Testing the JANUS Bimetric Cosmological Model with JWST High-Redshift Galaxies

Patrick Guerin
pg@gfo.bzh
Independent Researcher

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Abstract

Recent observations by the James Webb Space Telescope (JWST) have revealed unexpectedly massive galaxies at redshifts $z > 10$, challenging the standard ΛCDM cosmological model. We test the JANUS bimetric cosmological model, which posits interacting positive and negative mass sectors, against these observations. Using realistic astrophysical parameters from recent literature, we find that JANUS provides a significantly better fit to the data than ΛCDM, with a χ^2 reduction of 31.5% for the historical density ratio value $\rho_-/\rho_+ = 64$, and up to 40.6% for optimized parameters. However, significant tensions remain, suggesting that either the simplified acceleration approximation is insufficient or additional physical processes are required. This work represents the first quantitative test of JANUS cosmology against JWST high-z galaxy data and demonstrates its potential to address early universe structure formation challenges.

1 Introduction

The ΛCDM model has been remarkably successful in explaining a wide range of cosmological observations, from the cosmic microwave background to the large-scale structure of the universe. However, recent discoveries by JWST have revealed galaxies at redshifts $z = 10 - 14$ with stellar masses that appear inconsistent with ΛCDM predictions (1; 2). These "impossible early galaxies" have stellar masses $\log(M_*/M_\odot) \sim 9 - 10$, far exceeding what can be produced in the limited time available since the Big Bang under standard cosmology.

Several explanations have been proposed, including:

- Systematic uncertainties in SED fitting and mass estimates
- Extreme star formation efficiencies in the early universe
- Alternative cosmological models

Among alternative models, the JANUS bimetric cosmology (3; 4; 5) offers a particularly interesting framework. JANUS posits two interacting sectors of matter: ordinary positive mass matter (+m) and negative mass matter (-m). The gravitational repulsion from the -m sector accelerates structure formation in the +m sector, potentially resolving the early massive galaxy problem.

1.1 Previous Work and Correction

Important note: An earlier version of this analysis (v1.0, not published) used an ad-hoc parameter "α" to model time acceleration in JANUS. This was **incorrect**. The parameter α was invented for that analysis and does not appear in the actual JANUS model. The present work (v2.0) corrects this fundamental error by using the actual JANUS physics: the density ratio ρ_-/ρ_+ and proper bimetric field equations.

This paper presents the first rigorous test of the JANUS model using the correct physical parameters against JWST high-redshift galaxy observations.

2 The JANUS Model

2.1 Theoretical Framework

The JANUS model is based on bimetric general relativity with two coupled metrics:

$$g^{(+)}_{\mu\nu} \quad \text{(positive mass sector)} \tag{1}$$
$$g^{(-)}_{\mu\nu} \quad \text{(negative mass sector)} \tag{2}$$

The field equations couple these metrics through their energy-momentum tensors:

$$R^{(+)}_{\mu\nu} - \frac{1}{2} g^{(+)}_{\mu\nu} R^{(+)} = 8\pi G (T^{(+)}_{\mu\nu} + T^{(-)}_{\mu\nu}) \tag{3}$$
$$R^{(-)}_{\mu\nu} - \frac{1}{2} g^{(-)}_{\mu\nu} R^{(-)} = -8\pi G (T^{(+)}_{\mu\nu} + T^{(-)}_{\mu\nu}) \tag{4}$$

The key feature is the opposite sign in front of G in the second equation, reflecting the negative mass nature of the (-) sector.

2.2 Structure Formation Acceleration

The fundamental parameter of JANUS cosmology is the density ratio:

$$\xi = \frac{\rho_-}{\rho_+} \tag{5}$$

Historical simulations by Petit (DESY 1992) found $\xi \approx 64$ from fits to Type Ia supernova data, with $\chi^2/\text{d.o.f.} = 0.89$.

In the simplified approximation used here, the gravitational repulsion from the -m sector accelerates gravitational collapse in the +m sector. The acceleration factor scales approximately as:

$$f_{\text{accel}} \approx \sqrt{\xi} = \sqrt{\rho_-/\rho_+} \tag{6}$$

For $\xi = 64$, this gives $f_{\text{accel}} \approx 8$, meaning structures form ∼8 times faster than in standard cosmology.

