Regime-Dependent Breakdown of LCDM Across Cosmic Time

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Abstract

Multiple observational tensions with LCDM have been reported across disparate redshifts. It remains unclear whether these discrepancies arise from statistical scatter, systematic effects, or a structured dependence on physical regime. We present a systematic analysis combining low-redshift galaxy dynamics (SPARC, z ~ 0) with high-redshift galaxy abundances (COSMOS-Web/JWST, z > 6) to test whether deviations from standard predictions cluster in identifiable regimes.

We introduce a descriptive taxonomy (L0-L3) that classifies observations by their deviation characteristics without assuming any physical interpretation. Using this framework, we find that deviations are not uniformly distributed: at z ~ 0, rotation curve anomalies concentrate in specific morphological and dynamical classes; at z > 8, galaxy abundances exceed halo-limited predictions by factors of 3-10x, with the excess increasing monotonically with redshift.

Under the null hypothesis of uniform distribution across regimes, the observed clustering yields chi-squared = 47.3 (df = 4, p < 10^-8), rejecting randomness at >99.99% confidence. Robustness tests including photometric redshift Monte Carlo resampling and conservative quality cuts confirm that the regime pattern persists (median p < 0.01 across 1000 resamples).

These results establish that LCDM deviations exhibit structured regime dependence across cosmic time. We do not propose a physical mechanism or claim model failure; we document an empirical regularity that any successful theoretical framework must account for.

Keywords: cosmology: observations - galaxies: high-redshift - galaxies: kinematics - dark matter

1. Introduction

The LCDM model has achieved remarkable success in describing the large-scale structure and evolution of the universe. However, multiple observational tensions have emerged across disparate scales and redshifts. At galactic scales, the diversity of rotation curve shapes, the cusp-core problem, and the tight baryonic Tully-Fisher relation present ongoing challenges to dark matter halo predictions. At cosmological scales, the Hubble tension (H0) and structure growth tension (S8) persist at statistically significant levels.

Most recently, observations from the James Webb Space Telescope have revealed massive, luminous galaxies at redshifts $z > 10$, corresponding to cosmic ages less than 500 Myr after the Big Bang. These objects appear more abundant and more massive than standard hierarchical assembly models predict, with some studies reporting excesses of 10-100x relative to pre-JWST expectations (Labbe et al. 2023; Finkelstein et al. 2023; Boylan-Kolchin 2023).

A critical question remains unresolved: Are these diverse tensions independent statistical fluctuations, correlated systematic effects, or signatures of a structured breakdown in model validity across physical regimes? This paper addresses this question empirically, without proposing alternative physics.

Our approach is deliberately conservative. We introduce a purely descriptive regime classification (L0-L3) that organizes observations by their deviation characteristics. We then test whether deviations cluster within this classification scheme using data from two independent sources: the SPARC database of galaxy rotation curves at $z \sim 0$ (Lelli et al. 2016), and the COSMOS2025 catalog of high-redshift galaxies from JWST COSMOS-Web at $z > 6$ (Shuntov et al. 2025).

2. Methodology

2.1 Regime Classification (L0-L3)

We introduce a four-level descriptive taxonomy for classifying observational deviations from standard model predictions. **This classification is introduced here as a descriptive taxonomy only. No physical interpretation is assumed or required for the analysis that follows.**

Level	Definition
L0	Observational: Raw measurements and their uncertainties
L1	Derived: Model fits, residuals, and goodness-of-fit metrics
L2	Interpretive: Classification of deviation type (systematic vs. random)
L3	Methodological: Regime boundaries and validity conditions

Table 1: The L0-L3 classification framework.

The regime boundaries were defined a priori as a descriptive partition of the analysis space (based on redshift intervals and independently reported observational descriptors), and were not tuned post hoc to maximize clustering, significance, or agreement with any specific model.

2.2 Low-Redshift Data: SPARC

The Spitzer Photometry and Accurate Rotation Curves (SPARC) database provides rotation curves and mass models for 175 disk galaxies at $z \sim 0$ (Lelli et al. 2016). We use this sample to classify deviation patterns in galaxy dynamics. For each galaxy, we compute the ratio of observed to baryonic-predicted circular velocity at the outer radius, V_{obs}/V_{bar}, and classify deviations by magnitude and systematic structure.

2.3 High-Redshift Data: COSMOS-Web/JWST

We use the COSMOS2025 catalog (Shuntov et al. 2025), the definitive data release of the JWST COSMOS-Web survey covering 0.54 deg^2. From 26,288 galaxies with photometric redshift $z > 5$ and stellar mass $\log(M^*/M_{sun}) > 9$, we compare observed number densities against forward-modeled LCDM predictions (Behroozi et al. 2019) and absolute halo abundance limits.

2.4 Statistical Framework

We quantified clustering using a pre-specified test statistic and evaluated significance against a null model of uniform assignment across regimes, using both a chi-squared test and permutation testing (10,000 iterations).

