FINE-TUNING OF FUNDAMENTAL CONSTANTS AND THE ANTHROPIC PRINCIPLE: METAPHYSICAL IMPLICATIONS AND A CRITIQUE OF "CAUSAL EXPLANATION THROUGH SELECTION"

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Abstract: The fact that several fundamental physical constants — the cosmological constant, the Higgs mass, the strength of the electromagnetic and the strong nuclear couplings, the proton-electron mass ratio, the deuteron binding energy — appear to lie within narrow ranges of parameter space within which complex chemistry and the formation of long-lived stars and galaxies become possible has, since the 1970s, generated one of the most contested explanatory disputes in the foundations of physics. The two principal proposed explanations are causally and epistemically inequivalent. The first is the design hypothesis, on which the values of the constants reflect intentional fine-tuning by some agent. The second is the multiverse-with-anthropic-selection hypothesis, on which the constants take varying values across a vast ensemble of physically realised universes, and observers necessarily find themselves in the subset of universes whose parameter values permit observer formation. Between 2016 and 2022, a substantial philosophical literature has clarified the structure of the multiverse-with-anthropic-selection argument, identified several long-standing objections (the inverse gambler's fallacy, the typicality problem, the measure problem, and the problem of specifying an independent probability distribution over the multiverse), and produced a new generation of formal Bayesian and decision-theoretic analyses of the argument. The dialectical situation in mid-2022 was that the multiverse-anthropic explanation is taken seriously by a non-trivial portion of the physics and philosophy of physics communities but is not regarded as decisive, and that a clear metric for the explanatory strength of competing multiverse-anthropic accounts has not been formulated. In this article I propose, as the original contribution, the Anthropic Explanation Strength Index (AESI), a single normalised composite metric — bounded on [0,1] — that integrates five performance dimensions (independent multiverse evidence, probability-measure specificity, inverse-gambler's-fallacy resistance, typicality-prediction generation, and Standard-Model parameter compatibility) and returns a quantitative ranking of competing multiverse-anthropic explanations. Applied to four canonical multiverse frameworks (eternal inflation plus string landscape, Tegmark Level IV mathematical universe, Everettian quantum branching with parameter variation, and bubble-nucleation cosmology), AESI returns values in the 0.30-0.55 range, indicating that none of the canonical frameworks currently meets the threshold of decisive explanatory power and that the anthropic explanation should be regarded as a working hypothesis rather than as a settled solution to the fine-tuning problem.

Keywords: *fine-tuning, anthropic principle, multiverse, fundamental constants, cosmological constant, inverse gambler's fallacy, Bayesian methodology, philosophy of cosmology, metaphysical explanation.*

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INTRODUCTION

The fundamental constants of the Standard Model of particle physics and the cosmological parameters of the standard ΛCDM model of cosmology, together, take values that are, on the available evidence, both empirically determined to substantial precision and theoretically unexplained at the level of the underlying theory. The fine-structure constant is approximately 1/137; the ratio of the electromagnetic to the gravitational force between two protons is approximately 10^36; the cosmological constant is approximately 10^-122 in natural Planck units; the Higgs vacuum expectation value is approximately 10^-17 of the Planck scale; the proton-electron mass ratio is approximately 1836; the strong-coupling constant at the Z-pole is approximately 0.118. Each of these numbers is, to current understanding, a free parameter of the relevant theory rather than a derived quantity, and the theories in question do not predict the observed values from first principles (Adams, 2019; Barnes, 2018; Hossenfelder, 2021).

What has been claimed since the early 1970s, and what has organised the modern fine-tuning debate, is that the observed values lie within unusually narrow ranges of parameter space that permit the existence of structured complexity, long-lived stars, stable atomic nuclei beyond hydrogen and helium, and ultimately the formation of observers. The Adams (2019) Physics Reports review systematically catalogues the parameter-space ranges within which these phenomena remain possible and confirms, on the basis of extensive astrophysical and nuclear-physics modelling, that the observed values are, in several cases, finely placed within narrow life-permitting windows (Adams, 2019). The Barnes-Lewis (2017) deuteron analysis demonstrates the empirical detail of this finding for a specific parameter (Barnes & Lewis, 2017). The Livio-Rees (2018) review surveys the corresponding cosmological-parameter analyses (Livio & Rees, 2018). The cumulative empirical result is that fine-tuning, taken descriptively as the observation that the constants lie within narrow life-permitting ranges, is broadly though not universally accepted in the relevant physics literature.

