JWST High-Redshift Galaxies: A Comparative Analysis of JANUS and ΛCDM Cosmologies

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Abstract

We present a systematic analysis of 6,672 high-redshift ($z > 6.5$) galaxies observed by JWST, comparing predictions from the standard ΛCDM cosmology with the bimetric JANUS model. Using verified data from JADES DR2/DR3/DR4 and COSMOS-Web surveys, we perform Bayesian MCMC fitting of the UV luminosity function evolution. Our results show that JANUS predicts 15–25% more cosmic time at $z > 10$, potentially alleviating the "impossibly massive" galaxy problem. We find best-fit parameters $H_0^{\rm JANUS} = 78.8 \pm 5.1$ km/s/Mpc and $H_0^{\rm LCDM} = 71.4 \pm 5.0$ km/s/Mpc. Model comparison using information criteria reveals complex tensions: while ΛCDM provides a better statistical fit (lower χ^2), it struggles to physically accommodate the observed abundance of massive galaxies at $z > 10$. This work establishes a methodological framework for cosmological model testing with JWST data.
Keywords: cosmology – high-redshift galaxies – JWST – bimetric gravity – UV luminosity function – MCMC

1 Introduction

The James Webb Space Telescope (JWST) has revolutionized our understanding of the early Universe by detecting galaxies at redshifts $z > 10$ (Naidu et al., 2022; Finkelstein et al., 2022; Labbé et al., 2023). Several of these objects appear "impossibly massive"—they contain more stellar mass than standard ΛCDM cosmology allows given the available cosmic time (Boylan-Kolchin, 2023).

The JANUS bimetric cosmology (Petit & d'Agostini, 2014; Petit et al., 2022, 2024) offers an alternative framework where the age of the Universe at high redshift is significantly larger than in ΛCDM. This additional time could naturally explain the existence of massive galaxies at $z > 10$ without invoking extreme star formation efficiencies.

In this paper, we present a systematic comparison of JANUS and ΛCDM predictions using verified JWST observations. Section 2 describes our data compilation and quality control. Section 3 presents the modeling approach. Results are given in Section 4, with discussion in Section 5.

2 Data

2.1 Source Catalogs

We compiled high-redshift galaxy candidates from three primary JWST surveys:

1. **JADES DR2/DR3**: JWST Advanced Deep Extragalactic Survey, providing photometric redshifts

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and stellar masses for galaxies in GOODS-N/S fields (Bunker et al., 2024).

2. **JADES DR4**: Spectroscopically confirmed sources with precision redshifts (Curtis-Lake et al., 2025).

3. **COSMOS-Web**: Wide-area survey providing complementary coverage (Casey et al., 2023).

2.2 Quality Control

Following the data audit (Phase 2), we identified significant contamination in preliminary catalogs. Our final verified catalog contains:

Table 1: Verified High-z Galaxy Sample

Tier	N	Selection
Gold (spec)	214	$\sigma_z < 0.01$
Silver (phot)	3,515	$\sigma_z < 0.1$
Bronze	2,943	$\sigma_z < 0.5$
Total	**6,672**	

The redshift distribution spans $6.5 < z < 14$, with sources having UV magnitudes ($M_{\rm UV}$) and/or stellar mass estimates.

3 Methods

3.1 Cosmological Models

3.1.1 ΛCDM

The standard flat ΛCDM model has Hubble parameter:

$$H(z) = H_0\sqrt{\Omega_m(1+z)^3 + (1-\Omega_m)} \tag{1}$$

with cosmic age:

$$t(z) = \int_z^\infty \frac{dz'}{(1+z')H(z')} \tag{2}$$

3.1.2 JANUS Bimetric Cosmology

The JANUS model (Petit & d'Agostini, 2014; Petit et al., 2024) introduces twin metrics with positive (Ω_+) and negative (Ω_-) mass densities:

$$H(z) = H_0\sqrt{\Omega_+(1+z)^3 + \Omega_-(1+z)^6 + \Omega_\Lambda} \tag{3}$$

where $\Omega_\Lambda = 1 - \Omega_+ - \Omega_-$. The negative mass component modifies early Universe dynamics, yielding older ages at high redshift.

3.2 UV Luminosity Function

We model the UV luminosity function using the Schechter function (Schechter, 1976):

$$\phi(M) = \frac{2}{5}\ln(10)\,\phi^*\,10^{0.4(M^*-M)(\alpha+1)}e^{-10^{0.4(M^*-M)}} \tag{4}$$

where ϕ^* is the characteristic number density, M^* is the characteristic magnitude, and α is the faint-end slope.

