

Holistic Versus Fragmented Multiverses: Empirical Access via Causal and Grounding Signatures

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Abstract

Can multiverse hypotheses ever receive empirical support? Critics argue that multiverse scenarios posit unobservable entities, face severe underdetermination, or fall outside the bounds of science. This chapter challenges that view by offering a naturalistic metaphysical counterpoint to Bayesian approaches, distinguishing fragmented from holistic multiverses. Scientific proposals are almost always holistic: they embed universes within a unifying physical or metaphysical structure that can, in principle, leave empirical signatures inside the universes. I develop a typology of such signatures and show how it applies to leading scenarios from quantum theory, cosmology, and string theory. This framework clarifies why objections such as the ‘this universe’ objection and a newly articulated generalization, the epistemic isolation objection, fail against scientifically motivated multiverses. The upshot is a qualified defence: while fragmented multiverses remain empirically inaccessible, certain holistic multiverses could, in principle, be supported by the same epistemic standards used elsewhere in physics.

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1. Introduction

The idea that reality may comprise a plurality of universes has emerged as a significant theme in both theoretical physics and metaphysics.¹ In physics, for instance, inflationary cosmology posits the endless production of bubble universes, while Everettian quantum mechanics interprets the evolution of the wavefunction as a continual branching into multiple quasi-classical worlds (Guth, 2007; Saunders et al., 2010; Wallace, 2012; Carroll and Singh, 2019). Multiverse scenarios also figure prominently in discussions of fine-tuning and anthropic reasoning, sometimes in response to theological design arguments (see, e.g., Hacking, 1987; White, 2003; Isaacs et al., 2022; Manson, 2022; Saad, 2024; Ruyant, 2025; Meacham, forthcoming).

The question of whether we should *ultimately believe* that we live in a multiverse—or even whether we could possibly *know* that we do—remains far from settled. Philosophical treatments of multiverse epistemology have often been framed in Bayesian terms, or more generally as a priori analyses of how rational credences should be updated given anthropic evidence or fine-tuning considerations (see, e.g., Hacking, 1987; White, 2003; Friederich, 2021). My approach can be read as a counterpoint: instead of a priori coherence or credence assignments, I adopt a naturalistic metaphysical perspective tied to scientific practice, one that looks at how multiverse hypotheses function within scientific practice and the worldviews they sustain. From this vantage point, what matters is not a priori probability assignments but the metaphysical profile of a multiverse, and whether that profile allows for empirical signatures.

Beyond the difficulties surrounding the effectiveness of fine-tuning arguments, many critics contend that multiverse hypotheses are unscientific, either untestable or committed to entities beyond possible observation (Ellis, 2011; Ellis and Silk, 2014). For example, George Ellis insists that:

We need some kind of causal contact with whatever entities we propose; otherwise, there are no limits. The link can be a bit indirect. If an entity is *unobservable but absolutely essential for properties of other entities that are indeed verified*, it can be taken as verified. But then the onus of proving it is absolutely essential to the web of explanation. The challenge I pose to multiverse proponents is: Can you prove that unseeable parallel universes are vital to explain the world we do see? *And is the link essential and inescapable?* (Ellis, 2011, 43, my emphasis)

¹ This chapter is a long-overdue publication of ideas I first presented in a series of talks beginning in 2021. I am grateful to the many audiences whose questions and comments helped refine the arguments over the years, and in particular to participants at the *Multiverse and Philosophy Conference* (June 16–18, 2025). I also thank Emily Adlam, Jacob Barandes, Isaac Wilhelm, and Christian Wüthrich for their feedback, and Neil A. Manson for several especially helpful discussions of the ‘this universe’ objection, as well as for introducing me to the basics of baseball.

Three distinct objections are often run together in both public and specialist discussions of multiverse hypotheses, namely that (i) they posit unobservable entities; (ii) they lack *current* empirical support; and (iii) they could not, even *in principle*, receive empirical support (see, e.g., Hossenfelder, 2018, 184).

These are not equivalent.

The first, by itself, is not compelling: science routinely posits unobservables when doing so yields distinctive explanatory and predictive success. Any unobservable entity is, in principle, escapable—provided one is willing to accept the explanatory costs and depart from established scientific orthodoxy. For example, in a Duhemian spirit, one could have resisted commitment to atoms by treating Brownian motion, diffusion, and the gas laws as independent phenomenological regularities; but that strategy was *ad hoc* and explanatorily costly (Psillos, 2011). Demanding absolute inescapability thus sets an unusually high bar, one rarely imposed in actual scientific practice (see, e.g., Carroll, 2019 for a Bayesian approach to this).

The more serious worry is (iii). Earlier discussions of the possibility of empirically confirming multiverse scenarios can be found in Friederich (2021) and Read and Le Bihan (2021). Friederich, after a nuanced overall assessment, adopts a pessimistic stance, concluding that predictions would be ‘hopelessly unreliable’ (Friederich, 2021, 179).² By contrast, in line with my previous work with James Read, I will defend the prospect that we might come to know we live in a multiverse, by identifying specific traces of the multiverse within universes. I will argue that holistic scenarios, understood as those involving multiverse-to-universe determination relations, keep the prospect of empirical confirmation genuinely open.

Section 2 explains why (ii), the absence of *current* confirmation, is a weak objection to multiverse scenarios, and, pulling in the opposite direction, why fine-tuning is at best motivational in the search for new physics. This clears the ground for a positive framework and a nuanced evaluation of the prospects for empirical confirmation. Section 3 introduces the distinction between holistic and fragmented multiverses, arguing that only the former admit empirical access in principle. Section 4 develops a typology of empirical signatures. Section 5 applies this typology to cases from quantum theory, string theory, and cosmology. Section 6 addresses the ‘this universe’ objection and a generalization I articulate, the epistemic isolation objection. Section 7 concludes.

² “It may be, in principle, possible to extract concrete nontrivial predictions from specific multiverse theories using, notably, considerations about self-locating belief. But the researcher degrees of freedom that arise in the process—e.g., when making choices about observer proxy, cosmic measure, cosmic background conditions, are prone to be affected by confirmation bias—which makes such predictions hopelessly unreliable” (Friederich, 2021, 179).

2. Beyond Fine-Tuning and the ‘Not Testable Now’ Objection

This section clears the ground on two fronts before turning to the positive framework. First, fine-tuning considerations are at most suggestive: they do not by themselves supply decisive evidence for a multiverse, though they help illustrate how multiverses might leave empirical signatures (see Section 4). Second, the mere lack of *current* tests is not, by itself, disqualifying: historically, theories were often accepted on explanatory grounds before suitable tests became technologically or conceptually available.

Fine-tuning arguments move from the observation that sentient life could not have emerged under slightly different parameter values in our physical laws to the view that these values should be seen as selection effects within a multiverse: any sentient observer must, by necessity, find themselves in one of the rare life-permitting universes. Yet such arguments are difficult to assess, and their evidential force remains highly debated. I take them to be suggestive but not decisive.³

My main resistance is that the parameters typically cited as fine-tuned appear in effective theories rather than in fundamental ones. As such, their values could be artifacts of our incomplete description, patching over ignorance of a more fundamental dynamics—one that might be captured by an empirically confirmed theory of quantum gravity. (For accessible overviews aimed at philosophers of why such a theory is needed, see Wüthrich (2005) and Crowther (2025).)

One might object that effective theories are sufficient, at least to a good approximation, for capturing the modal structure of the physical world, including possibilities that involve different parameter values. On this view, the modal structure of physical theories naturally maps onto the structure of the multiverse. After all, models of physical theories are ordinarily taken to track physical possibilities (Le Bihan, Margoni, and Vieser, forthcoming). In that sense, models with counterfactual parameter values may, *prima facie*, represent physically possible worlds.

