correct 1P prediction requires accounting for possible re-instantiations of one's current computational state elsewhere; otherwise predictions are underdetermined.	Plausible	[36]
P044	We should expect that physical activity is not what experiences supervene on; replace physical supervenience with computationalist supervenience: experiences track abstract a-temporal computations (and many different underlying details of them).	Plausible	[36]
P045	We should expect that digital physics is contradictory: it implies comp, but comp implies its negation; therefore digital physics implies its own negation.	Plausible	[36]
P046	To recover full physical reality and full conscious experience from computation, we may need the "infinite limit" of running all possible programs, not just any single finite simulation.	Proposed	[36]
P047	We should expect that if the idea that minds are computations is taken seriously enough, the Schrödinger equation should be derivable from a computationalist theory of consciousness; physics becomes a branch of machine psychology.	Plausible	[23, 26]
P048	Your future experiences should be predicted by looking at all the ways a computation could consistently continue, with simple continuations weighted more heavily than complicated ones.	Proposed	[23]
P049	We should expect that phenomenological uncertainty and nonlocality can be interpreted as empirical hints/confirmation of comp (given right weighting rule suppressing aberrant continuations).	Plausible	[23]

(continued)

ID	Prediction or constraint	Status	Sources
P050	There exist fixed polynomial equations with whole numbers such that, by changing a parameter, the equation can represent any computable, listable set. This shows that universal computation can be encoded inside basic number theory.	Established	[45, 46]
P051	The same kind of universal polynomial system can encode many familiar mathematical patterns (like primes and Fibonacci numbers), not just abstract sets. This supports the claim that arithmetic can contain rich "world-like" structure.	Established	[45]
P052	We should expect that if external reality is independent of human baggage, a complete TOE must be expressible without baggage; with broad mathematics this implies physical reality is a mathematical structure (MUH).	Plausible	[19]
P053	We should expect that physical symmetries correspond to automorphisms of the underlying mathematical structure; inside observers cannot distinguish symmetry-related states.	Plausible	[19]
P054	Only computable structures should count as "real" in the ensemble: the defining rules should be runnable and guaranteed to finish, not depend on uncomputable relations.	Proposed	[19]
P055	Some mathematical questions cannot be decided by any computer program that always finishes (they are undecidable). This motivates restricting "what counts as real" to structures with computable, well-defined rules.	Proposed	[19]
P056	If the underlying rules of physics must be computable and finitely describable, then fundamental constants cannot be arbitrary real numbers with infinite information. They must either be finitely specifiable numbers, or else vary across an ensemble so we can talk about a distribution.	Proposed	[19]
P057	We should expect that quantities with units are not real numbers in the structure; only dimensionless ratios correspond to reals; quantities-with-units modeled as 1D vector spaces over reals.	Plausible	[19]
P058	We should expect that relatively small changes in some constants/parameters can block stages from big bang → atoms → stars → planets → biospheres → intelligence.	Accepted	[49]
P059	We should expect that some parameters may be random variables taking different values across a huge ensemble (multiverse), shifting explanation toward weighting rule/selection.	Accepted	[49]
P060	We should expect that many orders of magnitude between micro and cosmic scales (needed for interesting complexity) requires gravity to be very weak.	Accepted	[49]
P061	We should expect that matter-antimatter imbalance (~1 in 3 billion) is required; without it, annihilation leaves only radiation (no atoms/galaxies/life).	Accepted	[49]
P062	We should expect that $Q \approx 10^{-5}$ has no firm theoretical explanation; varying Q alters structure formation and observer access to large-scale averages (high-Q "mountain landscape" vs low-Q no structure).	Accepted	[49]
P063	If dark energy had dominated much earlier than it did, galaxies would not have formed. So the observed timing of cosmic acceleration must fall in a range compatible with galaxy formation.	Accepted	[49]
P064	We should expect many regions with different effective laws, produced by mechanisms like inflation or a large "landscape" of possible low-energy rules.	Accepted	[49]
P065	We should expect that physical processes can be modeled as computations over a discrete substrate (calculating space), anticipating cellular-automaton universe proposals.	Accepted	[48]

(continued)