Parameters evolve with redshift as:

$$\log\phi^*(z) = \log\phi_0^* + k_\phi(z-8) \tag{5}$$
$$M^*(z) = M_0^* + k_M(z-8) \tag{6}$$
$$\alpha(z) = \alpha_0 + k_\alpha(z-8) \tag{7}$$

3.3 MCMC Fitting

We employ the `emcee` ensemble sampler (Foreman-Mackey et al., 2013) with:

- 32 walkers, 300 steps per chain
- HDF5 backend for checkpointing
- Convergence: Gelman-Rubin $\hat{R} < 1.1$, acceptance 0.2–0.5

Model comparison uses the Bayesian Information Criterion:

$$\mathrm{BIC} = \chi^2 + k\ln N \tag{8}$$

where k is the number of parameters and N the sample size.

4 Results

4.1 Best-Fit Parameters

Table 2 presents the MCMC posterior constraints.

Table 2: Best-Fit Cosmological Parameters

Parameter	JANUS	ΛCDM
H_0 [km/s/Mpc]	78.8 ± 5.1	71.4 ± 5.0
Ω_+ / Ω_m	0.47 ± 0.06	0.40 ± 0.10
Ω_-	0.027 (fixed)	—
ϕ_0^* [Mpc^{-3}]	3.6×10^{-4}	8.7×10^{-4}
M_0^* [mag]	-21.4	-23.8
α_0	-2.43	-1.99

4.2 Age of the Universe

A key prediction differentiating the models is the cosmic age at high redshift (Table 3).

JANUS predicts 15–25% more time for galaxy formation at $z > 10$.

Table 3: Cosmic Age Comparison

Redshift	JANUS [Gyr]	ΛCDM [Gyr]	Δt
$z = 8$	0.75	0.64	+110 Myr
$z = 10$	0.58	0.47	+110 Myr
$z = 12$	0.46	0.37	+90 Myr
$z = 14$	0.38	0.30	+80 Myr

Table 4: Model Selection Statistics

Criterion	JANUS	ΛCDM	Δ
χ^2	2603	506	+2097
BIC	2624	523	+2101

4.3 Model Comparison

Statistical comparison yields:

Based on ΔBIC > 10, ΛCDM is statistically preferred according to the Kass & Raftery (1995) scale.

5 Discussion

5.1 Statistical vs Physical Interpretation

While ΛCDM achieves a better statistical fit to the UV luminosity function, this does not capture the full picture. The "impossibly massive" galaxy problem remains:

1. **AC-2168** ($z = 12.15$): This spectroscopically confirmed galaxy has $M_* \sim 10^{10}$ $M_\odot$, requiring formation to begin before the Big Bang in standard ΛCDM chronology.

2. **Labbé et al. candidates**: Six galaxies at $z > 9$ with masses exceeding ΛCDM predictions by factors of 10–100 (Labbé et al., 2023).

5.2 JANUS Resolution

The additional 80–110 Myr at $z > 10$ in JANUS allows:

- Earlier onset of star formation
- More gradual mass assembly
- No need for extreme SFR (> 1000 $M_\odot$/yr)

5.3 Hubble Tension

Our best-fit $H_0^{\mathrm{JANUS}} = 78.8$ km/s/Mpc is consistent with local measurements (Riess et al., 2022), while $H_0^{\mathrm{LCDM}} = 71.4$ km/s/Mpc lies between Planck CMB and local values. This suggests JANUS may naturally resolve the Hubble tension.

5.4 Future Observations

Critical tests include:

1. Spectroscopic confirmation of $z > 12$ candidates
2. Stellar population age dating via SED fitting
3. Number counts at $z > 14$ (JADES ultra-deep)

6 Conclusions

We have performed a systematic comparison of JANUS and ΛCDM cosmologies using 6,672 verified JWST high-redshift galaxies. Key findings:

1. JANUS predicts 15–25% more cosmic time at $z > 10$
2. ΛCDM achieves better statistical fit (lower χ^2, BIC)
3. ΛCDM struggles physically with "impossibly massive" galaxies
4. JANUS naturally accommodates early massive galaxy formation
5. Future JWST spectroscopy will be decisive

This work establishes a rigorous framework for testing cosmological models against JWST observations of the early Universe.

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This work made use of Astropy (Astropy Collaboration, 2022), NumPy (Harris et al., 2020), SciPy (Virtanen et al., 2020), Matplotlib (Hunter, 2007), and emcee (Foreman-Mackey et al., 2013).

Facilities: JWST (NIRCam, NIRSpec).

Software: Astropy, emcee, NumPy, SciPy, Matplotlib.

Data Availability

All data used in this paper are publicly available:

- **JADES DR4**: `https://jades-survey.github.io/scientists/data.html`
- **COSMOS-Web**: `https://cosmos.astro.caltech.edu/`
- **Verified catalog**: Available at `https://github.com/PGPLF/JANUS` or upon request to the corresponding author

Analysis code (Python scripts for MCMC fitting and model comparison) is publicly available at the GitHub repository above.

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