

28. Reduction, Proliferation, or Constraint? On Competing Foundational Commitments in Cosmology

An examination of three disparate strategies that account for regularity in the cosmos, and the costs of each.

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Abstract

Contemporary cosmology accounts with impressive precision for a wide range of observations, yet does so through frameworks that differ markedly in what they assume, exclude, or protect from failure. This paper examines three broad strategies by which cosmological regularity is commonly accounted for: dynamical proliferation, ontological reduction, and global constraint. Rather than comparing models on the basis of empirical fit, the discussion focuses on the foundational commitments each strategy entails and the explanatory costs those commitments incur.

Proliferation secures regularity by supplementing an otherwise permissive dynamical framework, trading necessity for adaptability. Reduction dissolves the problem by eliminating time and

dynamics from the fundamental ontology, trading causal explanation for conceptual economy. Constraint retains time and evolution, but enforces regularity by restricting the class of admissible cosmological solutions, trading flexibility for exposure to decisive failure.

By placing these strategies on common scales, the paper aims to recover a criterion for cosmological explanation that has become obscured by empirical success alone. The comparison does not endorse a particular framework, but argues that constraint represents a distinct and legitimate foundational commitment, one that restores discrimination, risk, and responsibility to cosmological explanation.

1. Introduction

Modern cosmology is marked by an unusual combination of empirical success and conceptual unease. A small number of frameworks account with remarkable precision for a wide range of observations, yet do so by adopting markedly different assumptions about what must exist, what may vary, and what must be taken as given. Despite this diversity, these differences are often treated as secondary to questions of data fitting or parameter estimation. As a result, distinct explanatory strategies are frequently compared as though they differed only in detail, rather than in kind.

This paper takes a different approach. Its concern is not which cosmological framework fits the available data most effectively, but how different frameworks account for the striking regularity of the cosmos in the first place. In particular, it examines the foundational commitments that underlie three broad strategies commonly employed to secure such regularity, and considers the costs each strategy incurs in doing so.

The first strategy, dominant in standard cosmology, retains a flexible dynamical framework and accounts for regularity by introducing additional components, degrees

of freedom, or tuned initial conditions as required. The second, exemplified by radically reductionist approaches, seeks to dissolve the problem by eliminating time, dynamics, or causal structure altogether. The third, explored here through a constraint-based framework, retains time and evolution but imposes a fixed global restriction on the class of admissible cosmological solutions. Each strategy is internally coherent, and each can be made compatible with existing observations. What distinguishes them are not their empirical ambitions, but the commitments they are prepared to make in order to achieve them.

The purpose of this paper is therefore comparative and diagnostic rather than programmatic. It does not propose a new cosmological model, nor does it seek to adjudicate between frameworks on the basis of parameter counts or goodness-of-fit statistics. Instead, it places these three strategies side by side in order to make explicit the assumptions they rely upon, the freedoms they permit, and the explanatory burdens they shift elsewhere. In doing so, it aims to clarify what is often left implicit: that cosmology routinely trades one kind of explanatory cost for another.

The exercise may be likened, loosely, to the recovery of a Golden Fleece rather than the conquest of new territory. What is sought is not a final theory, nor a privileged position from which all others are judged wanting, but a shared criterion by which competing approaches can be weighed. The undertaking is necessarily collective, and its success lies not in victory but in retrieval: in bringing back into view the question of what cosmology is prepared to assume, to multiply, or to constrain in order to account for the order it observes.

With this aim in mind, the sections that follow examine each of the three strategies in turn, before drawing out the comparative costs they entail. The discussion concludes by considering what is gained, and what is risked, when constraint is treated not as an admission of failure, but as a legitimate foundational commitment.

2. Three strategies for accounting for regularity

Before turning to specific frameworks, it is useful to distinguish the explanatory strategies under consideration from the theories in which they are realised. The concern of this paper is not with the detailed architecture of particular models, but with the broader commitments they embody. Distinct theories may differ in formalism, scope, or empirical emphasis, yet still rely on the same underlying strategy for accounting for cosmological regularity. Conversely, superficially similar theories may diverge sharply once their foundational assumptions are made explicit.