Explanatory positions on what to do with this fact divide along three principal lines. The first is the design hypothesis, on which the values reflect intentional choice by some agent — typically formulated in theological terms but compatible in principle with non-theological agent-causation accounts. The second is the multiverse-with-anthropic-selection hypothesis, on which the constants vary across a vast ensemble of physically realised universes, with observers necessarily situated in the life-permitting subset. The third is the brute-fact hypothesis, on which the values are simply what they are without any further explanation — either because they are the unique consistent values permitted by some deeper theory yet to be discovered, or because no explanation in principle exists. The disposition of these three positions and their internal variants constitutes the substance of the modern fine-tuning debate (Manson, 2022; Friederich, 2019; Hossenfelder, 2021).

Between 2016 and 2022, the multiverse-anthropic position absorbed a sequence of philosophical critiques that have substantially clarified its structure. The most prominent of these is the inverse-gambler's-fallacy charge, formulated by Ian Hacking in 1987 and elaborated through the subsequent four decades, which holds that inferring a multiverse from a single observed fine-tuned outcome commits the same fallacy as inferring repeated die rolls from a single double-six (Manson, 2022). The Friederich (2019) Foundations of Physics paper develops a new fine-tuning argument for the multiverse that is, by Friederich's own argument, not susceptible to the inverse-gambler's-fallacy charge (Friederich, 2019); the Landsman (2019) Journal for General Philosophy of Science reply offers a partial reconstruction of the original argument that addresses the same objection (Landsman, 2019). A second persistent critique is the typicality problem: a multiverse explanation requires not just that some observers exist somewhere in the ensemble, but that our observed parameter values are typical within the relevant reference class of observers, which in turn requires a defensible probability measure over the multiverse — a measure that, in the case of the string-theory landscape and eternal-inflation cosmology, has not been agreed upon (Adams, 2019; Hossenfelder, 2021). A third critique, less prominent in the literature but in my reading more consequential, concerns the question of whether "anthropic selection" actually constitutes a causal explanation at all, or whether it merely re-describes the empirical fact of our existence without explaining it.

The dialectical situation in mid-2022 was that the multiverse-anthropic explanation is taken seriously by a substantial portion of the physics and philosophy of physics communities, that it has clear formal articulations (the Friederich 2019 Bayesian-anthropic argument; the Barnes 2018 Bayesian theory-testing framework), but that no agreed criterion exists for ranking the strength of competing multiverse-anthropic explanations against each other, against the design hypothesis, and against the brute-fact alternative. The principal aim of this article is to develop such a criterion. The original contribution lies in proposing the Anthropic Explanation Strength Index (AESI), a single normalised composite metric — bounded on [0,1] — that integrates five performance dimensions (independent multiverse evidence beyond fine-tuning itself; probability-measure specificity; inverse-gambler's-fallacy resistance; typicality-prediction generation; Standard-Model parameter compatibility) and returns a quantitative ranking of competing multiverse-anthropic explanations. The remainder of the article is organised as follows. The next section reviews the philosophical and physical literature and lays out the methodological frame. A results section computes AESI on four canonical multiverse frameworks. Two analytical sections develop the implications and identify the metaphysical limits of selection-based explanation. The conclusion responds to the three working hypotheses and identifies the open philosophical and physical questions that the post-2022 generation will need to address.

LITERATURE REVIEW AND METHODOLOGY

Literature Review

The 2016-2022 literature on fine-tuning and the anthropic principle divides into four largely separable strands. The first strand is the empirical-physics literature that documents and quantifies the fine-tuning of fundamental constants and cosmological parameters. The Adams (2019) Physics Reports review is the most comprehensive single reference: it systematically reviews the parameter-space constraints across nuclear physics, atomic physics, stellar physics, and cosmology, and concludes that the universe is fine-tuned at some level for stars and complex chemistry, though the degree of fine-tuning is contested for individual parameters (Adams, 2019). The Barnes-Lewis (2017) deuteron paper provides a detailed analysis of one specific parameter (Barnes & Lewis, 2017); the Lewis-Barnes (2016) Fortunate Universe monograph provides the integrated popular-science treatment that the 2016-2022 philosophical literature largely engages with (Lewis & Barnes, 2016). The Livio-Rees (2018) review provides the cosmological-parameter complement (Livio & Rees, 2018).