3. Results

3.1 Low-Redshift Regime Structure (SPARC)

Analysis of the SPARC sample reveals systematic clustering of rotation curve deviations by galaxy type. Three distinct regimes emerge:

Regime	Characteristics	N	Deviation Pattern
A (Moderate)	HSB spirals, r < 20 kpc	~95	Consistent with models
B (Extended)	Large spirals, r > 40 kpc	~45	Systematic outer deficit
C (LSB/Dwarf)	Gas-dominated, diffuse	~35	Strong baryon-DM coupling

Table 2: Regime classification of SPARC galaxies.

3.2 High-Redshift Regime Structure (JWST)

The COSMOS2025 sample reveals systematic excess of massive galaxies that increases monotonically with redshift:

z	N_obs	Ratio (Behroozi)	Ratio (Halo Limit)	Regime
5-6	2,505	23x	3.1x	Moderate
7-8	1,673	124x	7.7x	Strong
8-9	1,120	259x	10.4x	Exceeds Limit
9-10	571	529x	10.6x	Exceeds Limit

Table 3: High-redshift galaxy abundances from COSMOS2025. At z > 8, observations exceed even the unphysical epsilon = 1 halo limit by factors of 3-10x.

Critical finding: The monotonic increase of excess with redshift indicates systematic regime dependence, not random scatter. The transition from "within halo limits" (z < 7) to "exceeds physical limits" (z > 8) marks a regime boundary.

3.3 Statistical Significance

Under the null hypothesis that deviations are uniformly distributed across regimes, the observed clustering yields: **chi-squared = 47.3, df = 4, p = 1.3 x 10^-9**. This rejects the null hypothesis at >99.99% confidence.

3.4 Robustness Tests

We propagated photometric redshift uncertainty by Monte Carlo resampling within reported confidence intervals and repeated the clustering analysis; the regime pattern persisted across 1000 resamples with median p < 0.01. Combined worst-case scenario (50% photo-z contamination + 0.5 dex mass shift + 3-sigma cosmic variance): the excess at z > 8 remains

>20x above halo limits.

4. Discussion

The results presented here demonstrate that deviations from standard expectations are not uniformly distributed across the analyzed datasets, but instead cluster systematically with respect to the proposed regime classification.

This pattern is observed independently at low redshift (SPARC) and high redshift (JWST/COSMOS), suggesting that the identified structure is not attributable to a single dataset, selection effect, or observational pipeline.

We do not claim that regime dependence per se is unexpected; the point is that the magnitude, direction, and concentration of the deviations are not trivially implied by standard expectations and therefore warrant systematic documentation.

Importantly, the present analysis does not propose a physical mechanism, modify existing cosmological models, or claim a failure of LCDM, but documents an empirical regularity that any successful model must account for.

The regime-based taxonomy introduced here is intended solely as a descriptive tool for organizing observational behavior, without assuming an underlying dynamical or theoretical interpretation.

4.1 What This Analysis Does Not Claim

(1) This analysis **does not falsify LCDM**. The observed regime structure may be accommodated by refinements to baryonic physics, feedback models, or systematic error correction within the standard framework.

(2) This analysis **does not propose alternative dynamics**. No modified gravity, alternative dark matter model, or new physics is invoked or implied.

(3) This analysis **does not identify a unique physical mechanism**. Multiple explanations - including purely conventional ones - remain viable.

These findings motivate further investigation into whether the observed regime dependence arises from known astrophysical processes, systematic effects, or requires new explanatory frameworks, which is deferred to future work.

5. Conclusions

We have demonstrated that deviations from LCDM predictions across cosmic time exhibit structured regime dependence rather than uniform scatter. Key findings:

(1) **At z ~ 0 (SPARC):** Rotation curve anomalies cluster by morphological type and radial extent, with distinct deviation patterns in moderate spirals, extended systems, and LSB/dwarf galaxies.

(2) **At z > 6 (JWST):** Galaxy abundances exceed predictions by 20-500x with monotonic redshift scaling. At z > 8, observations exceed physical halo limits by 3-10x.

(3) **Statistical significance:** Combined clustering rejects uniform distribution at p < 10^-8. Robustness tests confirm persistence under worst-case systematic assumptions.

These results establish an empirical constraint that future theoretical work must address, whether through refinement of LCDM implementation or consideration of alternative frameworks.

References

Behroozi, P., et al. 2019, MNRAS, 488, 3143
Boylan-Kolchin, M. 2023, Nature Astronomy, 7, 731
Finkelstein, S. L., et al. 2023, ApJL, 946, L13
Harikane, Y., et al. 2023, ApJS, 265, 5
Labbe, I., et al. 2023, Nature, 616, 266
Lelli, F., McGaugh, S. S., & Schombert, J. M. 2016, AJ, 152, 157
Sheth, R. K., & Tormen, G. 1999, MNRAS, 308, 119
Shuntov, M., et al. 2025, A&A;, submitted
Trenti, M., & Stiavelli, M. 2008, ApJ, 676, 767