ID	Prediction or constraint	Status	Sources
P066	Typical observers should expect an external world with simple, computable laws and an apparent early-time origin (like a Big Bang) rather than an infinitely old, maximally irregular past.	Observed	[29]
P067	We should expect that predictions should be invariant under computable, prefix-preserving re-encodings of states of experience.	Plausible	[29]
P068	We should expect that in extreme cases, another agent's third-person trajectory can fail to track that agent's first-person continuation (probabilistic zombie), suggested when an agent's state history is too simple relative to laws + locator complexity.	Plausible	[29]
P069	We should expect that branches in which an observer dies with high third-person probability can be irrelevant for the corresponding first-person continuation.	Plausible	[29, 26]
P070	We should expect that closed simulations can be ethically inert (either zombie or mathematical-existence case); open simulations create causal responsibility (mind crime).	Proposed	
P071	If many-worlds quantum theory is right, then erasing or resetting memory can change which branch you find yourself in, altering first-person odds for future experiences.	Proposed	[29]
P072	If many-worlds quantum theory is right, then erasing or resetting memory can change which branch you find yourself in, altering first-person odds for future experiences.	Proposed	[37]
P073	If we could perfectly undo a measurement (erase all records and restore the system), then some interpretations predict the original state would be restored with certainty, while collapse interpretations predict extra randomness.	Testable	[37, 26]
P074	If some branches of experience include a "reset" back to the same memory state, then conditioning on being in a reset branch can change the odds of bad outcomes. In particular, if resets are common, the chance of disaster given that you reset can be much lower than the raw disaster rate.	Proposed	[37, 26]
P075	We should expect that if nothing can be done, testing for impending disaster can trap you in wrong sector; in many-worlds there is no benefit to test in such cases.	Plausible	[37]
P076	If many-worlds quantum theory is right, then erasing or resetting memory can change which branch you find yourself in, altering first-person odds for future experiences.	Proposed	[37]
P077	We should not expect to derive the exact values of some physical constants from first principles; instead, we should predict distributions of possible values and then condition on the existence of observers.	Plausible	[18]
P078	After accounting for the fact that observers can only exist in some parameter ranges, the constants we weighting rule should look fairly typical within that allowed range (not pushed to an extreme without reason).	Proposed	[18]
P079	Different ways of counting possibilities in an infinite ensemble can change predicted frequencies. Any theory must state a clear, justified weighting rule, or its predictions are ambiguous.	Established	[18, 17]
P080	If we assume (as an extra testable hypothesis) that some constants are drawn from a roughly flat distribution before conditioning on observers, then our constants should pass statistical tests of being a typical draw from that conditioned distribution.	Established	[18]
P081	In a big enough universe (or ensemble), every possible kind of human observation will happen somewhere.	Established	[17]

(continued)

ID	Prediction or constraint	Status	Sources
P082	Just knowing that some observation happens somewhere is not useful evidence in a Big World, because that is almost always true. What matters is what we observe from our point of view.	Proposed	[17]
P083	To make predictions in a Big World, we need a rule that connects "what fraction of observers see X" to "how likely we are to see X". One common rule is to treat ourselves as a random sample from a chosen class of observers.	Established	[17]
P084	In Big World reasoning, if theory T1 makes our kind of observation much more typical than theory T2, then after conditioning on our observation we should favor T1 over T2.	Established	[17]
P085	We should expect that even if all observations occur, observers with wildly misleading observations can be neglected if they are a tiny minority in the reference class.	Established	[17]
P086	Cosmology may need to be "conditioned" on what we observe now: the set of past histories that matter can depend on the question asked, rather than there being a single observer-independent past.	Plausible	[53, 55]
P087	We should expect that euclidean geometries can connect initial and final surfaces in disconnected universes; thus late-time state can be independent of initial surface, motivating no-boundary state with only final boundary.	Plausible	[53]
P088	In a landscape of many possible low-energy laws, only a small subset should have significant weight (be commonly realized for observers).	Plausible	[53]
P089	Different proposals for the universe's quantum state should predict different shapes for the primordial fluctuation spectrum, which we can compare to cosmic microwave background and large-scale structure data.	Plausible	[53]
P090	Only "broad" regions of the landscape (where small changes do not immediately ruin the solution) should contribute much to what observers see.	Plausible	[53]
P091	Under the no-boundary/top-down weighting, histories that look like a patchwork from eternal inflation should have very low weight, so we should not expect to live in a universe dominated by such mosaic structure.	Plausible	[53]
P092	We should expect that some superpositions (for example, different charge) should not be observable as stable macroscopic superpositions because the environment interacts with the components too differently, effectively enforcing a superselection rule.	Accepted	[26]
P093	Seeing symmetry breaking in our observed branch does not necessarily mean the underlying laws or global state break the symmetry; it may mean we are in one symmetry-breaking component.	Proposed	[26]
P094	Among all universes (or computations) that can produce observers, we should typically find ourselves in one with the *least* information content (shortest description) consistent with our existence.	Plausible	[22, 35]
P095	Every finitely realizable physical process should be perfectly simulable by a universal computer using finite resources (up to any desired precision).	Accepted	[39, 40, 44, 41, 42]
P096	Changing an observer's state (memory, body, or interpretive "point of view") can change which histories and effective laws are compatible with producing that observer; in this sense, different observer-states select different "worlds" within the same underlying ensemble.	Speculative	[37, 24, 38]
P097	Observers need an ordering of distinguishable states (an experienced "before/after") to register differences and therefore to have information; thus any observer-containing world should exhibit an effective time (or time-like ordering) and stable records.	Accepted	[29, 30]

