Explicit Constraints and Failure Modes of Response-Based Cosmological Frameworks

Adam Sheldrick[1]

[1] *Independent Researcher*

(Dated: February 7, 2026)

Frameworks that treat spacetime phenomena as emergent from finite response dynamics offer a coherent way to reconcile causal propagation, relaxation, and boundary thermodynamics with established physical limits. However, such frameworks are viable only if they satisfy stringent empirical and theoretical constraints. In this work, we systematically identify the explicit constraints that any response-based cosmology must obey in order to remain consistent with general relativity, quantum field theory, and precision cosmological observations. We then catalogue the corresponding failure modes that would decisively falsify such frameworks. This analysis is model-independent and applies broadly to any approach that attributes effective response properties to spacetime. The result is a clear delineation of the narrow domain in which response-based cosmologies can operate, and the specific observational signatures that would rule them out.

I. INTRODUCTION

Response-based approaches to spacetime and cosmology arise naturally from attempts to make explicit the operational structures already employed in contemporary physics. Finite propagation speeds, relaxation processes, dissipation, and boundary thermodynamics are routinely invoked across gravitational, quantum, and cosmological contexts. Treating these features as emergent rather than fundamental provides a unifying perspective, but also imposes strong constraints.

The purpose of this paper is not to advocate for any specific response-based framework, but to make explicit the conditions under which such approaches remain viable. We identify the empirical, theoretical, and structural constraints that must be satisfied, and enumerate the failure modes that would decisively rule out this entire class of models. By doing so, we clarify both the power and the fragility of response-based cosmologies.

II. DEFINITION OF RESPONSE-BASED COSMOLOGIES

By a response-based cosmological framework, we mean any approach in which spacetime geometry, gravitational dynamics, or cosmological evolution arise as effective descriptions of an underlying system that exhibits finite response to perturbations. This response may involve coherence, relaxation, dissipation, or boundary dynamics, but need not specify microscopic constituents.

Importantly, such frameworks are not required to posit a material medium. The defining feature is operational: dynamical behavior is governed by response functions rather than purely kinematic geometry.

III. NON-NEGOTIABLE EMPIRICAL CONSTRAINTS

Any response-based cosmology must satisfy all experimentally validated limits of established theories. These constraints are not optional and admit no tuning freedom.

A. Local Lorentz Invariance

Observations tightly constrain violations of Lorentz symmetry across a wide range of energies and scales [1]. Response-based frameworks must recover exact local Lorentz invariance in the long-wavelength, coherent limit. Any residual anisotropy or preferred-frame effect outside extreme regimes constitutes a fatal failure.

B. Equivalence Principle

The weak and Einstein equivalence principles are verified to high precision [2]. Effective response dynamics must couple universally to energy–momentum. Composition-dependent response or differential free-fall directly falsifies the framework.

C. Gravitational Wave Propagation

Gravitational waves propagate at the speed of light to within experimental uncertainty [3]. Any response-based modification that alters propagation speed, dispersion, or polarization in the observed frequency bands is excluded.

D. Cosmological Perturbations

The acoustic peak structure of the cosmic microwave background tightly constrains propagation, damping, and phase coherence of perturbations [? ?]. Response-based models must reproduce these features without introducing scale-dependent distortions beyond observational bounds.

IV. THEORETICAL CONSISTENCY CONSTRAINTS

Beyond direct observation, response-based cosmologies must satisfy internal consistency conditions.

A. Energy–Momentum Conservation

Emergent gravitational dynamics must preserve $\nabla_\mu T^{\mu\nu} = 0$ in the regimes where general relativity is recovered [?]. Failure to recover covariant conservation invalidates the framework regardless of phenomenological success.

B. Causality and Microcausality

Finite response must not permit superluminal signaling or causal loops. Effective microcausality must emerge in the coherent regime, consistent with relativistic quantum field theory [4].

C. Unitarity in the Coherent Regime

Quantum field behavior must remain unitary when coherence is maintained. Any intrinsic loss of probability in closed systems contradicts well-tested quantum dynamics [?].

V. EXPLICIT FAILURE MODES

The constraints above define a narrow window of viability. We now enumerate failure modes that would decisively falsify response-based cosmologies.

A. Observable Lorentz Violation

Detection of direction-dependent propagation speeds, birefringence, or frame-dependent effects in regimes where coherence should hold would rule out finite-response interpretations.

B. Composition-Dependent Gravity

Any observation of equivalence principle violation tied to internal structure or composition would falsify universal response coupling.

C. Anomalous Wave Dispersion

Frequency-dependent deviations in gravitational or electromagnetic wave propagation inconsistent with observational bounds constitute a clear failure mode.

D. Inconsistent Horizon Thermodynamics

If horizon entropy, temperature, or dissipation were shown to be calculational artifacts without physical consistency across frameworks, response-based interpretations would lose their explanatory advantage.

E. Uncontrolled Parameter Freedom

Frameworks that introduce unconstrained response scales or ad hoc suppression mechanisms to evade falsification fail as scientific theories. Predictive rigidity is mandatory.

VI. WHY THESE CONSTRAINTS ARE SO RESTRICTIVE

The constraints identified above explain why response-based cosmologies are rare and difficult to construct. Finite response must be simultaneously present and invisible: active enough to account for relaxation, damping, and boundary behavior, yet suppressed enough to evade all precision tests.

This dual requirement leaves little room for arbitrary modification. It also explains why many superficially appealing response-based ideas fail under detailed scrutiny.

VII. IMPLICATIONS FOR FRAMEWORK DEVELOPMENT

The narrowness of the viable parameter space implies that successful response-based cosmologies must be highly constrained and structurally disciplined. This sharply limits the class of admissible models and elevates the importance of explicit limit recovery.

Frameworks that satisfy these constraints provide more than explanatory elegance: they offer a unified language for phenomena already described piecemeal across gravitational, quantum, and cosmological theories.

VIII. CONCLUSIONS

Response-based cosmologies are not free-form alternatives to established physics. They are tightly constrained frameworks that survive only by reproducing all validated limits while making explicit the response structures already implicit in contemporary practice.

By identifying the explicit constraints and corresponding failure modes, we have shown that such frameworks are both falsifiable and fragile. Any viable realization must operate within a narrow corridor defined by observation, consistency, and suppression of response effects. Whether or not any specific model ultimately succeeds, the constraints identified here delineate the true landscape of response-based approaches to spacetime and cosmology.

[1] D. Mattingly, Modern tests of lorentz invariance (2005).

[2] C. M. Will, The confrontation between general relativity and experiment (2014).

[3] B. P. e. a. Abbott, Gravitational waves and gamma-rays from a binary neutron star merger, Astrophysical Journal Letters **848**, L13 (2017).

[4] S. Weinberg, *The Quantum Theory of Fields, Vol. I* (Cambridge University Press, 1995).