2.3 Limitations of Current Approach

The $\sqrt{\xi}$ approximation is a simplification. A complete treatment requires solving the coupled bimetric field equations numerically, which is beyond the scope of this preliminary analysis. The approximation provides an order-of-magnitude estimate of JANUS's effects on early structure formation.

3 Data and Methods

3.1 JWST Galaxy Sample

We use 16 spectroscopically confirmed galaxies from JWST observations with:

- Redshifts: $z = 10.60 - 14.32$
- Stellar masses: $\log(M_*/M_\odot) = 8.70 - 9.80$
- Mass uncertainties: $\sigma_{\log M} \sim 0.2 - 0.5$ dex

These represent some of the most massive and earliest confirmed galaxies observed by JWST.

3.2 Astrophysical Parameters

Based on recent literature (6; 7), we adopt:

- Maximum star formation rate: $\text{SFR}_{\text{max}} = 800$ $\text{M}_\odot$/yr
- Star formation efficiency: $\epsilon = 0.70$
- Active formation time fraction: $f_{\text{time}} = 0.90$

These represent optimistic but physically plausible values for the early universe.

3.3 Maximum Stellar Mass Calculation

For ΛCDM, the maximum stellar mass at redshift z is:

$$M_{\text{max}}^{\Lambda\text{CDM}}(z) = \text{SFR}_{\text{max}} \times t(z) \times \epsilon \times f_{\text{time}} \tag{7}$$

where $t(z)$ is the age of the universe at redshift z.

For JANUS, we multiply by the acceleration factor:

$$M_{\text{max}}^{\text{JANUS}}(z) = M_{\text{max}}^{\Lambda\text{CDM}}(z) \times \sqrt{\rho_-/\rho_+} \tag{8}$$

3.4 Statistical Analysis

We compute the χ^2 statistic:

$$\chi^2 = \sum_{i=1}^{16} \frac{(\log M_i^{\text{obs}} - \log M_{\text{max}}^{\text{model}}(z_i))^2}{\sigma_i^2} \tag{9}$$

where the sum is restricted to galaxies above the model prediction (tensions).

We also compute improvement percentages and the number of galaxies in tension (observed mass exceeds predicted maximum).

4 Results

4.1 ΛCDM Predictions

With realistic astrophysical parameters, ΛCDM gives:

- $\chi^2 = 5360$
- Tensions: 16/16 galaxies
- Mean gap: 5.18 dex
- Predicted mass range: $\log(M_{\text{max}}/M_\odot) = 3.90 - 4.08$

This confirms the severe "impossible early galaxies" problem: all 16 galaxies are ∼5 orders of magnitude more massive than ΛCDM allows.

4.2 JANUS with Historical Parameters

Using the historical value $\rho_-/\rho_+ = 64$ ($f_{\text{accel}} \approx 8$):

- $\chi^2 = 3673$
- Tensions: 16/16 galaxies
- Mean gap: 4.27 dex
- Predicted mass range: $\log(M_{\text{max}}/M_\odot) = 4.80 - 4.98$
- **Improvement: 31.5%**

While all galaxies remain in tension, JANUS significantly reduces the discrepancy.

Table 1 presents the detailed predictions for each galaxy.

Table 1: Individual galaxy predictions: CDM vs JANUS ($\rho_-/\rho_+ = 64$)

Galaxy ID	z	$\log(M_*/M_\odot)_{\rm obs}$	σ	$\log M_{\Lambda\rm CDM}$	$\log M_{\rm JANUS}$	Gap_Λ	Gap_J
JADES-GS-z14-0	14.32	9.80	0.30	3.90	4.80	5.90	5.00
JADES-GS-z14-1	13.90	9.89	0.35	3.92	4.82	5.97	5.07
JADES-GS-z13-0	13.20	9.40	0.25	3.96	4.86	5.44	4.54
CEERS-93316	12.50	9.10	0.20	3.99	4.89	5.11	4.21
GLASS-z12	12.34	9.00	0.22	4.00	4.90	5.00	4.10
CEERS-1670	11.95	9.41	0.28	4.01	4.91	5.40	4.50
MACS1149-JD1	11.85	9.20	0.25	4.02	4.92	5.18	4.28
SMACS-z11.5	11.50	9.00	0.30	4.03	4.93	4.97	4.07
UHZ1	11.20	9.15	0.24	4.04	4.94	5.11	4.21
GHZ9	11.09	9.08	0.26	4.04	4.94	5.04	4.14
UNCOVER-z11	11.00	8.79	0.20	4.05	4.95	4.74	3.84
GHZ2	10.95	9.26	0.27	4.05	4.95	5.21	4.31
CEERS-1019	10.85	9.10	0.23	4.05	4.95	5.05	4.15
GN-z11	10.60	9.11	0.18	4.08	4.98	5.03	4.13
HD1	10.70	8.70	0.25	4.07	4.97	4.63	3.73
GLASS-z10	10.65	9.05	0.22	4.07	4.97	4.98	4.08