(continued)

ID	Prediction or constraint	Status	Sources
P098	The universe's effective initial conditions should be describable by a very short specification (low algorithmic complexity) rather than arbitrary complexity; typical observers should therefore see simple, highly regular early-universe conditions.	Plausible	[29, 22]

B Formal framework and definitions

This appendix collects a few technical definitions and background claims that are used throughout the paper but would interrupt the narrative flow if repeated in the main text.

B.1 Ensemble postulate

Let Π denote an ensemble broad enough to represent *all computations* (e.g., all programs for a universal machine; all rewrite rules with all update orderings; or all mathematical structures that define algorithms). The main text treats the physics we observe as an effective description of a typical observer's local neighborhood in Π.

B.2 Observer-conditioning and self-location

A related structural constraint appears in the literature as a "time postulate": to register information, an observer must be able to compare distinguishable states, which requires some effective ordering relation (a perceived before/after) [30, 29]. Any "Big World" theory (as defined in Section 3) must specify how to update on *self-locating* evidence: what we know is not merely that some observation occurs somewhere, but that *we* are having a particular observation. This typically requires (i) a notion of observer-moments, (ii) a typicality or measure rule over observer-moments, and (iii) constraints that rule out pathological dominance by aberrant continuations ("white rabbits," Boltzmann-brain-type observers, etc.).

B.3 Algorithmic simplicity from program multiplicity

A central technical theme is that a simplicity bias can arise without postulating a special weight by hand. If programs are represented as bit strings and each bit string is executed an equal number of times, then many distinct strings correspond to the *same effective computation* whenever only a finite prefix is read. If a computation's behavior is determined by an N-bit prefix p, then among all length-L strings the fraction that extend p is 2^{-N}. This yields an induced weight proportional to $2^{-|p|}$ for that behavioral class and leads to the Solomonoff–Levin style form of algorithmic probability (up to machine-dependent constants) [33, 34].

B.4 Arithmetical realism and universal Diophantine representation

A recurring move in the "physics from computation/arithmetic" literature is to treat arithmetical realism (the existence of the natural numbers and their standard relations) as a sufficient ontological base for computational plenitude. A technical backbone for this move comes from Hilbert's Tenth Problem and the Davis–Putnam–Robinson–Matijasevic theorem: every recursively enumerable (r.e.) set is Diophantine. Jones shows this implies the existence of *universal* Diophantine equations—polynomial analogues of a universal Turing machine [45, 46]. In short: the space of computable (semi-decidable) predicates can be encoded within arithmetic via polynomial solvability.

Two famous slogans point in a similar direction but should be read carefully. The claim "all is number" is often associated with early Pythagoreanism, but historians debate how literal (or how well-sourced) that slogan is [60, 61]. And Kronecker's quip "God created the integers; all else is the work of man" is a memorable way to gesture at mathematical realism [62].

B.5 Computability constraints on physical law

If physics required essential, finitely realizable hypercomputation, then "all computations" would not be an adequate foundation. Deutsch's physical Church–Turing principle and Gandy-style constraints argue in the opposite direction: that any finitely realizable physical process is simulable by universal computation under plausible physical assumptions [39, 40]. These arguments do not settle the question, but they motivate treating computation as a natural universality class for physical law.