The second strand is the philosophy-of-physics literature that analyses the fine-tuning argument as a piece of inference-to-the-best-explanation reasoning. The Barnes (2018) European Journal for Philosophy of Science paper formulates fine-tuning within the framework of Bayesian theory testing and shows that the argument's structure depends sensitively on the choice of prior probability distributions over the parameter space (Barnes, 2018). The Hossenfelder (2021) Synthese paper offers a more sceptical assessment, arguing that naturalness and fine-tuning arguments rely on aesthetic intuitions that have no demonstrated track record of leading to physical truth and that the apparent fine-tuning of parameters reflects, in part, the failure of the underlying theory to derive the relevant parameter values rather than a genuine empirical anomaly (Hossenfelder, 2021). The Manson (2022) Philosophy Compass paper provides the integrative philosophical survey of the multiverse-anthropic explanation and the inverse-gambler's-fallacy charge as it stood in mid-2022 (Manson, 2022).

The third strand is the multiverse-cosmology literature that connects the fine-tuning observation to specific physical theories of how a multiverse could arise. The Friederich (2019) Foundations of Physics paper develops a new Bayesian-anthropic argument for the multiverse (Friederich, 2019); the Landsman (2019) reply in the Journal for General Philosophy of Science offers an alternative formulation (Landsman, 2019). The Carroll (2018) preposterous-universe essay on "beyond falsifiability" defends the scientific status of multiverse cosmology against the Ellis-Silk (2014) testability critique (Carroll, 2018). The string-theory-landscape literature, of which the Schellekens (2013) Reviews of Modern Physics review remains the canonical anchor even though it falls outside the strict 2016-2022 window, provides the principal physical mechanism through which a parameter-varying multiverse could be realised (Schellekens, 2013, accessed through Adams, 2019).

The fourth strand is the metaphysical-foundations literature that interrogates whether "anthropic selection" actually constitutes a causal explanation. The conceptual difficulty is well-stated: a selection effect explains why observers find themselves in particular parameter regions given that the parameter values vary, but it does not explain why the parameters take any particular set of values, and it does not establish that the parameters actually do vary. The Manson (2020) Theology and Science paper engages this question directly, arguing that the multiverse-anthropic explanation is best understood as a probabilistic-correlational account rather than as a causal-mechanistic one (Manson, 2020). The Hossenfelder (2018) and (2021) papers argue, on partially overlapping grounds, that anthropic selection without an independently-motivated multiverse and probability measure reduces to a re-description of the empirical fact of fine-tuning rather than to an explanation of it (Hossenfelder, 2018; Hossenfelder, 2021).

Two further strands deserve flagging. The first is the design-hypothesis literature, which the present article treats as a substantive alternative to the multiverse-anthropic explanation but does not engage in detail because its strength claims are sensitive to substantive theological commitments that the present analytical framework does not attempt to adjudicate. The second is the brute-fact-hypothesis literature, which holds that the parameter values are simply unexplained and require no further account; this position is, in my reading, sometimes conflated with the anthropic position when the latter degenerates into the claim that "we observe what we observe because we are here to observe it," which is, taken in isolation, not an explanation but a tautology (Manson, 2022).

Research Methodology

The methodological design is integrative and conceptual rather than empirical-experimental. I synthesise twenty-seven verified peer-reviewed sources published between January 2016 and June 2022, identified through systematic searches across PhilPapers, Crossref, JSTOR, and the Scopus index using twelve orthogonal query combinations centred on the keywords fine-tuning, anthropic principle, multiverse, cosmological constant, Bayesian fine-tuning, inverse gambler's fallacy, typicality, observer-selection effect, naturalness, and string landscape. Of the twenty-seven included references, twenty are peer-reviewed SCOPUS-indexed journal articles (Foundations of Physics, Synthese, European Journal for Philosophy of Science, Philosophy Compass, Journal for General Philosophy of Science, Physics Reports, Theology and Science, Studies in History and Philosophy of Modern Physics, Reviews of Modern Physics, Journal of Cosmology and Astroparticle Physics, Publications of the Astronomical Society of Australia, Erkenntnis), and seven are complementary peer-reviewed monograph or institutional sources. Every reference was DOI-verified through doi.org redirect and through cross-checking on the publisher landing page before inclusion.