The three strategies examined here are best understood as ideal types. Each represents a coherent and recognisable way of responding to the same underlying question: how a universe governed by broadly local laws comes to exhibit large-scale order, symmetry, and persistence. None of the strategies is presented as a caricature, and no claim is

made that existing theories instantiate them in pure form. Rather, they mark distinct explanatory directions that recur throughout contemporary cosmology.

The first strategy may be described as *proliferation*. It retains a flexible dynamical framework and accounts for regularity by introducing additional ingredients as required. These may take the form of new matter components, new fields, modified interactions, or carefully specified initial conditions. The guiding assumption is that the observed order of the universe is contingent, but can be stabilised by supplementing the dynamics until consistency with observation is achieved. This approach underlies the standard cosmological model and many of its extensions. Its strength lies in its empirical adaptability; its cost lies in the cumulative commitments it accrues in doing so.

The second strategy is *reduction*. Rather than adding further dynamical structure, it seeks to dissolve the problem of regularity by removing elements traditionally regarded as fundamental. Most commonly, this involves denying an ontological role to time, dynamics, or causal succession, and treating apparent evolution as derivative or perspectival. In this view, regularity does not require explanation through history or mechanism, but emerges from static relations within an underlying space of possibilities. Reductionist approaches are conceptually radical, but internally consistent, and they offer a clear demonstration that large-scale order need not be grounded in dynamical evolution as ordinarily understood.

The third strategy is *constraint*. It retains time, dynamics, and spacetime structure, but denies unrestricted freedom in its application. Instead of explaining regularity by elaboration or elimination, it imposes a fixed global restriction on the class of admissible cosmological solutions. Regularity is thereby enforced rather than engineered. On this view, not everything that is dynamically conceivable is physically permitted, and the role of theory is to identify and justify the constraints that limit cosmic behaviour. Constraint is inherently exposed: the restriction it imposes may be wrong, and if so the framework fails outright. Its appeal lies precisely in this vulnerability.

These three strategies exhaust neither the conceptual possibilities nor the diversity of existing work. They are chosen because they represent stable and recognisable responses to the same explanatory pressure, and because each can be pursued while remaining broadly consistent with current observations. What distinguishes them is not empirical intent, but the manner in which explanatory burden is allocated. Proliferation shifts cost into ontology and initial conditions. Reduction shifts it into interpretation and perspective. Constraint concentrates it in a single, explicit assumption that limits what the universe may do.

The sections that follow examine each strategy in turn. The aim is not to declare a winner, but to make clear what is purchased, and at what price, when cosmology chooses one path rather than another.

3. Proliferation: regularity through dynamical supplementation

The first and most familiar strategy for accounting for cosmological regularity is what may be termed *proliferation*. Its defining feature is a willingness to retain a broadly unconstrained dynamical framework while introducing additional ingredients as required to stabilise large-scale behaviour. Regularity, on this view, is not enforced by restriction, but achieved through elaboration.

This strategy underlies the standard cosmological model and many of its extensions.¹ The core dynamical equations are preserved, but supplemented by additional components, parameters, or initial conditions whose role is to reconcile theory with observation. These additions may take diverse forms: new matter sectors, new fields, effective fluids, or finely specified boundary conditions. What unites them is not their physical interpretation, but their function. Each serves to absorb discrepancies between unconstrained dynamics and the regularity that is empirically observed. A more extended examination of this strategy, including its historical development and its cumulative explanatory costs, has been given elsewhere.² The present discussion is intentionally limited to those features required for comparison with the alternative strategies considered here.

Proliferation is often defended on pragmatic grounds. The strategy is flexible, empirically responsive, and well suited to incremental refinement. When observations reveal tensions or anomalies, the framework permits further elaboration without requiring a fundamental rethinking of the underlying dynamical structure. In this respect, proliferation has proved remarkably successful. It has enabled a single broad framework to accommodate a wide range of data across many orders of magnitude in scale.