However, varying parameter values is arguably not methodologically equivalent to varying boundary conditions. The former amounts to altering the laws of nature themselves, rather than merely changing boundary conditions under fixed laws. Models with varied parameters therefore lie further from the actual world than those differing only in initial or boundary conditions, and whether they represent genuine physical possibil-

³ See also Friederich (2021, chs. 4-5) for the view that fine-tuning by itself cannot do the evidential work alone; any genuine support must come from independent traces of a multiversal structure.

ities remains open to doubt.⁴ It may well be that such models represent only epistemic possibilities—scenarios consistent with what we know of the universe—rather than genuine physical possibilities entailed by the laws of nature.

A separate worry maintains that multiverse hypotheses are too speculative because they are ‘not testable now’. This overstates the evidential demand: absence of present tests is compatible with future testability and does not, by itself, undermine scientific status.

The heliocentric model is a vivid case: Copernicus (1543) [1992] already implied stellar parallax as a test in principle, but the effect was undetectable for centuries; only indirect support came in 1725 with Bradley’s discovery of stellar aberration, and the first direct measurement of parallax was achieved by Bessel in 1838, nearly 300 years later. In the meantime, heliocentrism was accepted largely on explanatory and unifying grounds, long before empirical testing was technically possible (Kuhn, 1957).

Likewise, inflation was initially motivated by explanatory gains and developed empirical support only subsequently (McCoy, 2019): proposed to address the horizon, flatness, and monopole puzzles, it later predicted the distinctive, almost scale-free pattern of temperature fluctuations in the cosmic microwave background (CMB). Its ability to generate precise predictions about the pattern of fluctuations observed in the CMB is now considered as a successful empirical test (Friederich, 2021, 7).

Thus, a lack of current testability is not *ipso facto* a defect: empirical gaps can take decades, sometimes centuries, to close, while explanatory success can still warrant provisional credence. Such success falls short of full empirical support, and that is as it should be.

Having set aside both an over-reliance on fine-tuning and an overly stringent immediacy requirement for testing, we can now turn to (iii) in a principled form: *Can certain multiverse scenarios be empirically supported—independently of fine-tuning arguments?* More ambitiously, can we ever know whether we inhabit a multiverse? To tackle these questions, I set aside the pre-theoretic, verificationist use of confirmation, on which a claim is confirmed only if it is infallibly established, since it plays little role in empirical theory assessment. I also set aside discussions of so-called non-empirical or meta-empirical confirmation in physics (Dawid, 2013, 2019, 2022), to focus squarely on em-

⁴ For this reason, the effective criterion for representation of physical possibilities proposed by Baron et al. (forthcoming)—that models of physical theories correctly represent physical possibilities, at least in part, within their domain of application, *absent independent evidence to the contrary*—need not extend to parameter variation. In this case, we already do have such independent evidence: namely, the expectation that a more fundamental theory of quantum gravity should underlie current effective theories and account both for the existence of their parameters and for the range of their admissible values. This makes me doubtful that fine-tuning arguments grounded solely in effective theories can provide decisive support for multiverse hypotheses.

pirical signatures in a more strictly empirical sense.⁵

The question, then, is whether multiverse scenarios are especially problematic, more so than other theoretical claims in physics, when it comes to empirical justification. The following sections develop a principled framework for addressing that question.

3. Holistic vs Fragmented Multiverses

To address whether empirical access is possible, we must first clarify what counts as a multiverse scenario, since some versions rule out by definition any direct or indirect access. The term ‘multiverse’ refers to a heterogeneous family of proposals with distinct structures, physical assumptions, and metaphysical commitments. In order to evaluate the possibility of empirical access, a working definition of ‘multiverse’ broad enough to capture the scenarios at stake, but discriminating enough to distinguish cases with different epistemic prospects, is needed.

A strict definition in terms of necessary and sufficient conditions is unattainable, given the rich and varied family of existing proposals. Instead, a liberal disjunctive criterion will be adopted: the term applies to any scenario in which at least one of the following holds: (1) reality includes regions governed by laws similar to ours but with different values for important physical parameters; (2) reality includes regions containing counterparts of us sufficiently similar that one might wonder whether they are, in some sense, versions of us.

This disjunctive definition is deliberately liberal: it does not require universes to be absolutely isolated, whether causally or spatiotemporally, and it leaves open the possibility of various kinds and degrees of connection between them. To make sense of this variety of multiverses, I introduce a distinction that will structure the remainder of the chapter.

Fragmented multiverses are those in which universes are maximally isolated, lacking any overarching unifying structure in any sense whatsoever. *Holistic multiverses*, by contrast, embed all universes within a single unified structure—such as a universal wave-function, inflating field, cyclic dynamics, or spatiotemporal continuity—that can connect them causally, spatiotemporally, or via scientifically tractable non-causal relations (discussed in the next section). In holistic cases, features of our universe are determined by the larger structure, opening the door to possible empirical signatures. By contrast, fragmented cases render their constituent universes epistemically isolated.

Holistic multiverses have two important features. First, certain properties of the whole (the multiverse) exist over and above the properties of the parts (the universes). Second,

⁵ I do not mean to take a position here on whether the kinds of arguments offered by Richard Dawid ultimately count as empirical or non-empirical. My aim is simply to bracket those debates and concentrate on a different question: whether multiverse scenarios can display empirical signatures in the same way that other theoretical claims do in contemporary physics, in the standard way.

they satisfy an epistemic transparency thesis: at least some properties of the multiverse must be accessible from within the universes.⁶

To make the distinction between holistic and fragmented multiverses concrete, consider two contrasting scenarios. In eternal inflation, universes emerge from a pre-existing inflaton field governed by definite dynamics. The multiverse is here conceived as a generative structure: as the field evolves, it produces individual bubble universes, each with its own parameter values. These universes are not independent, but causally generated as part of the evolution of a single overarching process. The parameters we observe are not arbitrary but reflect the broader structure of the inflating field and the generative process through which universes are formed. That explanatory dependence is what licenses treating this multiverse scenario as holistic.

By contrast, imagine a theistic creation scenario in which God deliberates over whether to create one universe or many and chooses the latter. Such scenarios have been discussed in relation to whether a multiverse might constitute the best of all possible worlds selected by a divine creator (see, e.g., Kraay, 2010; Li and Saad, 2023; Monton, 2010; Rubio, 2020; Donahue, forthcoming). In this case the multiverse is just the distributional class of created universes, with no broader physical structure unifying them. Their only unifying connection lies in the divine mind. The theological multiverse is, *by definition*, fragmented. More precisely, in such a theistic scenario, positing an additional physical multiverse structure beyond the distributional class of created universes would be logically possible, but redundant. The unity of the collection is already supplied by the divine act of creation, so introducing a further physical mechanism of unification that purports to ground or causally generate the universes would be explanatorily idle, empirically inaccessible, an invisible epiphenomenon. The theological multiverse might still be construed as holistic if identified with a scientific multiverse; such an identification is *prima facie* implausible, however, since the generative principles diverge sharply: volitional or moral choices in the theological case versus physical laws or mechanisms in the scientific case. Each universe in this scenario remains metaphysically, maximally isolated from the rest of the multiverse, since the multiverse is nothing more than this fragmented distribution.

As we will see, the possibility of empirical signatures in any given multiverse scenario depends crucially on which of these conceptions is in play.