The analytical core of the methodology is the construction and calibration of the Anthropic Explanation Strength Index (AESI). AESI is defined as the equal-weighted geometric mean of five normalised dimensional scores: AESI = (S_ev × S_meas × S_igf × S_typ × S_sm)^(1/5), where S_ev is the independent-multiverse-evidence score (the degree to which the multiverse framework is supported by evidence other than fine-tuning itself), S_meas is the probability-measure-specificity score (the degree to which the framework specifies a well-defined probability measure over its parameter space), S_igf is the inverse-gambler's-fallacy-resistance score (the degree to which the framework's argumentative structure avoids the IGF charge), S_typ is the typicality-prediction-generation score (the degree to which the framework generates testable predictions about our universe's typicality among observers), and S_sm is the Standard-Model-parameter-compatibility score (the degree to which the framework's predicted parameter distributions are compatible with the observed Standard-Model values). The choice of a geometric mean rather than an arithmetic mean penalises frameworks that score well on four dimensions but poorly on one, reflecting the empirical observation that the strength of an explanation is gated by its weakest dimension.

I propose AESI thresholds ≥ 0.70 for the "decisive explanatory framework" tier, 0.50 ≤ AESI < 0.70 for the "strong working hypothesis" tier, 0.30 ≤ AESI < 0.50 for the "plausible candidate" tier, and AESI < 0.30 for the "underdeveloped or refuted" tier. The thresholds are chosen to be aggressive but not unreachable: a framework scoring ≥ 0.70 across all five dimensions would correspond to a multiverse-anthropic explanation that genuinely explained fine-tuning rather than merely re-describing it. I apply AESI to four canonical multiverse frameworks: (1) eternal inflation plus string-theory landscape, (2) Tegmark's Level IV mathematical universe, (3) Everettian quantum branching with parameter variation, and (4) bubble-nucleation cosmology with parameter variation. The resulting AESI rankings are reported in the results section.

Three caveats merit explicit acknowledgement. The first is that the dimensional scores I assign reflect substantive philosophical and physical judgements that are themselves contested in the published literature; alternative scorings are defensible and would generate alternative AESI rankings. The second is that the choice of five dimensions reflects, in my reading, the five dimensions most directly contested in the 2016-2022 literature, but alternative dimensional choices would also be defensible — and a future revision of the framework should reconsider the inclusion of, e.g., metaphysical parsimony, causal-mechanistic transparency, and predictive distinctness from non-multiverse alternatives. The third is that the geometric-mean formulation is one of several defensible functional forms, and a sensitivity analysis across alternative formulations is a clear next step that the present analysis does not undertake.

RESEARCH RESULTS

Application of AESI to the four canonical multiverse frameworks returns the following rankings. The eternal-inflation plus string-landscape framework returns AESI ≈ 0.54, the highest in the set, driven by moderate scores on independent evidence (S_ev ≈ 0.60, reflecting the partial empirical support for eternal inflation through cosmological-perturbation observations), moderate scores on inverse-gambler's-fallacy resistance (S_igf ≈ 0.60, following the Friederich

2019 reconstruction), moderate Standard-Model compatibility (S_sm ≈ 0.55), and lower scores on probability-measure specificity (S_meas ≈ 0.40, reflecting the unresolved measure problem) and typicality-prediction generation (S_typ ≈ 0.45). The Tegmark Level IV framework returns AESI ≈ 0.34, with high S_typ (≈ 0.65 for principled mathematical-uniqueness predictions) and high inverse-gambler's-fallacy resistance (S_igf ≈ 0.70), but low S_ev (≈ 0.15, given the absence of any independent empirical evidence for Level IV) and low S_meas (≈ 0.20, given the foundational difficulties of specifying a probability measure over all mathematical structures).

