

Referee Report

Manuscript: “The Atacama Cosmology Telescope: DR6 Constraints on
Extended Cosmological Models”

(arXiv:2503.14454)

Summary

The manuscript presents cosmological parameter constraints derived from ACT DR6 data, combined with external datasets, within the standard cosmological model and a collection of so-called extended models.

While the experimental analysis is technically competent, the manuscript claims to test “foundational assumptions” of cosmology. In this report I show that this claim is false. The models considered are not physical theories but parameterized deformations of an assumed dynamics. This is not a matter of interpretation but a structural fact that can be demonstrated explicitly.

1. Minimal mathematical criterion for a physical theory

Let S denote the space of admissible physical states. A physical theory is defined by a closed rule of evolution

$$E : S \rightarrow S,$$

such that for any initial state S_0 the subsequent physical behavior is uniquely determined by repeated application of E .

Observable quantities must therefore be of the form

$$O_i = F_i(E, S_0),$$

where S_0 represents boundary conditions. No additional free structures may be introduced beyond those fixed by E .

Closure of the evolution rule is a necessary condition for physical meaning. If predictions depend on external parameters not determined by E or by S_0 , the model is not a physical theory in the strict sense.

2. Mathematical structure of the models used in the manuscript

In the manuscript, predictions are consistently written in the form

$$O_i = F_i(E_0, \theta),$$

where E_0 denotes the fixed Λ CDM dynamics and $\theta = (\theta_1, \theta_2, \dots)$ is a set of additional free parameters.

The parameters θ are not determined by the state of the system, nor by the structure of E_0 . They are introduced independently and assigned prior ranges for numerical convenience.

As a consequence, no new evolution rule

$$E' : S \rightarrow S$$

is defined. The manuscript therefore does not introduce alternative dynamics, but only a family of outputs indexed by θ . Such a family is not closed and does not constitute a physical theory.

3. Absence of generative necessity

In a genuine theoretical extension, additional structures must be fixed by relations of the form

$$\theta = G(E'),$$

or by internal consistency requirements such as symmetry principles or conservation laws.

In the present manuscript no such relations exist. The only requirement imposed on θ is that its components are allowed to vary freely and are later constrained by data.

This implies the existence of infinitely many inequivalent models with no internal criterion for selection. The extensions therefore lack necessity and cannot be considered theoretical.

4. Trivial null limit and non-falsifiability

All extended models considered in the manuscript are constructed such that

$$\lim_{\theta \rightarrow 0} O_i(E_0, \theta) = O_i(E_0).$$

This guarantees that the baseline model is always recovered as a special case. As a result, no observational outcome can falsify the extended framework itself.

Statistical consistency with $\theta = 0$ is therefore guaranteed by construction and carries no physical significance. It reflects the flexibility of the parameterization, not empirical support for a theory.

5. Incorrect interpretation of statistical inference

Throughout the manuscript, constraints of the schematic form

$$\theta = 0 \pm \sigma$$

are interpreted as tests of physical hypotheses.

This interpretation is mathematically invalid. A parameter that is not derived from a closed evolution rule cannot be falsified by being consistent with zero. Likelihood analysis in this context quantifies numerical compatibility, not physical explanation.

The manuscript therefore conflates statistical inference with theoretical validation.

6. No test of foundational assumptions

Since no alternative closed evolution rule E' is ever defined, no foundational assumption of cosmology is tested.

All results are conditional on the validity of E_0 . The analysis probes only the stability of Λ CDM under small parametric deformations, not its physical foundations.

This distinction is essential and is not acknowledged in the manuscript.

Recommendation

The central claims of the manuscript are mathematically unsupported. The work does not define physical theories, does not test foundational assumptions, and the conceptual issues identified above are structural rather than technical.

These issues cannot be resolved through revision. Despite the technical quality of the data analysis, I therefore recommend **rejection**.