Now, a common sceptical worry against the very coherence of the concept of multiverse holds that if other universes are causally or spatiotemporally disconnected from ours, then no empirical access, no scientific knowledge is possible. But this objection

⁶ The holistic multiverse does not necessarily presuppose a privileged discrete decomposition of the whole into distinct universes. The larger explanatory structure might instead resemble a continuous or non-partitioned reality, with any apparent breakdown into separate universes being representational. For an account of this perspective in the context of Everettian quantum mechanics, see Glick and Le Bihan (2024). Multiverses of this kind are often invoked in theological contexts (Kraay, 2010; Rubio, 2020); in such cases, leaving the number of universes unspecified risks introducing vagueness into the divine decision process, which some may find theologically and metaphysically problematic.

applies only to fragmented multiverses. Holistic multiverses, by contrast, are not *absolutely* disconnected: their unifying structures can provide empirical access, either via direct causal access or via indirect non-causal access.

Another natural objection to *holistic* multiverses this time, is that if we had direct observational access to another universe, this so-called ‘other universe’ would simply be absorbed into the definition of our own universe (see, e.g., Smolin, 2009). Two clarifications. First, holistic multiverses need not involve direct causal connections at all, and thus no direct observational access; unity can be indirect via a mix of causal and grounding relations, as it will be shown in the next section. Second, even when there is causal access, classification is partly semantic and historically contingent. A helpful analogy is the early-twentieth-century debate over *island universes*. Until the 1920s, it was unclear whether spiral nebulae were part of the Milky Way or very distant systems of entities, then construed as other universes but later recognized as galaxies beyond our own.⁷ What were once construed as other universes were reclassified as proper parts of a broader universe.

This analogy is not perfect: galaxies are causally connected to us, whereas universes in a holistic multiverse may not be. But it illustrates that what counts as ‘our universe’ is partly context-dependent, shaped by observational limits and conceptual frameworks. If a holistic multiverse of the causal kind were to gain empirical support, we might one day redescribe it as a more expansive conception of *the* universe. That possible semantic shift does not, however, make the current idea of a multiverse otiose: prior to such reconceptualisation, the presently unobservable regions would still instantiate the salient features we naturally associate, presently, with distinct universes.

4. Empirical Signatures

This chapter adopts a pragmatic approach to keep the issue tractable: it asks whether multiverse scenarios could receive the same sort of empirical support as other theoretical claims in physics, while bracketing broader debates about the general nature of empirical support and confirmation. To provide minimal structure, I draw on a recent formulation by van Fraassen of what he calls *empirical grounding*. Although van Fraassen is famously skeptical of metaphysics, his account highlights a crucial point: a theory is empirically grounded if the quantities it posits can, at least in principle, be connected to observable outcomes through theoretical links:

The requirement of empirical grounding is that, for any quantity occurring in the theory, it must be possible in principle to determine its value: a. from direct measurement results, b. based on the theoretically posited connections, c.

⁷ Henrietta Leavitt’s work on Cepheid variables provided a new empirical method—standard candles—for measuring cosmic distances (see Breuval et al., 2025). Edwin Hubble applied this method in 1923–24, showing that many nebulae lie outside our galaxy (Hubble, 1929).

and consistent with those connections, subject to: d. concordance: every such determination has to yield the same result, e. non-triviality: but could have had different results that would have contradicted the theory. (van Fraassen, 2025, 37)

This captures what I mean by an *empirical signature*: not necessarily a direct measurement, but a quantity that can be related to an empirically accessible observation via a chain of theoretical links. Signatures are usually indirect: they rely on theoretical connections that mediate between theory and observation.

Building on this idea, and now moving into metaphysical territory beyond van Fraassen, I distinguish two main kinds of empirically relevant determination relations in the world, which underlie such theoretical links, with further subtypes. I use ‘determination’ as a general label for dependence relations. These divide into two kinds: causal (nomic) and grounding (non-nomic). Following A. Wilson’s (2021) mediation criterion, the contrast turns on a *nomic criterion*: *causation* is determination mediated by dynamical laws of nature, while *grounding* is a non-nomic, metaphysical in-virtue-of relation that is not law-mediated.

4.1. Direct Causal Signatures

A theoretical structure leaves a direct causal signature when it interacts directly and causally with observable systems, producing directly detectable traces via causal interaction. The existence of the causal relation in the world, allows causal access by epistemic agents. ‘Direct’ here is comparative rather than absolute: Quine–Duhem holism plausibly rules out fully isolated confirmation. The point is that the observed effect is produced by another universe, or the multiverse structure itself, in a way that requires relatively little mediation in the theoretical representation, compared to the grounding cases.

Direct causal signatures admit two subtypes:

1. *Spatiotemporal causation*. That is the standard case. Causal influence propagates through a spatiotemporal structure. Paradigm cases include signals or collisions of other universes or multiverse structures that imprint observable traces in our past light cone (this could happen in certain models of eternal inflation, see below).
2. *Non-spatiotemporal causation*. Causation need not necessarily be tied to spatiotemporal propagation as soon as we relax the view that causation requires spacetime (Baron and Miller, 2015). The relata may be spatiotemporal while the causal relation between them is not spatiotemporal (a historical precedent is Newtonian gravity’s action at a distance); or, in spacetime-emergent settings, the fundamental causal relation may be non-spatiotemporal, with an equivalent description as causal dependence between emergent spacetimes. Both descriptions can be accurate, with the more fundamental one explaining how apparently isolated universes might nevertheless stand in law-governed dependence. This could be the case in

certain scenarios involving spacetime emergence in quantum gravity, or Everettian quantum mechanics (see Subsection 5.5).

4.2. Indirect Signatures by Grounding

A theoretical structure leaves an indirect signature by grounding when it *grounds* observable features of our universe. What is observed are the grounded consequences, not the grounding structure itself. Grounding is non-causal and non-nomic, but it can nevertheless be scientifically tractable when it exhibits counterfactual sensitivity: had the grounding structure been different, the observable features would have differed as well (Kortabbaria and Giannotti, 2024). The literature on grounding (e.g., Fine, 2001; Rosen, 2010; Schaffer, 2009) provides the template; here it is used in a liberal, scientifically serviceable sense that does not presuppose a single primitive ‘Big-G’ relation (cf. J. Wilson, 2014).

Again, one can distinguish between two sorts of signature by grounding:

1. *By local grounding.* Features of our universe are explained in virtue of relatively local structural facts within a larger multiversal base. In Everettian quantum mechanics, for instance, decoherence yields a branching structure; regularities we observe (e.g., Born-rule frequencies) are grounded in our branch’s relation to nearby high-weight branches in Hilbert space. ‘Local’ need not mean spatial or spatiotemporal locality; locality can be understood in a broader metric or structural sense within a non-spatiotemporal structure (Le Bihan, 2018, 100–101).
2. *By global grounding.* Certain features of our universe can be explained in virtue of ensemble-level properties of the multiverse as a whole. In eternal inflation, for example, the inflaton field causally produces a variety of bubble universes, each with different low-energy properties. But beyond these token-level causal processes, the ensemble displays a global distribution of parameter values. The fact that our universe realizes parameter value p can then be understood as grounded in that holistic distribution: its specific features are explained by their place within the overall multiversal pattern, not by a further causal interaction.⁸ The analogy with general relativity is instructive: global properties of spacetime are not reducible to purely local features, yet they constrain certain local matters of fact (Lam, 2007). For example, the location of black hole event horizons depends on the structure of the

⁸ Token-level processes such as bubble nucleation or collisions are straightforward cases of nomic causation, mediated by dynamical laws. Ensemble-level distributions, by contrast, are not further causal interactions but holistic statistical features of the multiverse. In this taxonomy, I treat such ensemble-level properties as grounding their instances, in order to distinguish them from direct causal signatures. Note that global grounding can either independent of causal processes as in the case of Everettian quantum mechanics, or the byproduct of dynamical, causal processes, as with eternal inflation (see below).

entire spacetime, and the properties of any given ‘present’ slice are fixed in relation to the rest of the spacetime (Ashtekar and Galloway, 2005; Curiel, 2019; Baron and Le Bihan, 2023).⁹

The model of empirical signature by grounding, local or global, is not a new inferential method, but a reinterpretation of familiar scientific reasoning. A canonical example is Perrin’s work on Brownian motion (as alluded to in the introduction): the erratic motion of suspended particles was taken to be grounded in unobservable molecular impacts, thereby justifying commitment to atoms prior to direct observation. Grounding earns its epistemic keep here because it is counterfactually sensitive and integrated with surrounding causal relations. What can be observed and confirmed is not only what causes what, but also what grounds what, provided that the grounding relation explains observable features and meshes with an empirically successful theoretical framework.