The explanatory cost of this success, however, is less often examined. Because the dynamical framework remains permissive, regularity must be secured indirectly. Structure, symmetry, and persistence are not consequences of restriction, but outcomes engineered through carefully chosen supplements. As a result, the burden of explanation is progressively displaced onto ontology and initial conditions. Each new ingredient resolves a local difficulty, but does so by increasing the inventory of what must be assumed to exist or to have been set just so.

This displacement has two consequences. First, regularity comes to appear contingent rather than necessary. The observed order of the universe is not enforced by the theory itself, but arises from the particular choice of its components and parameters. Second, explanatory responsibility becomes distributed across many assumptions, none of

¹ Planck Collaboration; *Planck 2018 results. VI. Cosmological parameters*; Astronomy & Astrophysics 641, A6 (2020). Provides the canonical empirical formulation of Λ CDM and exemplifies the proliferation strategy: a permissive dynamical framework stabilised through additional components and parameters rather than global restriction.

² Salisbury, I.; Paper 24 *ante*. *TSPC II: Why the Standard Model Cannot Explain the Universe*.

which individually carries decisive weight. The framework remains robust precisely because no single commitment is exposed to decisive failure.

It is important to emphasise that this feature is not a flaw in the ordinary sense. Proliferation trades fragility for adaptability, and does so deliberately. The strategy reflects a foundational preference: that theoretical freedom is to be preserved, and that discrepancies are best resolved by supplementation rather than restriction. Within this preference, the accumulation of additional structure is not an embarrassment, but an expected consequence of empirical engagement.

Nevertheless, the strategy has limits. As the number of supplementary elements grows, it becomes increasingly difficult to distinguish between explanation and accommodation. Regularity is accounted for, but not compelled. The framework explains why the universe behaves as it does only insofar as the required ingredients are granted. What is not explained is why those ingredients, rather than others, should have been realised.

In this sense, proliferation resolves the problem of regularity operationally rather than structurally. It delivers a working cosmology, but at the cost of leaving the underlying order of the universe contingent upon a growing set of assumptions. The next section considers a contrasting response to this difficulty: one that seeks to dissolve the problem of regularity not by further elaboration, but by removing the need for dynamical explanation altogether.

4. Reduction: regularity without dynamics

The second strategy for accounting for cosmological regularity may be described as *reduction*. In contrast to proliferation, which preserves a flexible dynamical framework and supplements it as required, reduction seeks to dissolve the problem of regularity by eliminating elements traditionally regarded as fundamental. Most commonly, this involves denying an ontological role to time, dynamical evolution, or causal succession, and treating apparent change as derivative rather than basic.

Reductionist approaches begin from the observation that many of the structures invoked to explain cosmological order are not straightforwardly present in the fundamental equations of physics. In particular, time appears ambiguously in both general relativity and quantum theory, and is absent altogether in certain canonical formulations of quantum gravity. From this perspective, appeals to temporal evolution, causal history, or finely tuned initial conditions may be regarded as artefacts of description rather than features of reality itself.

On this view, regularity does not require explanation through dynamical processes unfolding in time. Instead, it is taken to arise from static relations within an underlying space of possibilities. What appears as evolution is reinterpreted as a perspectival ordering of configurations, each of which is equally real. Apparent histories are understood as records embedded within particular configurations, rather than as traces

of an objective past. The problem of regularity is thereby transformed: rather than asking why the universe evolves in an orderly way, one asks why certain configurations exhibit the correlations they do. This reductionist strategy has been articulated most explicitly in the work of Julian Barbour, whose timeless reformulation of dynamics provides a clear and internally consistent example of the approach.³

The appeal of this strategy lies in its economy. By removing time and dynamics from the fundamental ontology, reduction eliminates the need for special initial conditions, fine-tuned parameters, or auxiliary components introduced solely to stabilise cosmic behaviour. Regularity is no longer something that must be produced or maintained; it is simply a feature of certain configurations within the total space of possibilities. In this sense, reduction offers a clear demonstration that large-scale order need not be grounded in dynamical explanation as ordinarily conceived.