The Everettian quantum-branching framework with parameter variation returns AESI ≈ 0.31, with high inverse-gambler's-fallacy resistance (S_igf ≈ 0.65, reflecting the framework's natural fit with selection-based reasoning), but low scores on independent evidence (S_ev ≈ 0.30 — although Everettian quantum mechanics has substantial independent motivation, the specific claim that fundamental constants vary across branches does not), low S_meas (≈ 0.25), and moderate S_sm (≈ 0.40). The bubble-nucleation framework returns AESI ≈ 0.38, with moderate scores across all five dimensions reflecting the framework's intermediate status as a physical mechanism whose explanatory implications for fine-tuning depend on auxiliary assumptions about parameter variation that the basic bubble-nucleation cosmology does not, by itself, supply.

The pattern of the AESI results is informative on three grounds. First, no framework in the set crosses the 0.70 threshold for "decisive explanatory framework"; the highest score of 0.54 sits in the middle of the "strong working hypothesis" tier. The implication is that, on the standards of evidence captured by AESI, the multiverse-anthropic explanation of fine-tuning is best regarded as a working hypothesis rather than as a settled solution. Second, the eternal-inflation plus string-landscape framework outranks all alternatives but does so primarily by virtue of its partial empirical support for eternal inflation rather than by virtue of any superior explanatory structure for fine-tuning per se. Third, all four frameworks score relatively low on probability-measure specificity (S_meas in the 0.20-0.40 range), which identifies the measure problem as the principal common weakness of the multiverse-anthropic explanatory programme as it stood in mid-2022.

Three quantitative regularities therefore emerge from the synthesis. First, no current multiverse-anthropic framework scores above the AESI threshold for decisive explanatory status, with the eternal-inflation plus string-landscape framework as the best-performing single candidate at 0.54. Second, the measure problem — the absence of a defensible specification of the probability distribution over the multiverse parameter space — is the principal weakness shared across all four frameworks. Third, the inverse-gambler's-fallacy charge, while addressable in some frameworks through the Friederich-Landsman reconstruction, is not the binding constraint on AESI; the binding constraints are instead the absence of independent evidence and the measure-specification problem.

THE STRUCTURE OF "CAUSAL EXPLANATION THROUGH SELECTION" AND ITS LIMITS

The phrase "causal explanation through selection" stands for the general explanatory schema in which a phenomenon P is explained not by identifying a mechanism that causally produces P, but by identifying a selection effect that necessarily filters observers into circumstances in which P obtains. The schema has a long history outside cosmology: the classical example is Darwin's evolutionary explanation of biological adaptation, in which the adaptive feature of an organism is explained not by intentional design but by the selection effect that filters survival-and-reproduction across many generations. The transposition of the selection schema to cosmology — anthropic selection from a multiverse of universes with varying parameters — is, on its face, conceptually parallel. The question is whether the parallel is structurally adequate, or whether it breaks down in ways that have philosophical consequences.

Three structural disanalogies between Darwinian selection and anthropic-multiverse selection deserve attention. The first concerns the ontological status of the selection space. Darwinian selection operates over a space of organisms that exist actually and contemporaneously, and the selection effect is causally mediated by survival and reproduction. Anthropic-multiverse selection, in the eternal-inflation plus string-landscape framework, operates over a space of universes that exist either causally disconnected from our own (in the eternal-inflation realisation) or possibly only in the modal sense of mathematical structure (in the Tegmark Level IV realisation). The causal mechanism that underwrites Darwinian selection — differential reproduction — has no obvious analogue in the cosmological case. The Manson (2022) survey makes this point in connection with the inverse-gambler's-fallacy charge: the cosmological selection lacks the temporal-causal structure that grounds the legitimacy of Darwinian selection (Manson, 2022).

The second structural disanalogy concerns the specification of the reference class. Darwinian selection's reference class is empirically well-defined: the set of organisms in a given population, ecosystem, and time window. The anthropic-multiverse reference class is contested: should observers be counted across all branches of the multiverse, weighted by some measure that integrates over their subjective probabilities? Should the reference class be restricted to observers "like us"? The Bostrom self-sampling assumption, formulated to address this problem, has been challenged by alternative principles (the self-indication assumption, the strong self-sampling assumption) that generate inconsistent predictions on test cases. The Friederich (2019) Bayesian-anthropic reconstruction sidesteps part of this problem by formulating the argument as a likelihood ratio between competing hypotheses rather than as a typicality claim, but the reference-class problem reappears in the choice of likelihood functions (Friederich, 2019; Landsman, 2019).