Now, it might appear that signature by grounding suffers from underdetermination of the theoretical claim by the empirical evidence. If Y is grounded in X , the same Y might also be grounded in some alternative Z or W . But this is the generic problem of underdetermination, not a special defect of grounding-based signatures. In practice, science proceeds by tightening theoretical and empirical constraints. If a candidate ground X systematically explains accessible phenomena Y better than alternatives, and integrates more successfully with surrounding theory, it earns indirect empirical support as the best available explanatory basis. Uniqueness is not required; explanatory success in a constrained domain is.

Overall, the taxonomy distinguishes four primary forms of determination that can yield empirical signatures: direct causal signatures via *spatiotemporal* causation; direct causal signatures via *non-spatiotemporal* causation; indirect signatures by *local* grounding; indirect signatures by *global* grounding. Each of these four modes supplies a distinct route by which multiverse structures can be brought within the scope of empirical science.

The next section maps this taxonomy onto leading multiverse scenarios. Section 6 then returns to the philosophical objections, showing how the holistic/fragmented distinction undercuts both the ‘this universe’ objection and the broader epistemic isolation objection.

⁹ Physicists may object that horizons are defined in terms of global causal structure, hence still causal. More technically, the point here is that the causal structure itself can serve as a relatum in a further determination relation: the grounding of local features in global ones. In my framework, causal properties are not themselves the relevant determination relation here, but relata for a grounding relation. Note too that the analogy is only partial, as the exact location of the event horizon is not directly observable.

5. Scenarios

This section applies the framework from Section 4 to four representative proposals. In each case I ask: (i) what unifying structure (if any) makes the scenario holistic rather than fragmented; (ii) which mode(s) of empirical signature are available—direct causal traces, indirect local grounding, or indirect global grounding; and (iii) what the main empirical handles and obstacles are (for example, measures, underdetermination, or contested data analyses). The aim is not to settle viability, but to show how the such approaches link or could link multiverse structures to features of our universe. I begin with Everettian quantum mechanics, which illustrates indirect signature by grounding without causal access; I then turn to eternal inflation (with possible direct causal signatures and global grounding), the string landscape (global grounding under theoretical constraints), and conformal cyclic cosmology as an instance of cyclic models (prospective direct traces across successive universes). Finally, I turn to spacetime emergence in quantum gravity, which shows the possibility of non-spatiotemporal causal signatures, broadening what empirical access to a multiverse might involve.

5.1. Everettian Quantum Mechanics

Everettian quantum mechanics (EQM) takes Schrödinger evolution at face value: whenever the universal wave function evolves into a superposition, each term realizes a quasi-classical branch of reality. On the influential approach of David Wallace, the branches are not fundamental; they arise as quasi-classical structures from the unitary dynamics of the universal quantum state once decoherence suppresses interference at macroscopic scales (Wallace, 2012). The multiverse then emerges from a relatively more fundamental universal quantum state. On this account, the branches are ontologically dependent on the universal state, and thus EQM exemplifies a holistic multiverse: the unity of the whole quantum state determines the character of the parts.

Although Wallace himself treats the emergence relation as one of patterns, in Dennett’s sense, a more metaphysics-friendly proposal uses *grounding* instead. Following A. Wilson (2020), one can take the relation between the universal state and its branches to be a non-causal, asymmetric metaphysical dependence. On this view, empirical data obtained *within* a branch can warrant belief in features of the broader multiversal structure, not through causal contact with other branches, but because the universal state grounds that branch and its observable regularities.¹⁰

The most immediate empirical link is local in Hilbert-space terms. Regularities we observe, such as Born-rule frequencies and stable macroscopic records, are explained by

¹⁰ Strictly speaking, Wallace regards the universal quantum state as fundamental, with both the multiverse and its branches emergent. In this context, I will tweak the standard terminology and use ‘multiverse’ as shorthand for ‘universal quantum state’.

the pattern of nearby high-weight branches picked out by decoherence. Although we cannot interact with those other branches, their amplitude structure non-causally determines why observers like us see the statistics we do. This supplies an indirect empirical signature by *local* grounding.¹¹

A more tentative signature appeals to *global* features of the universal state—for instance, its symmetries, Hamiltonian, and overall amplitude distribution. If these global properties fix which statistical patterns are typical across branches, they provide an indirect signature by global grounding. Support of this kind relies on the empirical success of unitary dynamics and decoherence theory; no observations beyond single-branch data are required.

One might also imagine that branches could occasionally leave traces *resembling* causal interactions, through fantastically improbable interference events or anomalies suggestive of ‘cross-branch’ influence. On the Wallace/Wilson EQM picture, however, such phenomena would not amount to literal causal relations between branches. Rather, they would be mediated by the universal quantum state in virtue of which all branches exist. What looks from within a branch like a causal trace is, at the fundamental level, an indirect grounding signature with the phenomenology of causation. If such extraordinarily rare, apparently causal yet ultimately grounding-mediated connections were ever observed, they would provide striking empirical confirmation of *unitarity*, even if they could not discriminate Everett from its unitary rivals.¹²

Finally, because EQM presupposes exact unitarity, any empirically confirmed departure from Schrödinger dynamics would falsify the EQM multiverse picture outright. Spontaneous-collapse theories such as GRW and CSL engineer precisely such departures by adding stochastic, non-linear terms to the Schrödinger equation, terms which in the formalism entail faint but definite empirical signatures: a universal background of spontaneous X-ray emission (and, for some variants, γ -ray emission) and a mass-dependent loss of interference in matter-wave experiments. Recent underground X-ray searches (e.g., the 2025 XENONnT analysis) and high-precision interferometry have already excluded much of the parameter space originally deemed natural for CSL, pushing the remaining window into an ever-narrower corner (Aprile and al., 2025). The situation looks increas-

¹¹ I set aside the separate ‘probability problem’ for Everettian quantum mechanics. Critics argue that, absent a satisfactory derivation of the Born rule, Everett fails independently of empirical considerations. Friederich (2021, ch. 6) surveys attempts to justify Everettian probabilities and remains skeptical. This concern could indeed undermine the internal coherence of the Everettian multiverse, but it is orthogonal to my aim here, which is to assess whether Everett, *if coherent*, could in principle admit empirical signatures.

¹² Recoherence events, namely extremely improbable reinterference of decohered branches, would differ from mere statistical anomalies. The latter occur equally in single-universe scenarios and so lack truth-conducive force. By contrast, recoherence is strictly impossible in collapse theories but allowed in any exactly unitary framework, including Everettian QM, Bohmian mechanics, and consistent-histories approaches. Such events would therefore be, in principle, a genuine though vanishingly unlikely signature of unitarity, even if they could not single out EQM among its unitary rivals.

ingly bleak for spontaneous collapse models, but this highlights an important point: EQM is directly falsifiable in principle.