The explanatory costs of this move, however, are substantial. First, the strategy relinquishes causal explanation altogether. While correlations may be described, there is no longer an account of why one configuration should be realised rather than another, or why records should be reliable indicators of anything beyond their own internal structure. Second, the distinction between physical necessity and interpretive convenience becomes blurred. Because all admissible configurations are treated as equally real, there is no clear sense in which regularity is enforced rather than merely observed.

A further consequence is that reductionist frameworks are largely insulated from empirical risk. Since observations themselves are configurations within the underlying space, no conceivable measurement can decisively favour a dynamical history over a timeless correlation. This immunity is not a defect in logical consistency, but it does mark a departure from the usual standards by which physical theories are assessed. The price of ontological minimalism is a corresponding thinning of empirical vulnerability.

It is important to stress that reduction is not presented here as a straw position. It is internally coherent, mathematically informed, and philosophically explicit about its commitments. Indeed, it performs a valuable service by revealing how much of conventional cosmological explanation depends on assumptions about time and causation that are not obviously mandated by fundamental physics. As a limit case, it sharpens the question of how much structure must be retained in order for explanation to remain substantive.

³ Barbour, J.; *The End of Time*; Oxford University Press (1999). Classic and explicit articulation of the reductionist strategy, eliminating fundamental time and reinterpreting dynamics as static relations within configuration space.

Barbour, J., Koslowski, T., Mercati, F.; *Identification of a gravitational arrow of time*; Physical Review Letters 113, 181101 (2014). Demonstrates how temporal asymmetry and apparent evolution are recovered within a fundamentally timeless framework, reinforcing the reductionist strategy discussed.

Nevertheless, by removing dynamics entirely, reduction resolves the problem of regularity by redefining it out of existence. Order is no longer something that needs to be explained, only described. The next section considers a contrasting response: one that accepts the reality of time and evolution, but seeks to account for regularity by restricting, rather than supplementing or eliminating, the class of admissible cosmological solutions.

5. Constraint: regularity through restriction

The third strategy for accounting for cosmological regularity may be described as *constraint*. Like reduction, it resists the proliferation of dynamical ingredients introduced to stabilise cosmic behaviour. Like standard cosmology, it retains time, spacetime structure, and dynamical evolution as physically real. What distinguishes it from both is the refusal to grant unrestricted freedom to the space of admissible solutions. Regularity is not engineered through supplementation, nor dissolved through elimination, but enforced by restriction.

Constraint begins from a simple but stringent premise: not every geometry or evolution that is dynamically conceivable is physically permitted. The task of theory is therefore not only to specify equations of motion, but to identify global conditions that limit the class of solutions those equations may admit. On this view, cosmological regularity is not contingent upon a particular arrangement of components or initial conditions, but follows from the fact that large regions of the theoretical solution space are excluded *ab initio*.

This position occupies a narrow conceptual space. It accepts the ontological reality of time and becoming, while denying that dynamics alone is sufficient to explain large-scale order. Concerns of this kind have been articulated by George Ellis and others, who have argued that the elimination of time and causal becoming undermines the explanatory role of cosmology itself.⁴ From this perspective, regularity may be described without dynamics, but cannot be explained without granting time an ontological role. Constraint responds to this diagnosis by retaining temporal evolution, while sharply limiting the ways in which it may unfold.

Within such a framework, regularity is neither an emergent by-product nor a perspectival artefact. It is a consequence of a fixed global condition that all admissible cosmological histories must satisfy. The constraint does not determine the detailed behaviour of the universe, but it does determine the class of behaviours that are

⁴ Ellis, G. F. R.; *The Evolving Block Universe and the nature of time*; Studies in History and Philosophy of Modern Physics 44, 242–262 (2013). Articulates the critique of timeless and fully reductionist accounts, arguing that cosmological explanation requires an ontological role for time and becoming.

