ABSTRACT

This work presents a comprehensive survey and mathematical reconstruction of the foundational concepts, observational evidence, and theoretical framework of modern cosmology with emphasis on the Λ Cold Dark Matter (ΛCDM) model, it successes, its tensions, and its philosophical implications.
Using a functional-programming approach to document equations, the core equations of cosmology—from the Friedmann equations and distance measures to the cosmic microwave background (CMB) power spectrum and the matter power spectrum —are restated in explicit, computationally verifiable form. Observational pillars including baryon acoustic oscillations (BAO), large-scale structure (LSS), weak gravitational lensing, nucleosynthesis, and the distance ladder are analyzed and reproduced through mathematical modeling.

The study also evaluates major challenges to the concordance model, including the Hubble tension, early galaxy formation anomalies from JWST, dark matter and dark energy uncertainties, the lithium problem, and the entropy and horizon problems of the early universe. Updated cosmological data sets are incorporated (Planck, WMAP, SDSS, DES, eBOSS, DESI, and JWST).

A second part of this work addresses epistemological and theological dimensions of cosmology. These sections examine the limits of scientific inference, the philosophy of mathematics, the role of metaphysics in cosmological models, and the historical relationship between Christian theology and scientific cosmology. The discussion integrates classical theological insights on creation, rationality, and the intelligibility of the universe as understood through the Imago Dei. Overall, this document serves as both a technical cosmology reference and a philosophical commentary on the nature, origin, and coherence of the universe.

EXECUTIVE SUMMARY

Purpose of the Work

This manuscript has three primary goals:

1. To survey and reconstruct the mathematical structure of modern cosmology using explicit, computable models.
2. To critically evaluate the ΛCDM concordance model, discussing both its successes and unresolved tensions.
3. To explore philosophical and theological implications related to cosmology, scientific reasoning, and the origin of the universe.

Scope of Analysis

The work encompasses the entire structure of cosmology:

- General Relativity & the Friedmann–Lemaître–Robertson–Walker, FLRW, model
- Friedmann equations
- Composition of the universe (baryons, cold dark matter, radiation, dark energy)
- Distance ladder calibration
- Cosmic microwave background anisotropies
- Baryon acoustic oscillations
- Large-scale structure and matter power spectra
- Weak gravitational lensing
- Nucleosynthesis constraints
- Reionization, early structure formation, and high-redshift galaxies
- Cosmological tensions (H_0, S_8, lithium anomaly)
- Early universe physics (inflation, reheating, baryogenesis

Key Findings — Strengths of ΛCDM

- Accurate prediction of the acoustic peak structure in the CMB
- Remarkably successful fit to BAO measurements
- Correct large-scale matter distribution shape
- Consistent results across multiple data sets (CMB, SN Ia, BAO, LSS)
- Predictive framework for light-element abundances

Major Challenges

- Hubble tension (~5–9% discrepancy between early- and late-universe values)
- S_8 tension (weak lensing vs CMB growth-of-structure mismatch)
- Early massive galaxies in JWST (orders of magnitude earlier star formation)
- Lithium problem (BBN prediction exceeds measurement by factor 3–4)
- Fine-tuning in inflation and cosmological constant
- Dark matter and dark energy remain unobserved in laboratory physics

Mathematical Reconstruction

The paper includes full Math implementations for:

The equations for:

- Hubble Equation *H(a),*
- *a* is the scale factor, describes the expansion rate of the universe
- *T*otal energy density of the universe *ρ(a),*
- *CM*B Temperature Scale Factor Relation *T(a),*
- *A*ngular diameter distance to an object, relating its physical size to observed angular size on the sky. $d_A(z)$
- Luminosity distance to an object at a given redshift, $d_L(z)$,

Friedmann equations solved under multiple cosmological assumptions
Reproduction of the TT spectrum using transfer functions
Matter power spectrum *P(k)* from Eisenstein–Hu
BAO sound horizon calculations
Weak lensing convergence
Nucleosynthesis abundance modeling

Epistemology & Theology

This work recognizes that cosmology sits at the boundary of science and metaphysics.
Topics include:

- Popper's falsifiability
- The limits of inference for singular origins
- The philosophy of mathematics
- Interpretive frameworks for Genesis
- Classical Christian perspectives on the intelligibility of the universe
- The fine-tuning of physical constants

Conclusion

Cosmology is now a high-precision discipline, yet profound conceptual questions remain. The ΛCDM model is both powerful and incomplete. Mathematics continues to be the bridge between human understanding and cosmic structure, raising deep philosophical questions about the origin and nature of the universe.