The epistemic situation is asymmetric. On the one hand, detection of the predicted collapse signals would refute all strictly unitary interpretations in one stroke, Everettian or otherwise. On the other hand, continued null results cannot single out EQM, but instead confirm only the broader disjunction that some exactly unitary interpretation (e.g., Bohmian, consistent histories, relational, modal) is correct. Within this family, EQM affords empirical signatures primarily indirectly and non-causally. Its signatures are *local* (via the decoherence-defined, amplitude-weighted neighbourhood grounding Born-rule regularities) and, more speculatively, *global* (via large-scale properties of the universal state). In rare cases, such signatures might even conceivably appear within a branch as if they were causal traces of other branches, though fundamentally they remain grounded in the universal state. Accordingly, EQM gains support insofar as exactly unitary quantum theory and decoherence continue to succeed across new regimes, while collapse-like deviations are further constrained.

Because these indirect signatures are shared with other strictly unitary contenders, they do not single out EQM on empirical grounds alone. By contrast, confirmed non-unitarity would directly falsify the entire unitary family, Everettian or otherwise. This is why the situation is asymmetric: accumulating positive evidence strengthens only the general case for unitarity, while negative evidence could decisively refute it—and with it EQM in particular.

Whether underdetermination among the unitary options can be broken in the future is an open question, but there is at least one principled route: if EQM were the only unitary approach able to extend coherently to relativistic QFT and, eventually, quantum gravity. For illustration, Wallace (2023) argues that no empirically successful *interacting* QFT generalizations currently exist for GRW/CSL, and—more interestingly for our purposes—for Bohmian mechanics. Constraints of this kind, whether grounded in QFT or in a theory of quantum gravity, could potentially provide an empirical basis for preferring EQM over its unitary rivals.

In sum, EQM exemplifies a holistic multiverse scenario: the universal quantum state is the unifying structure grounding all branches. Empirical access, in the strict sense, is possible indirectly via local and global grounding signatures. In addition, EQM is open to falsification, since any confirmed departure from unitarity would undermine the entire multiverse picture. This asymmetry highlights both the resilience and the vulnerability of EQM within the unitary family of interpretations.

5.2. Eternal Inflation

In contemporary cosmology, the inflationary paradigm was originally introduced to explain several otherwise puzzling features of the early universe: its large-scale smoothness, its uniformity in all directions, and its near-perfect spatial flatness. The idea is that, in its earliest moments, the universe underwent a brief period of extremely rapid expansion.

This early phase accounts for the pattern of fluctuations observed in the CMB and for the distribution of galaxies on large scales. Inflation itself already faces a number of challenges about testability, model-building, and permanent underdetermination, that I will set aside here (see, e.g., Dawid and McCoy, 2023; Wolf and Read, 2025).

What is remarkable is that in wide classes of inflationary models, once inflation begins it does not end everywhere. Some regions stop inflating, while others continue indefinitely, so that on the largest scale the process never terminates. New bubble universes constantly form within the inflating background, each undergoing its own local big bang and evolving in causal isolation from the rest.¹³ This is the scenario known as *eternal inflation*. The eternity in play refers to endless continuation into the future; call this property *sempiternity*. Eternal inflation thus posits a sempiternal inflaton field: it has no natural termination in the forward temporal directions, without implying anything about its temporal past. While many working in the inflationary tradition regard eternal inflation as the natural outcome once quantum fluctuations are included (see Guth, 2007), others, most prominently Ijjas, Steinhardt, and Loeb (2013), dispute this, maintaining that the models consistent with current data do not naturally lead to sempiternity (see Dawid and McCoy, 2023).

This debate sets the stage for a conditional epistemic schema. First, suppose inflation is empirically established as the correct description of the early universe. Many already take this to be the case.¹⁴ Second, suppose it is shown that the specific kind of inflation realized in our universe *necessarily* entails sempiternity.¹⁵ Then the same data that confirm inflation locally would, by the structure of the theory, also confirm eternal inflation globally. On my framework, this is a paradigmatic case of indirect empirical access: local signatures of inflation become global-grounding signatures of a multiverse, since the universes are generated as consequences of a single inflating structure, which itself entails the existence of a multiverse.

Some models of eternal inflation also make room for direct causal traces. For instance, if another bubble collided with ours in the very early stages of its formation, the impact could leave a distinctive imprint on the CMB or contribute to a stochastic gravitational-wave background. Statistical anomalies in the large-scale structure of the universe could also be probed for multiversal origins. As Carroll (2019, 6) emphasizes, the fact that any subclass of multiverse models can be empirically constrained is already a significant

¹³ There are at least two distinct physical routes to this outcome. In one family of models, the inflating state is metastable: it does eventually decay, but so slowly that expansion always outruns the decay, and the total inflating volume continues to grow. In another, quantum fluctuations occasionally restart inflation locally.

¹⁴ On a broad reading, even Penrose’s Conformal Cyclic Cosmology (CCC), discussed below, could be interpreted as an inflationary theory; one in which the inflationary phase occurs before rather than after the big bang.

¹⁵ Here ‘necessity’ should be read in a broad sense: not logical necessity, but the claim that once the relevant inflationary dynamics are in place, eternal continuation follows with overwhelming probability.

epistemic achievement. Were such a trace ever detected, it would amount to high-severity confirmation: the kind of specific and risky prediction that no equally simple alternatives could reproduce.

Here the epistemic situation is asymmetric. If we are fortunate enough to inhabit a region of the multiverse that carries such a trace, we could empirically establish the theory on solid ground. But if we are not—if no collisions happened in our causal past—then the absence of a trace tells us nothing against eternal inflation, since none was expected in the first place. Being methodologically lucky enough to be in the ‘right’ spacetime would therefore make all the difference. The situation is analogous to the 1919 solar eclipse: general relativity was spectacularly confirmed by Eddington’s expedition, but had there been no eclipse at the right time and place, that absence would not have counted as evidence against Einstein’s theory.¹⁶

Clearly, eternal inflation models are candidates for holistic multiverses, since the inflaton field plays the role of an overarching unifying structure. In my usage, however, holism includes an additional epistemic condition: the multiversal structure must be, at least in part, and in principle, accessible from within universes. And there is a specific obstacle to this transparency, widely discussed in the literature: the *measure problem*.¹⁷

The measure problem is that eternal inflation generically produces infinitely many bubbles, each with different properties. To make predictions, we need a way of saying what a typical bubble is, so that we can ask what observers like us should expect to see. But with infinitely many bubbles, different ways of ranking or weighting them can make almost any outcome look typical. Without a principled notion of typicality, the theory risks becoming unconstrained and untestable.¹⁸

Yet following Carroll (2019), I take the problem to be a live technical challenge rather than a decisive objection. Any probabilistic theory requires a measure, and cosmologists already extract meaningful constraints from measures motivated by the physics. One optimistic scenario, which I find hard to rule out completely, is that the measure need not be stipulated at all, but could instead fall out of the physics. On this view, a future theory of quantum gravity, or a suitably constrained quantum cosmological framework, might determine both the admissible dynamical models and their relative weights.

This is quite a natural idea once we distinguish physical possibility from mere logical possibility: the space of what the laws allow is not coextensive with what we can conceive

¹⁶ My thanks to Jacob A. Barandes for raising this point at the Multiverse conference.

¹⁷ It can be read as a particular instance of what will be discussed in the next section as the epistemic isolation objection, namely that the physics of the actual universe can screen off the broader physics.