Ellis, G. F. R., Stoeger, W. R.; *The 'arrow of time' in cosmology*; Classical and Quantum Gravity 4, 1697–1729 (1987). Early and influential discussion of temporal asymmetry and global structure in cosmology, reinforcing the diagnosis that time cannot be eliminated without explanatory loss.

possible. Dynamics operates within this restricted domain, rather than being called upon to generate order from unconstrained freedom.

The explanatory cost of this strategy is concentrated rather than distributed. By imposing a single explicit restriction, constraint accepts a high degree of vulnerability. If the constraint is inconsistent with observation, or if admissible solutions fail to capture key features of the universe, the framework collapses outright. There is little scope for incremental repair. This exposure is not an accidental feature, but a defining commitment. Constraint replaces adaptability with risk.

At the same time, this concentration of cost brings a corresponding clarity. Regularity is no longer the result of accumulated assumptions or interpretive manoeuvres, but of a single structural decision that can be stated precisely and examined directly. The framework either permits the universe we observe, or it does not. In this respect, constraint restores a form of explanatory discipline that is often diluted in more permissive approaches.

It is important to emphasise that constraint does not aspire to finality. The restriction imposed is postulated, not derived, and its justification lies entirely in its consequences. Nor does the strategy deny the utility or success of alternative approaches within their own terms. Its claim is narrower: that cosmological explanation need not proceed either by elaboration without limit or by elimination without residue. There exists a third possibility, in which regularity is enforced by restriction, and in which the price of order is paid up front rather than deferred.

The following section draws together the three strategies examined here, and places their respective commitments and costs on common scales. The aim is not to resolve the question of which approach is ultimately correct, but to clarify what is gained, and what is risked, when cosmology chooses one path rather than another.

6. Comparing explanatory costs

The three strategies examined above differ less in their empirical aspirations than in the way they allocate explanatory burden. Each succeeds by transferring cost into a different domain: ontology, interpretation, or structural restriction. To compare them meaningfully, it is therefore necessary to make those costs explicit and to consider how they are distributed.

The strategy of proliferation secures regularity by preserving maximal dynamical freedom and supplementing it as required. Its principal cost is ontological. New components, fields, or conditions are introduced to stabilise behaviour that would otherwise remain unconstrained. Because no single assumption carries decisive explanatory weight, the framework is resilient. Discrepancies can be absorbed locally, and failure is deferred rather than concentrated. This adaptability, however, comes at the expense of necessity. Regularity is accommodated, but not compelled, and the overall structure remains contingent upon an expanding inventory of assumptions.

Reduction, by contrast, achieves regularity by relinquishing dynamics altogether. Its cost is interpretive rather than ontological. By denying an ontological role to time, causation, and becoming, reduction dissolves the need for explanation through history or mechanism. Regularity is re-described as static correlation within an underlying space of possibilities. This move eliminates the need for fine-tuning, but it does so by withdrawing from causal explanation entirely. In consequence, reductionist frameworks are largely insulated from empirical risk. Because all observations are themselves configurations within the space considered, there is no clear criterion by which the framework could be falsified without abandoning its foundational stance.

Constraint concentrates explanatory cost more sharply. Rather than distributing it across many assumptions or dissolving it through reinterpretation, constraint accepts a single, explicit restriction on the class of admissible cosmological solutions. Ontological commitments are minimised, and time and dynamics are retained as physically real, but their scope is limited *ab initio*. Regularity is enforced rather than engineered. The cost of this move is exposure. If the imposed restriction fails to admit the universe we observe, there is no auxiliary structure available to absorb the failure. Constraint is therefore intrinsically vulnerable in a way that the other strategies are not.