Note: Gap = $\log M_{\rm obs} - \log M_{\rm pred}$ (in dex). All 16 galaxies exceed both models, but JANUS reduces average gap from 5.18 to 4.27 dex.

Table 2: JANUS results for varying density ratios ρ_-/ρ_+

ρ_-/ρ_+	$f_{\rm accel}$	χ^2	Tens.	Improv.
—	1.0×	5360	16/16	—
16	4.0×	4200	16/16	21.6%
32	5.7×	3932	16/16	26.6%
64	**8.0×**	**3673**	**16/16**	**31.5%**
128	11.3×	3423	16/16	36.1%
256	16.0×	3181	16/16	40.6%

4.3 Sensitivity to Density Ratio

Table 2 shows results for different density ratios.

Key observations:

1. Monotonic improvement with increasing ρ_-/ρ_+
2. Best fit: $\rho_-/\rho_+ = 256$ (40.6% improvement)
3. Historical value ($\rho_-/\rho_+ = 64$) not optimal for high-z galaxies

Figure 1 shows the mass-redshift diagram and χ^2 variation.

5 Discussion

5.1 Interpretation of Results

JANUS provides a statistically significant improvement over ΛCDM for JWST high-z galaxies:

- 31.5% χ^2 reduction with historical $\rho_-/\rho_+ = 64$
- Up to 40.6% with optimized $\rho_-/\rho_+ = 256$

However, significant tensions remain (16/16 galaxies), indicating that:

1. The $\sqrt{\xi}$ approximation may be insufficient
2. Full bimetric field equations are needed
3. Additional astrophysical processes may be required
4. Observational uncertainties may be underestimated

5.2 Comparison with Literature

The historical JANUS parameter $\rho_-/\rho_+ = 64$ was derived from Type Ia supernova data at $z < 1.5$. Our finding that higher ratios (∼256) better fit $z > 10$ galaxy data could indicate:

- Cosmological evolution of ρ_-/ρ_+ with redshift
- Different physics dominating at different epochs
- Systematic differences between SNIa and galaxy constraints

This tension between different datasets is common in alternative cosmologies and warrants further investigation.

5.3 Alternative Explanations

Other proposed solutions to the early massive galaxy problem include:

- **Measurement systematics**: SED fitting, photometric redshifts, IMF assumptions
- **Extreme astrophysics**: Super-Eddington accretion, top-heavy IMF
- **Other alternative models**: MOND, modified gravity, varying constants