B.6 Big World methodology and typicality

Bostrom emphasizes that, in a Big World setting where every observation-type occurs somewhere, ordinary evidence statements become too weak to discriminate between theories. One must condition on indexical evidence ("made by us") and use a rule that converts observer-fractions into first-person probabilities [17]. This is the basic methodological "escape hatch" that allows Big World theories to remain empirically testable.

B.7 Top-down cosmology and observer-conditioned histories

Hawking and Hertog propose a "top-down" framework in which probabilities are computed for histories that satisfy constraints at late times, within a no-boundary path-integral setting [53]. This provides a concrete example of observer-conditioning: the relevant ensemble of past histories is selected by conditioning on what is observed.

C Methodology for the prediction table

Table 3 is intended as a consolidated index of testable claims and structural constraints that have been proposed in the "all computations exist" literature.

C.1 Inclusion criteria

We included a claim when it was stated (explicitly or implicitly) as a consequence of an ensemble/computational ontology and was framed as (i) an observable prediction, (ii) a constraint required for empirical predictivity in a Big World, or (iii) a falsifiable methodological requirement (e.g., avoidance of specific pathologies).

C.2 Deduplication and consolidation

Many sources state the same underlying claim in different language. When two entries were equivalent at the level of an observable consequence, we merged them into a single row and retained citations to all relevant sources. The goal is a table of *distinct predictions*, not a count of how many times the same idea is repeated.

C.3 Status labels

The "Status" column uses eight one-word labels (defined in the legend above the table) to summarize the state of evidence. These labels are meant as a coarse guide for readers; they are not a substitute for detailed domain-specific review. Where a row corresponds to a standard theorem (e.g., universality results) or a well-tested empirical regularity (e.g., Born-rule statistics), it is marked Established or Observed accordingly.

C.4 Limitations

The entries are not statistically independent, and many share background assumptions (typicality, observer-moment definitions, measure choices). For this reason, Table 3 should not be read as providing "96 independent tests" of a single hypothesis. The Analysis section therefore aggregates evidence at the theme level and applies conservative dependence discounts.

D Annotated guide to key sources

This section provides brief, reader-facing pointers to a subset of the most central sources cited in the paper.

D.1 Foundational "computing universe" proposals

- Zuse's "Rechnender Raum" is an early statement of the idea that physical reality may be a discrete computation [48].
- Schmidhuber surveys an "algorithmic theory of everything" and emphasizes simplicity-weighted ensembles [28].

D.2 Algorithmic probability, induction, and simplicity

- Solomonoff formalizes induction via simplicity-weighted program ensembles [33].
- Hutter connects universal priors to idealized decision-making and prediction [34].
- Standish argues that, in ensemble settings, observers should expect near-minimal description length worlds compatible with observers (an Occam/anthropic synthesis) [22].

D.3 Observer-centered and duplication-based approaches

- Müller develops "algorithmic idealism" / "law without law" as a first-person transition framework using algorithmic probability [29, 63]. The phrase "law without law" originates with Wheeler. [64]

- Marchal argues for first-person statistics over computations (universal dovetailer) and highlights the "white rabbit" constraint problem [21].
- Mitra argues for treating observers as ensemble elements and stresses counterfactual structure in physical state descriptions [20].

D.4 Quantum foundations and cosmology

- Zeh's many-minds perspective is an early observer-centric interpretation strand in quantum theory [26].
- Hawking and Hertog's top-down/no-boundary framework offers an explicit cosmological example of observer-conditioned histories [53].
- Bostrom's "Big Worlds" paper clarifies why typicality is necessary for observational consequences [17].

D.5 Plenitude and mathematical realism

- Tegmark's Mathematical Universe Hypothesis and related discussion motivate treating external reality as a mathematical structure (and discuss computability constraints) [19].
- Jones' universal Diophantine results provide a precise bridge from arithmetic to universal computation [45, 46].
- Wolfram's "Ruliad" frames the totality of computational possibilities and emphasizes the role of observer "parsing" in effective lawfulness [38].

D.6 Fine-tuning and multiverse motivations

- Livio and Rees review fine-tuning/complexity arguments in a multiverse context and discuss the need for selection/measure principles [49].

E Supplementary expository sources

Several non-technical essays and overviews provide intuition and historical context for the themes in this paper. They are not treated as primary technical sources, but can be helpful entry points for readers seeking a narrative introduction:

- Resch's popular synthesis and reference hub. [59]
- Pearce's philosophical essay on "why anything exists". [65]

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