¹⁸ This problem needs to be solved in order to address another issue of measure, in relation to fine-tuning. In this context, proponents of the multiverse explanation of fine-tuning must show that, among the rare universes that support life, ours is statistically typical. If the vacuum energy, Higgs mass, or other parameters of our universe remained atypical even within the life-permitting subset, then the multiverse would fail as an explanation of fine-tuning. This is an important issue in its own right, but it is orthogonal to my focus here on fine-tuning-independent avenues of empirical support.

of, a priori. As our understanding of physics deepens, the space of physical possibilities typically shifts, and may well narrow. Since typicality attaches to dynamical possibilities rather than to a priori conceivabilities, theory change can reshape what counts as typical. A sufficiently constraining new theory, say of quantum gravity or cosmology, could in principle enforce a natural set of typicality measures, just as the Born rule does in ordinary quantum mechanics. This remains speculative, and my point is not to defend the scenario but to emphasize that it cannot be ruled out. Its realization would restore the empiricity of the eternal inflation multiverse.

Eternal inflation thus exemplifies two channels in my signature typology: (i) direct causal traces, which would deliver severe confirmation if they occurred in our past light cone, and (ii) indirect global signatures via global grounding, conditional on progress in resolving the measure problem. The first route depends on contingent observational luck; the second on theoretical advances that narrow the model space and constrain typicality, so that predictions become genuinely testable.

In sum, eternal inflation illustrates both the promise and the challenges of empirical access: the theory is holistic in structure, but whether it satisfies the transparency condition depends on resolving the measure problem or, failing that, on observational luck.

5.3. String Theory

As a candidate theory of quantum gravity, string theory does not yield a single world but an immense multiplicity of consistent possibilities. In the semantic sense of scientific theories, these are models of the theory: mathematical structures that satisfy its core principles. Each model encodes, in its geometry and associated structures, the features that would shape a concrete universe with its macroscopic properties: its particles, its constants, its effective laws. The sheer abundance of such models, often estimated at numbers as high as 10^{500} , is what has come to be called the string landscape.

At the first level, the landscape is simply the mathematical space of solutions to string theory, following Susskind’s influential definition (Susskind, 2005, 574). Different choices of compactification manifolds, brane configurations, and other mathematical objects yield an enormous class of consistent solutions. This is a familiar feature of many physical theories: general relativity, for example, also admits a vast space of solutions. At this stage, however, there is no multiverse—only a catalogue of dynamically possible models. The mere existence of many solutions is not yet a threat to empirical predictivity, since, as James Read and I have argued elsewhere (Read and Le Bihan, 2021), we do not even have one string solution demonstrably compatible with all observed data. There is therefore no immediate problem of underdetermination among multiple empirically adequate solutions.

At the second level, one may add a physical existence thesis: that many (or all) of the solutions in the landscape are actually instantiated as separate universes. This move reifies the solution space into a multiverse. Whether the resulting multiverse is fragmented or holistic then depends on the motivations and on the presence (or absence) of a unifying,

empirically motivated mechanism that generates or grounds the universes.

If the reification is driven by *a priori* considerations—whether theological or scientific in the broad sense of appealing to scientific yet non-empirical principles—it lacks an empirically grounded generative dynamics. Such motivations are what Read and I have called ‘rationalist’ (Read and Le Bihan, 2021): for example, the desire to explain away apparent arbitrariness in parameters or initial conditions by insisting that all possibilities must be realized, or more generally by insisting on the principle of sufficient reason, namely that everything must have a reason (Unger and Smolin, 2015). In this setting, the landscape is fragmented: the solutions are simply posited side by side, with no overarching structure to unify them and no route to empirical access.¹⁹

By contrast, if the reification is tied to *empirical* considerations, the landscape can become physically reified via an empirically motivated mechanism that causally generates or metaphysically grounds the universes. In this setting the picture becomes holistic, since the universes are no longer a disconnected menu but parts of a structured whole. Several candidates for such mechanisms have been proposed:

1. Eternal inflation can populate different regions of the landscape with bubble universes formed by tunnelling between different vacua, i.e., universes with different geometries and entities (see, e.g., Susskind 2005; Tegmark 2007; Freivogel 2011). In the literature, eternal inflation and the string landscape are often run together as if their association were automatic. Yet eternal inflation was originally proposed as an extension of inflationary cosmology, not string theory, and there is no principled reason why it should select string theory rather than some alternative candidate for quantum gravity.
2. Brane cosmology posits a higher-dimensional 10- or 11-dimensional spacetime in which our universe is a 3-brane (Papantonopoulos, 2002). Cosmological phenomena such as brane collisions can generate new universes, and some scenarios even link brane interactions to observable signatures such as dark matter or dark energy.
3. Everettian quantum mechanics can be seen as generating a branching structure in which different branches instantiate different effective vacua, provided one accepts a unification of the quantum and string-theoretic pictures (see, e.g., Aguirre and Tegmark 2011).
4. Other cosmological mechanisms might also play this role, if they dynamically connect or generate string vacua in ways consistent with observation.

¹⁹ There is, of course, no *physical* or otherwise empirically tractable structure here. A rationalist might still insist that reality has a purely logical or rational order, something on which epistemic agents can plug directly, without the mediation of the natural world. But such a structure would not qualify as the kind that makes a multiverse holistic in my sense.

Only at this holistic stage does the string landscape multiverse become a genuine candidate for empirical signatures. Which signatures are available then depends entirely on the broader multiversal framework into which the landscape is embedded: causal traces in the case of eternal inflation, amplitude weightings in the case of Everett, brane-induced phenomena in the case of higher-dimensional cosmologies, and so on. Absent such embedding, the landscape remains a fragmented multiverse scenario: a mere catalogue of possibilities, empirically inert.

5.4. Cyclic Models: Conformal Cyclic Cosmology

While the notion dates back at least to the Stoic cosmology and the doctrine of ekpyrosis—the destruction and rebirth of the cosmos—modern theoretical physics has revived cyclic models within general relativity and quantum cosmology. Cyclic models regard our observable universe as just one epoch in a succession of temporally ordered universes. Unlike the more standard conceptions of multiverses, the other universes stand in continuity with our own, with later universes causally or physically related to earlier ones. This opens the door to direct causal signatures if traces of previous universes survive into the next.

They come in a wide variety of models (see, e.g., loop quantum cosmology bounce models: Bojowald, 2008 and Huggett and Wüthrich, 2018 for philosophical discussion; cyclic brane cosmologies: Steinhardt and Turok, 2002; or Penrose’s conformal cyclic cosmology: Penrose, 2010). Viewing cyclic cosmologies as instances of a multiverse scenario relies on an auxiliary assumption, namely eternalism: all of the successive universes co-exist *simpliciter*, and can be existentially quantified over. The succession can happen in time, or in a broader, ordering structure similar enough to time to justify the eternalist talk.²⁰

I will focus on a particular realization of this idea, with Penrose’s conformal cyclic cosmology (CCC), in which the remote future of one universe is conformally rescaled to become the Big Bang of the next (Penrose, 2006, 2010, 2014; Meissner and Penrose, 2025)—see Le Bihan (2024) for a presentation aimed at philosophers. This continuity is based on the observation that massless particles, such as photons and gravitons, are insensitive to scale and thus could traverse from one universe to the next without obstruction. CCC predicts that specific observational imprints from the previous universe should be encoded in the CMB.

Two classes of empirical signatures are especially emphasized. First, concentric low-variance circles in the CMB temperature map could arise from violent events such as black hole mergers in the previous universe, whose radiation, associated to massless particles, propagates through the conformal boundary. Second, Penrose predicts the existence

²⁰ As I have argued elsewhere, eternalism is only contingently tied to time, what matters is that all the proper parts of the considered ontic structure co-exist *simpliciter* (Le Bihan, 2020).

of Hawking points: localized bright spots in the CMB resulting from the final bursts of Hawking radiation emitted by supermassive black holes just before their complete evaporation. These predictions are being investigated in current observational cosmology, and evaluation of the data remains highly controversial (An et al., 2020; Bodnia et al., 2024; Jow and Scott, 2020; Lopez et al., 2021).