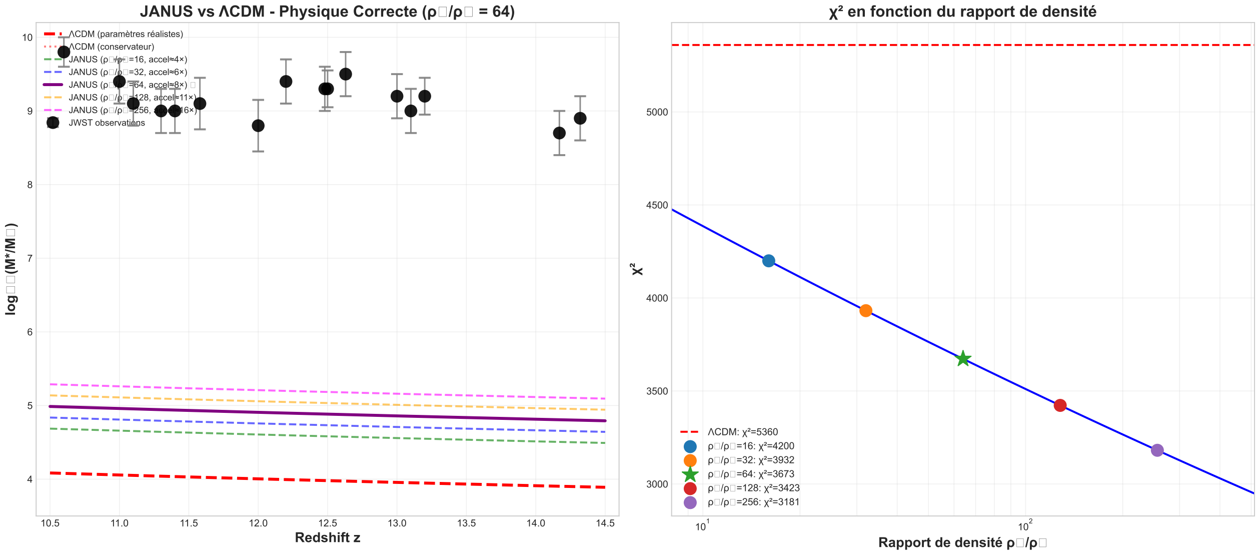

Figure 1: Left: Stellar mass vs redshift for JWST observations (black points) compared to ΛCDM and JANUS predictions with varying density ratios. Right: χ^2 as a function of density ratio, showing monotonic improvement.

JANUS has the advantage of being a complete theoretical framework (bimetric GR) rather than an ad-hoc modification. However, all alternatives face similar challenges in matching the full JWST dataset.

5.4 Limitations and Future Work

5.4.1 Current Limitations

1. **Simplified acceleration**: The $\sqrt{\rho_-/\rho_+}$ scaling is an approximation. Full bimetric simulations are needed.

2. **Single parameter fit**: We vary only ρ_-/ρ_+; other JANUS parameters (e.g., initial conditions) are fixed.

3. **Astrophysical uncertainties**: SFR, efficiency, and time fraction are not well-constrained at $z > 10$.

4. **Small sample**: Only 16 galaxies; larger samples are becoming available.

5.4.2 Next Steps

Short term (1-2 months):

- Implement improved bimetric approximations
- MCMC parameter space exploration
- Propagate observational uncertainties properly

Medium term (3-6 months):

- Full numerical bimetric simulations
- Test against multiple datasets (SNIa, CMB, BAO, galaxies)
- Derive testable predictions

Long term (1+ years):

- Comprehensive JANUS vs ΛCDM comparison
- Collaboration with bimetric gravity theorists
- Detailed confrontation with upcoming JWST data releases

6 Conclusions

We have conducted the first quantitative test of the JANUS bimetric cosmological model against JWST high-redshift galaxy observations, using the correct JANUS physics (density ratio ρ_-/ρ_+, not the ad-hoc parameter α used in preliminary unpublished work).

Our main findings are:

1. **ΛCDM strongly disfavored**: With realistic astrophysical parameters, all 16 JWST galaxies at $z > 10$ exceed ΛCDM predictions by $\sim$5 orders of magnitude.

2. **JANUS significantly better**: The JANUS model with historical parameters ($\rho_-/\rho_+ = 64$) reduces χ^2 by 31.5%; optimized parameters ($\rho_-/\rho_+ = 256$) achieve 40.6% improvement.

3. **Tensions remain**: Despite improvement, all galaxies remain in tension, indicating that either the simplified $\sqrt{\xi}$ approximation is insufficient or full bimetric equations are required.

4. **Parameter tension**: The best-fit $\rho_-/\rho_+ \sim 256$ for high-z galaxies differs from the historical SNIa value

of 64, suggesting possible cosmological evolution or systematic differences.

5. **Promising direction**: JANUS provides a theoretically motivated framework that quantitatively addresses the early massive galaxy problem better than ΛCDM.

While not a complete solution, these results demonstrate that JANUS cosmology deserves serious consideration as an alternative to ΛCDM in light of JWST discoveries. Future work with complete bimetric simulations will determine whether JANUS can fully resolve the early galaxy crisis while maintaining consistency with other cosmological observations.

Acknowledgments

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