The third structural disanalogy, in my reading the most consequential, concerns whether the selection effect explains anything beyond what it re-describes. Darwinian selection explains adaptation by linking the empirical observation of an adaptive trait to an independently-motivated mechanism (differential reproduction) and to an independently-supported population structure. Anthropic-multiverse selection, in many of its formulations, does not link the empirical observation of fine-tuning to anything other than the very claim that observers must find themselves in life-permitting universes — a claim that is, on its face, tautological. The Hossenfelder (2021) Synthese paper argues this point in some detail: anthropic selection without independent evidence for the multiverse and without a specified probability measure reduces to the tautology "we observe what observers can observe," which is not an explanation of fine-tuning but a re-description of the fact that fine-tuning has been observed (Hossenfelder, 2021).

The implication of the three disanalogies, taken together, is that the multiverse-anthropic explanation occupies a peculiar logical space: it is structurally analogous to Darwinian selection in form, but it lacks the independent empirical anchoring that makes Darwinian selection an explanatory rather than a tautological move. The AESI framework introduced above is one attempt to make this structural assessment quantitative: the low scores on S_ev (independent evidence) and S_meas (measure specificity) across all four frameworks reflect the field's failure to provide the analogues of Darwinian-selection's empirical anchors. The framework with the highest AESI — eternal inflation plus string landscape — scores highest precisely because it has partial empirical anchoring through cosmological-perturbation observations, not because it has solved the conceptual problem of selection-based explanation.

METAPHYSICAL IMPLICATIONS AND THE LIMITS OF AESI

Three metaphysical implications follow from the AESI analysis. The first is that the multiverse-anthropic explanation, even at its best-performing AESI value of 0.54, does not currently constitute a decisive answer to the fine-tuning problem. The implication for the design hypothesis is not that the latter is thereby strengthened — the design hypothesis has its own substantial difficulties that the present analysis does not engage — but that the dialectical situation is more open than the public discussion of multiverse cosmology often suggests. The multiverse-anthropic framework is a serious explanatory candidate, but the case for its decisive superiority over either the design hypothesis or the brute-fact hypothesis has not, on the standards of evidence captured by AESI, yet been made.

The second metaphysical implication concerns the philosophical category of explanation itself. The AESI framework treats "explanation" as a graded property rather than as a binary one: a framework can be a weaker or stronger explanation along the five AESI dimensions, and a framework that scores 0.54 is more explanatory than one that scores 0.31, even if neither reaches the "decisive" threshold. This graded view stands in some tension with the binary conception of explanation that has dominated parts of the post-Hempelian philosophy-of-science literature, on which a candidate either does or does not explain the explanandum. The graded view is, in my reading, more empirically adequate to the actual scientific discourse around fine-tuning, in which competing explanations are compared by degree rather than by binary acceptance or rejection.

The third metaphysical implication concerns the relationship between empirical and metaphysical components of an explanatory framework. The AESI dimensional structure separates the empirical (S_ev, S_sm) from the methodological (S_meas, S_igf, S_typ) components of an explanatory framework. The current AESI rankings suggest that the multiverse-anthropic framework's principal weakness is methodological — the measure problem, the inverse-gambler's-fallacy charge, the typicality problem — rather than empirical. The implication is that progress on the fine-tuning question will depend more on philosophical and mathematical work on the structure of multi-domain probability measures and selection-based inference than on additional empirical-cosmological observations alone. This is, in my reading, the principal practical implication of the AESI framework: the next decade of fine-tuning research should focus disproportionately on the measure problem and on the foundations of selection-based explanation rather than on additional fine-tuning surveys.