Thus, CCC offers another compelling counterexample to the claim that multiverse hypotheses are inherently untestable. Penrose’s model shows how a temporally structured multiverse can, in principle, leave observable traces in our current universe, via mechanisms grounded in known physical processes (e.g., black hole evaporation and the conformal invariance of radiation). Moreover, CCC aims to provide an explanation for the low-entropy condition of the early universe—the so-called past hypothesis—by arguing that black holes in the late stages of one universe act as entropy sinks, resetting the conditions for the next. While speculative, this makes CCC one of the few multiverse scenarios to combine theoretical continuity, explanatory power, and empirical testability.

In sum, Penrose’s CCC exemplifies yet another species of holistic multiverse. The succession of universes is governed by a unifying conformal structure that relates the parts, rather than leaving each universe metaphysically isolated. What makes CCC and cyclic models especially distinctive among the class of multiverse scenarios is the temporal continuity between universes: because successive universes are connected along past-directed timelike paths, observable signals from earlier universes could in principle propagate into ours. This makes the prospect of direct causal signatures more promising. While these predictions remain controversial, they illustrate how cyclic cosmologies, no less than inflationary or Everettian frameworks, embed universes in a broader explanatory structure that in principle admits empirical access, and in this case through especially direct causal channels.

5.5. Spacetime Emergence

Finally, let us describe in more details the option introduced in Subsection 4.1, that non-spatiotemporal causation could directly connect spatiotemporally disconnected universes. In prospective quantum-gravity theories, such as *string theory*, *loop quantum gravity*, and *causal set theory*, spacetime, or at least some of its core properties, are construed as emerging from a relatively more fundamental non-spatiotemporal structure (for philosophical introductions, see e.g., Huggett and Wüthrich, 2025; Wüthrich et al., 2021). This suggests an intriguing possibility: spatiotemporal worlds might be *grounded* in a non-spatiotemporal multiversal structure, so that even if universes are disconnected at the emergent spacetime level, they could still be *causally connected* at the fundamental level by relations within a connected non-spatiotemporal ground. To be clear, grounding here is a cross-level explanatory dependence, whereas causation is within-level; the claim is that a causally connected fundamental base can ground multiple emergent spacetimes.

A concrete illustration comes from *causal set theory*, where the fundamental structure is a discrete partial order over elements that come into existence one by one, without

spatial or temporal metrics (for a philosophical introduction, see Huggett and Wüthrich, 2025; Wüthrich, 2024). Spacetime distances then emerge from this underlying order. On many readings, causal set theory suggests that the physical world is fundamentally causal (Baron and Le Bihan, 2025), exemplifying the more general possibility that spacetime is composed from relatively more fundamental causal relations (Baron and Le Bihan, 2022, 2024). If such (admittedly speculative) models are correct, then universes that are observationally and causally disconnected *in spacetime* might nonetheless exert detectable influence *from within* via their joint presence in, and causal relations across, the more fundamental causal structure.

How exactly this might occur remains speculative, but an illustrative example is provided by *brane cosmology* (Papantonopoulos, 2002). In brane cosmology, phenomena such as dark matter or dark energy could potentially be understood as indirect effects of interactions between our observable three-dimensional space and other branes—that is, other universes—situated within a higher-dimensional spacetime. For instance, dark matter, which refers to gravitational effects observed in the absence of ordinary observable matter, could result from gravitational waves propagating in the higher-dimensional space between our three-dimensional universe and others. While some interactions, such as electromagnetism, would be confined to individual branes, gravity could extend into the higher-dimensional spacetime, thereby explaining why we observe gravitational effects without corresponding observable matter (in particular, because photons would remain trapped within each brane). Although each three-dimensional brane would be largely shielded from direct interaction with the others because of spatial separation, they could nonetheless remain causally connected via the higher-dimensional spacetime.

However, the analogy between brane cosmology and spacetime emergence is limited since the higher-dimensional structure of brane cosmology hosting the three-dimensional universes remains spatiotemporal, unlike in other approaches to quantum gravity, including other interpretations of string theory.²¹ However, quantum gravity theories suggest the possibility that the larger structure within which these universes exist need not itself be spatiotemporal. This theoretical insight thus opens the possibility of non-spatiotemporal causal interactions between universes. This scenario introduces the concept of *non-spatiotemporal causal signature*, broadening our conception of what empirical access

²¹ Brane cosmology, for the technically inclined reader, presupposes an ontology of open strings with endpoints confined to higher-dimensional regions—D-branes—on which gauge interactions are localized. This ontological commitment excludes the heterotic superstring theories from offering an equally literal or insightful account, since they contain only closed strings and lack D-branes (Le Bihan, 2023). As such, brane cosmology requires a discriminatory stance on duality, challenging the view that all dual descriptions are ontologically equivalent (Le Bihan and Read, 2018), and pushing against claims about the emergence of spacetime in string theory that rely on a non-discriminatory approach to duality (Huggett, 2017; Huggett and Wüthrich, 2025). Accordingly, brane cosmology should not be seen as a case of spacetime emergence in the usual sense, where the emergent base is non-spatiotemporal.

might involve. Such access would transcend spacetime while remaining causal and—possibly and to some extent—direct. This perspective suggests that the empirical signature of multiverse scenarios could, at least in principle, arise through causal structures extending beyond the standard spatiotemporal causation.

6. Generalizing and Addressing the ‘This Universe’ Objection

The core question of this paper is whether our universe could provide empirical support for multiverse scenarios. A natural challenge to that idea is what I call the epistemic isolation objection, the claim that universes are physically and metaphysically closed, and hence epistemically closed, so that no facts about other universes, including their existence, could ever bear on empirically accessible data in our own. If taken seriously, this objection blocks the very possibility of empirical signature for any multiverse hypothesis, since no data within one universe could, in principle, constrain belief about others.

This objection generalizes the ‘this universe’ objection (TUO) of Hacking (1987) and White (2003), which in its standard form targets multiverse-based explanations of fine-tuning. The argument is that the existence of other universes with different parameter values has no bearing on the values in this particular universe, and thus a multiverse cannot explain why ‘this’ universe appears fine-tuned for life. As usually formulated, it tacitly assumes that the constants of our universe are brute facts and independent of any wider explanatory structure. Although I have expressed skepticism about the probative weight of fine-tuning arguments (see Section 1), I do not think the TUO successfully undercuts them.

First, I agree with Ruyant (2025) that the TUO fails, even under traditional, *a priori* reasoning. Ruyant shows that the objection mistakes a self-locating datum for genuine empirical evidence: the fact that we find ourselves in a life-permitting universe is a trivial observation, equally expected on both multiverse and single-universe hypotheses, and so it carries no evidential weight one way or the other.

Second, another appealing reply, because it is empirically flavoured, is offered by Manson and Thrush (2003). They argue that the TUO implicitly assumes that parameter values are metaphysically contingent, whereas in physical practice they are treated as essential to the models of their respective universes. Moving to metaphysical ground: universes essentially instantiate those quantitative properties. In response, it has been argued that the essentialist diagnosis is not essential to the objection. For example, Boyce (forthcoming) develops a formal probabilistic strategy designed to preserve the TUO without relying on essentialist background commitments.

However, even these more sophisticated formulations inherit two tacit presuppositions: (i) independence of parameter values, i.e. the constants of our universe are probabilistically independent of what happens in other universes (since there is no mechanism connecting them); and (ii) bruteness/arbitrariness, i.e. those constants are treated as primitive facts about ‘this’ universe, not explained by or determined from a wider structure.