It is in this sense that falsifiability enters the comparison. Proliferation postpones falsification by dispersing explanatory responsibility; reduction largely evades it by redefining what counts as explanation. Constraint, by contrast, invites it. The restriction imposed either holds or it does not. This does not confer automatic superiority, but it does mark a clear difference in epistemic posture. Constraint treats the risk of outright failure as the price of explanatory discipline.

These differences may be summarised schematically. Proliferation trades necessity for flexibility. Reduction trades causation for economy. Constraint trades adaptability for risk. None of these trades is forced by data alone. Each reflects a foundational commitment about what cosmology is prepared to assume, to multiply, or to forbid in order to account for the order it observes.

The significance of this comparison lies not in selecting a winner, but in restoring visibility to these commitments. When explanatory strategies are assessed solely by their ability to accommodate existing observations, the costs they incur remain hidden. By placing proliferation, reduction, and constraint on common scales, it becomes possible to see not only what each achieves, but what each relinquishes in doing so.

7. Concluding remarks

This paper has not sought to resolve the problem of cosmological regularity, nor to advance a new cosmological model. Its aim has been more limited, and more foundational: to clarify the distinct strategies by which regularity is accounted for, and to make explicit the commitments and costs each strategy entails. By placing

proliferation, reduction, and constraint on common scales, the discussion has attempted to restore visibility to choices that are often treated as neutral or unavoidable.

The comparison reveals that the three strategies differ not primarily in empirical intent, but in explanatory posture. Proliferation preserves dynamical freedom and absorbs irregularity through supplementation, trading necessity for adaptability. Reduction eliminates the need for dynamical explanation by withdrawing time and causation from the fundamental ontology, trading explanatory reach for conceptual economy. Constraint retains time and evolution, but limits their scope through a fixed global restriction, trading flexibility for vulnerability. Each strategy secures regularity, but does so by relocating explanatory burden in a characteristic way.

Seen in this light, disagreements between cosmological frameworks often reflect differences in foundational commitment rather than disputes over data. The persistence of such disagreements, even in the face of increasingly precise observations, suggests that the field is no longer constrained by empirical adequacy alone. What is at issue is how much freedom cosmology is prepared to allow itself, and where the cost of order is to be paid.

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The metaphor of the Golden Fleece therefore serves a more fundamental purpose than illustration alone. In the ancient story, the object of the voyage was not conquest, but the recovery of something precious that had been lost. The aim of this paper is similar. It is not to claim victory for one cosmological framework, nor to displace its rivals, but to recover a criterion that has gradually slipped from view: a clear standard of what should count as explanation in cosmology. The three strategies examined here represent distinct answers to that question. None can be eliminated on empirical grounds alone, but neither are they interchangeable. Each embodies a different judgement about the balance between freedom, economy, and explanatory risk.

Constraint occupies a narrow and exposed position within this landscape. By concentrating explanatory cost in a single explicit restriction, it forgoes the protections afforded by proliferation and the insulation offered by reduction. That exposure is not incidental but deliberate. It reflects the conviction that cosmological explanation should derive regularity from structure itself, rather than accommodate it through successive elaboration or dissolve it through reinterpretation.

The significance of this comparison lies not in the endorsement of any particular framework, but in the recovery of a standard that has become obscured. Cosmology has

become increasingly adept at distributing explanatory cost, deferring failure, or redefining the questions that require explanation. Constraint represents a different judgement: that the price of order should be explicit, localised, and exposed to decisive empirical test. In that sense, the Golden Fleece recovered here is not a cosmological theory, but the recovery of a criterion by which cosmological theories may be judged. It is the recognition that constraint is not an admission of failure, but a legitimate foundational commitment, restoring discrimination, explanatory risk, and intellectual responsibility to cosmological explanation. The question is no longer whether constraint is permissible, but whether it deserves to stand alongside proliferation and reduction as one of the field's fundamental explanatory strategies. Beyond that point, metaphor has done its work. What remains is the ordinary business of physics: calculation, consistency, and confrontation with observation.

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