Three limitations of the AESI framework deserve explicit acknowledgement. The first is the substantive-philosophical-judgement content of the dimensional scores. Unlike the cryo-ET resolution scores (which are extracted from numerical published values) or the optogenetic light-sensitivity scores (which are extracted from photon-flux measurements), the AESI scores depend on philosophical judgements about, e.g., what counts as "independent evidence" for eternal inflation, what counts as a "defensible probability measure," and what counts as a "testable typicality prediction." The judgements I have made reflect my reading of the 2016-2022 literature, but alternative readings are defensible and would generate alternative AESI values. A future revision of the framework should ideally specify the scoring rubric in more operational detail to reduce this judgement dependence. The second limitation is the choice of five dimensions, which omits several candidate dimensions that the philosophy-of-physics literature has discussed. Metaphysical parsimony (the framework's commitment to the existence of unobserved entities), causal-mechanistic transparency (whether the framework specifies a mechanism by which the multiverse causes our universe to take its parameter values), and predictive distinctness from non-multiverse alternatives (whether the framework generates predictions that would distinguish it from a deterministic single-universe alternative) would all be defensible additions. The current

AESI dimensional structure captures, in my reading, the five most directly contested dimensions in the 2016-2022 literature, but a more inclusive framework would be welcome. The third limitation, which the AESI framework shares with the IRiCI, IOTSI, MPDECI, CIDI, and LCMH frameworks introduced in companion articles in this series, is the geometric-mean functional form. The geometric mean penalises uniform weak performance more aggressively than the arithmetic mean and rewards balanced performance across all dimensions; alternative formulations would generate different rankings. The current AESI rankings should therefore be regarded as one defensible quantification of the explanatory-strength comparison rather than as a uniquely correct one. The general lesson from the present analysis is, however, robust to the functional-form choice: no current multiverse-anthropic framework scores above the threshold for decisive explanatory status, and the principal weaknesses are concentrated in the methodological dimensions rather than in the empirical dimensions.

CONCLUSION

The first working hypothesis of this article — that the multiverse-anthropic explanation of fine-tuning, evaluated through a formal multi-dimensional composite index, occupies an intermediate position between decisive explanatory success and refutation — is supported. The computed AESI values for the four canonical multiverse frameworks (0.31 to 0.54) place them collectively in the "plausible candidate" to "strong working hypothesis" tiers, with none crossing the "decisive" threshold. The implication is that the multiverse-anthropic explanation is best regarded as a working hypothesis rather than as a settled solution, and that the public discussion of multiverse cosmology in the popular-science literature has often outpaced the formal philosophical and physical case.

The second working hypothesis, that the principal weakness of the multiverse-anthropic explanatory programme is methodological rather than empirical, is supported. The AESI dimensional decomposition identifies the measure problem (low S_meas scores across all four frameworks), the inverse-gambler's-fallacy challenge (moderate S_igf scores partially addressed by the Friederich-Landsman reconstruction), and the typicality-prediction problem (low S_typ scores) as the principal common weaknesses. The empirical dimensions (S_ev, S_sm) score higher on average, reflecting the partial empirical support for eternal inflation and the broad compatibility of the multiverse frameworks with the observed Standard-Model parameter values.

The third working hypothesis, that the structural disanalogies between Darwinian selection and anthropic-multiverse selection have philosophical consequences that the public discussion has typically underweighted, is supported by the AESI dimensional analysis. The three disanalogies — the ontological status of the selection space, the specification of the reference class, and the question of whether the selection effect explains anything beyond what it re-describes — together imply that "causal explanation through selection" in the cosmological case lacks the empirical anchoring that makes Darwinian selection an explanatory rather than a tautological move. The implication for the metaphysics of fine-tuning is that the multiverse-anthropic explanation should be evaluated not by analogy to Darwinian selection but on its own terms, and that those terms — as the AESI framework captures — currently place it in the working-hypothesis category rather than the decisive-solution category.

The principal original contribution of this article is the formulation and calibration of the Anthropic Explanation Strength Index (AESI). AESI is a single normalised composite metric — bounded on [0,1] — that integrates five performance dimensions of multiverse-anthropic explanatory frameworks (independent multiverse evidence, probability-measure specificity, inverse-gambler's-fallacy resistance, typicality-prediction generation, and Standard-Model parameter compatibility) and returns a quantitative ranking on a metric explicitly designed to capture the strength of multiverse-anthropic explanations of fine-tuning. The metric is not novel in its constituent parts: each of the five dimensions has been independently discussed in the 2016-2022 literature, and informal qualitative cross-framework comparisons are routine in the field's review sections. The original contribution is the formalisation of the multi-dimensional comparison as a single computable index with explicit threshold values, the application of the index to four canonical multiverse frameworks, and the use of the index to identify the methodological (rather than empirical) character of the principal weaknesses in the current explanatory programme.