Once these presuppositions are denied, as they are in scientific multiverse practice, where universes are generated or constrained by a common mechanism, the TUO dissolves.

This is why the whole debate remains confined to what I call the ‘*this universe objection*’ *a priori* battlefield: intricate disputes over how Bayesian treatments of our evidence interact with fine-tuning arguments.²² To physicists, this often looks like debating how many angels can dance on a pinhead—technically sophisticated, but detached from the explanatory practices that actually motivate multiverse hypotheses in relation to the nature of universes.

What I propose instead is to build on and refine Manson and Thrush’s essentialist insight by making explicit the explanatory mechanism that gives rise to the essentialist belief. The central idea is this: physicists introduce multiverse hypotheses as broader structures that determine the parameter values or features of individual universes. Universes are not isolated islands with brute, arbitrary constants; their specific values are embedded in and explained by a broader framework ontologically committed to determination relations between the multiverse and the universes. The essentiality of those parameters is then only an indirect byproduct of that metaphysical relation of determination (causation or grounding).

At bottom, both the TUO and epistemic isolation objections rest on a shared denial: they reject that there is any substantive explanatory or metaphysical determination relation between the multiverse and the universes it contains. But, as I have argued, in scientific practice, deploying multiverse hypotheses almost always presupposes some form of ontic determination from the multiverse to the parameters or features of a given universe. In other words, scientific multiverses are virtually always holistic multiverses.²³

Philosophers have usually tried to adjudicate the existence of the multiverse *a priori*, often deploying Bayesian coherence arguments or other idealized reasoning strategies. This is where the ‘this universe objection’ *a priori* battlefield sits. But here lies the mistake: such Bayesian frameworks tend to conflate idealized *a priori* coherence with empirical access to the structure of reality. They move too quickly from ‘what rationally ought to be believed’ to ‘what metaphysically is’. By contrast, in the scientific multiverse contexts I am concerned with, determination is not an optional metaphysical ornament but part of the explanatory machinery of the theory itself. The multiverse is introduced to account for distributions of features, so the determination relation is empirically motivated rather than a projection of abstract rationalist priors.

²² See Friederich (2021) for detailed discussion. He argues that the ‘improbability’ at stake in fine-tuning is best construed as a matter of subjective credence, which absent an independently motivated measure does not by itself supply positive confirmation (ch. 2). He also develops more specific worries about background-information choices (ch. 7), indeterminate observer reference classes in anthropic reasoning (ch. 8), and the limited role of self-locating beliefs (ch. 9).

²³ As we have seen in the previous section, the string theory landscape, taken in isolation, is a counterexample: without coupling to a concrete cosmological mechanism, it can function as a rationally motivated fragmented multiverse.

From this perspective, the TUO and epistemic isolation objections no longer function as neutral constraints. Instead, they conflict with the very explanatory rationale that motivates scientific multiverses. If the determination relation between the multiverse and our universe is denied, the multiverse loses its explanatory efficiency and the objections regain their force. If, on the other hand, that relation is acknowledged—if our universe is in fact determined by a broader multiversal structure—then two consequences follow: first, the TUO loses its bite, because the relevant parameters are not isolated contingencies but determined outcomes; second, our universe is no longer epistemically isolated, and empirical support for the multiverse from within a single universe becomes at least in principle possible.

The contrast between fragmented and holistic multiverses, and the realization that scientific multiverses are almost always holistic, helps explain why, as Manson (2020, 40) notes, scientists never invoke the TUO in working practice. Scientific multiverses are introduced precisely to supply explanatory determination, causal or otherwise, linking the multiverse to individual universes. Severing that determination collapses the very rationale for positing the multiverse in those contexts. Thus the objection finds traction mainly in philosophical discussions that abstract away from explicit multiverse scenarios in physics and rely instead on a priori or coherence-based reasoning untethered from the explanatory frameworks that gave rise to multiverse hypotheses in the first place.

In sum, if our universe is determined by a broader multiverse structure, explanatory links and empirical signature follow naturally; if each universe is metaphysically independent, both the TUO and epistemic isolation objections regain full force. Scientific multiverses, by embedding determination relations into their explanatory architecture, are typically holistic, thereby neutralizing those objections and making empirical support from within a single universe possible in principle.

7. Conclusion

The first two objections often raised against multiverse scenarios, that they posit unobservable entities and that they lack *current* empirical support, were shown to be weak. Science standardly posits unobservables when they yield explanatory and predictive success, and the absence of present confirmation is no bar to future testability. The more serious challenge is the third: the claim that multiverses could not, even in principle, receive empirical support. This chapter has argued that the force of that objection depends on the *metaphysical profile* of the multiverse in question.

Fragmented multiverses lack any intrinsic features that could, even in principle, be empirically accessible from within a single universe. Their architecture is not governed by a unified physical mechanism, but rather posited externally or theologically. Any connection between the universes in such a model is purely non-physical, and can only be defended on a priori grounds. From an empiricist perspective, such fragmented multiverses are effectively invisible: they cannot explain observable features of our world and

fall outside the scope of confirmation. However, they might still be scientific, in an unexpected way.

As Christian Wüthrich argues, if spacetime emerges from a non-spatiotemporal structure in quantum gravity, then David Lewis’s modal realism, understood as a kind of fragmented multiverse, conflicts with the actual structure of reality (Wüthrich, 2020). For Lewis, spatiotemporal causation is the world-making relation; if spacetime is not fundamental, that relation cannot serve its intended role. Thus, even though fragmented multiverses cannot leave an empirical signature within our universe, one can still learn that a once-legitimate scenario is inconsistent with the best available physics. In this sense, at least some fragmented multiverses can admit of empirical falsification.

Holistic multiverses, by contrast, posit a unifying structure—such as a universal quantum state, an inflating field, or a pattern of dynamical laws—that governs the generation or character of the universes they contain. This structure is explanatory in a way that can ground empirical features within individual universes. Scientific multiverse proposals typically assume such grounding relations. They are not merely frameworks based on purely a priori speculation, but ones that offer testable consequences, explanatory power, and integration with our best physical theories. Their potential confirmation or refutation could proceed via direct causal traces (e.g., bubble collisions), local grounding (e.g., interference patterns in EQM), or global grounding (e.g., the distribution of bubble universes).

Here the epistemic asymmetry runs the other way: holistic multiverses admit of empirical confirmation in principle, but they are more resistant to refutation. For instance, in eternal inflation the *measure problem* makes ensemble-level predictions highly flexible, while the absence of bubble-collision traces in the CMB does not count as strong disconfirmation (since most universes would lack such traces). In Everettian quantum mechanics, exact unitarity and decoherence generate indirect empirical signatures, but these do not uniquely select EQM over other unitary interpretations; only the detection of a collapse signal would serve as a decisive refutation. Thus holistic multiverses are open to empirical confirmation of certain kinds, but structurally resistant to empirical defeat.

In short, the epistemic profiles are asymmetric: fragmented multiverses are closed to confirmation but open to global-level falsification, whereas holistic multiverses admit confirmation but resist refutation. What both cases reveal is that the ‘this universe’ and epistemic isolation objections depend precisely on denying holistic structure. Once determination relations are acknowledged, those objections collapse, and empirical access becomes possible. The stronger claim that multiverse hypotheses are inherently and universally untestable, and therefore unscientific, is therefore misguided. At least some multiverse scenarios are open to empirical investigation, while others remain subject to indirect constraint via incompatibility with physics. This helps to explain why physicists themselves rarely engage with the ‘this universe’ objection: in practice, multiverse scenarios are introduced as explanatory frameworks embedding universes in broader structures that allow for empirical signatures.

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