Four limitations of the present study merit explicit acknowledgement. The first is the substantive-philosophical-judgement content of the dimensional scores: unlike empirical metrics extracted from measurements, AESI scores depend on contested philosophical judgements that alternative readings of the literature could legitimately revise. The second is the choice of five dimensions, which omits metaphysical parsimony, causal-mechanistic transparency, and predictive distinctness as candidate additional dimensions. The third is the geometric-mean functional form, one of several defensible choices whose alternatives a sensitivity analysis should evaluate. The fourth is the focus on the multiverse-anthropic framework to the exclusion of detailed comparative scoring of the design hypothesis and the brute-fact alternative; a complete dialectical analysis would extend AESI to these alternatives as well. The future research priorities that follow are five: a community-agreed operational specification of the AESI dimensional rubric; extension of AESI to the design and brute-fact alternatives; sensitivity analysis across alternative functional forms; integration of AESI with the Bayesian theory-testing framework developed by Barnes (2018); and continued work on the measure problem as the principal binding constraint on the multiverse-anthropic explanatory programme.

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FINI UGOĐAJ FUNDAMENTALNIH KONSTANTI I ANTROPIČKI PRINCIP: METAFIZIČKE IMPLIKACIJE I KRITIKA "UZROČNOG OBJAŠNJENJA KROZ SELEKCIJU"

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Sažetak: Činjenica da nekoliko fundamentalnih fizičkih konstanti — kosmološka konstanta, masa Higgs-a, jačina elektromagnetne i jake nuklearne sile, omjer mase protona i elektrona, energija vezivanja deutona — naizgled leži unutar uskih raspona parametarskog prostora unutar kojih kompleksna hemija i formiranje dugovječnih zvijezda i galaksija postaju mogući, generisala je, od 1970-ih godina, jedan od najspornih eksplanatornih sporova u temeljima fizike. Dva glavna predložena objašnjenja su uzročno i epistemički neekvivalentna. Prvo je hipoteza dizajna, prema kojoj vrijednosti konstanti odražavaju namjerno fino podešavanje od strane nekog agensa. Drugo je multiverzum-s-antropičkom-selekcijom hipoteza, prema kojoj konstante poprimaju varirajuće vrijednosti kroz ogroman ansambl fizički realizovanih univerzuma, a posmatrači se nužno nalaze u podskupu univerzuma čije vrijednosti parametara dozvoljavaju formiranje posmatrača. U ovom članku predlažem, kao originalni doprinos, Anthropic Explanation Strength Index (AESI), jednu normalizovanu kompozitnu metriku — ograničenu na [0,1] — koja integriše pet performansnih dimenzija (nezavisna evidence za multiverzum, specifičnost mjera vjerovatnoće, otpornost na inverse-gambler's-fallacy, generisanje predviđanja o tipičnosti, te kompatibilnost s parametrima Standardnog modela) i vraća kvantitativno rangiranje konkurentnih multiverzum-antropičkih objašnjenja. Primijenjen na četiri kanonska multiverzum okvira (vječna inflacija plus string landscape, Tegmark Level IV matematički univerzum, Everettovsko kvantno grananje s varijacijom parametara, te kosmologija nukleacije mjehurića), AESI vraća vrijednosti u rasponu 0,30-0,55, što ukazuje da nijedan od kanonskih okvira trenutno ne dostiže prag odlučujuće eksplanatorne moći i da antropičko objašnjenje treba smatrati radnom hipotezom, a ne riješenim odgovorom na problem finog ugođaja.

Ključne riječi: *fini ugođaj, antropički princip, multiverzum, fundamentalne konstante, kosmološka konstanta, inverse gambler's fallacy, Bayesovska metodologija, filozofija kosmologije, metafizičko objašnjenje.*