JANUS Cosmological Model Constraints from Type Ia Supernovae: Reproduction and Pantheon+ Extension

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Contributions: P.G. designed study, performed analyses, wrote manuscript.
Funding: None. *Conflicts*: None declared.
Data: `https://github.com/PGPLF/JANUS-S`

January 4, 2026 (v0.1)

Abstract

We reproduce D'Agostini & Petit (2018) JANUS model constraints using JLA supernovae (740 SNe Ia), obtaining $q_0 = -0.086 \pm 0.014$ with $\chi^2/\text{dof} = 0.88$, validating the original result ($q_0 = -0.087$). Extension to Pantheon+ (1543 SNe Ia) yields $q_0 = -0.035 \pm 0.014$, revealing significant dataset dependence ($\Delta q_0 = 0.05$). Subsample analysis shows q_0 evolution: -0.26 at $z < 0.1$ to ~ 0 at high-z. Comparison with ΛCDM shows comparable fits ($\Delta\chi^2/\text{dof} < 4\%$) with slight ΛCDM preference ($\Delta\text{AIC} \approx -25$).

1 Introduction

The JANUS bimetric model (Petit and D'Agostini, 2014; D'Agostini and Petit, 2018; Petit et al., 2024) explains cosmic acceleration through positive/negative mass sector interactions, avoiding dark energy. D'Agostini & Petit (2018) constrained the deceleration parameter to $q_0 = -0.087 \pm 0.015$ using JLA data (Betoule et al., 2014).

We aim to: (1) reproduce the 2018 analysis, (2) extend to Pantheon+ (Brout et al., 2022), and (3) compare with ΛCDM.

2 Methods

2.1 JANUS Model

The luminosity distance is:

$$d_L(z) = \frac{c}{H_0}\left[z + \frac{z^2(1-q_0)}{1+q_0 z+\sqrt{1+2q_0 z}}\right] \quad (1)$$

with distance modulus $\mu = 5\log_{10}(d_L/\text{Mpc}) + 25$.

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2.2 Data

JLA: 740 SNe Ia, $0.01 < z < 1.30$, using $\mu = m_B - M_B + \alpha x_1 - \beta c$ with $\alpha = 0.141$, $\beta = 3.101$, $M_B = -19.05$.

Pantheon+: 1543 unique SNe Ia, $0.001 < z < 2.26$, using calibrated MU_SH0ES distances.

2.3 Fitting

Minimize $\chi^2 = \sum_i [(\mu_i^{\text{obs}} - \mu_i^{\text{th}} - \delta)/\sigma_i]^2$ via Nelder-Mead. Bootstrap (100 samples) for uncertainties.

3 Results

3.1 2018 Reproduction

Table 1: JLA results comparison

	This work	Ref. (2018)
q_0	-0.086 ± 0.014	-0.087 ± 0.015
χ^2/dof	0.883	0.89

3.2 Pantheon+ Extension

Table 2: Dataset comparison

	JLA	Pantheon+
N	740	1543
q_0	-0.086	-0.035
χ^2/dof	0.883	0.497

3.3 Redshift Dependence

Table 3: Pantheon+ subsamples

Range	N	q_0	χ^2/dof
$z < 0.1$	583	-0.260	0.58
$z < 0.5$	1333	-0.165	0.50
$z < 1.0$	1518	-0.070	0.49
Full	1543	-0.035	0.50

3.4 JANUS vs ΛCDM

Table 4: Model comparison

Dataset	JANUS	ΛCDM	ΔAIC
JLA	0.883	0.852	-24
Pantheon+	0.497	0.481	-26

4 Discussion

The 2018 reproduction is excellent ($\Delta q_0 = 0.001$). The JLA/Pantheon+ discrepancy ($\Delta q_0 = 0.05$) reflects: (1) different z distributions, (2) calibration differences, (3) possible $q_0(z)$ evolution.

The q_0 redshift trend (Fig. 3) suggests single-parameter JANUS may be insufficient for extended z ranges, motivating theoretical extensions.

Both models fit comparably; ΛCDM is slightly preferred statistically but JANUS remains competitive with one free parameter.

5 Conclusions

1. 2018 reproduction validated: $q_0 = -0.086$, χ^2/dof $= 0.88$
2. Pantheon+ yields different $q_0 = -0.035$
3. Evidence for $q_0(z)$ evolution: -0.26 to ~ 0
4. JANUS and ΛCDM comparably fit SNe Ia data

Acknowledgments

We thank the JLA and Pantheon+ collaborations for public data access.

References

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Figures

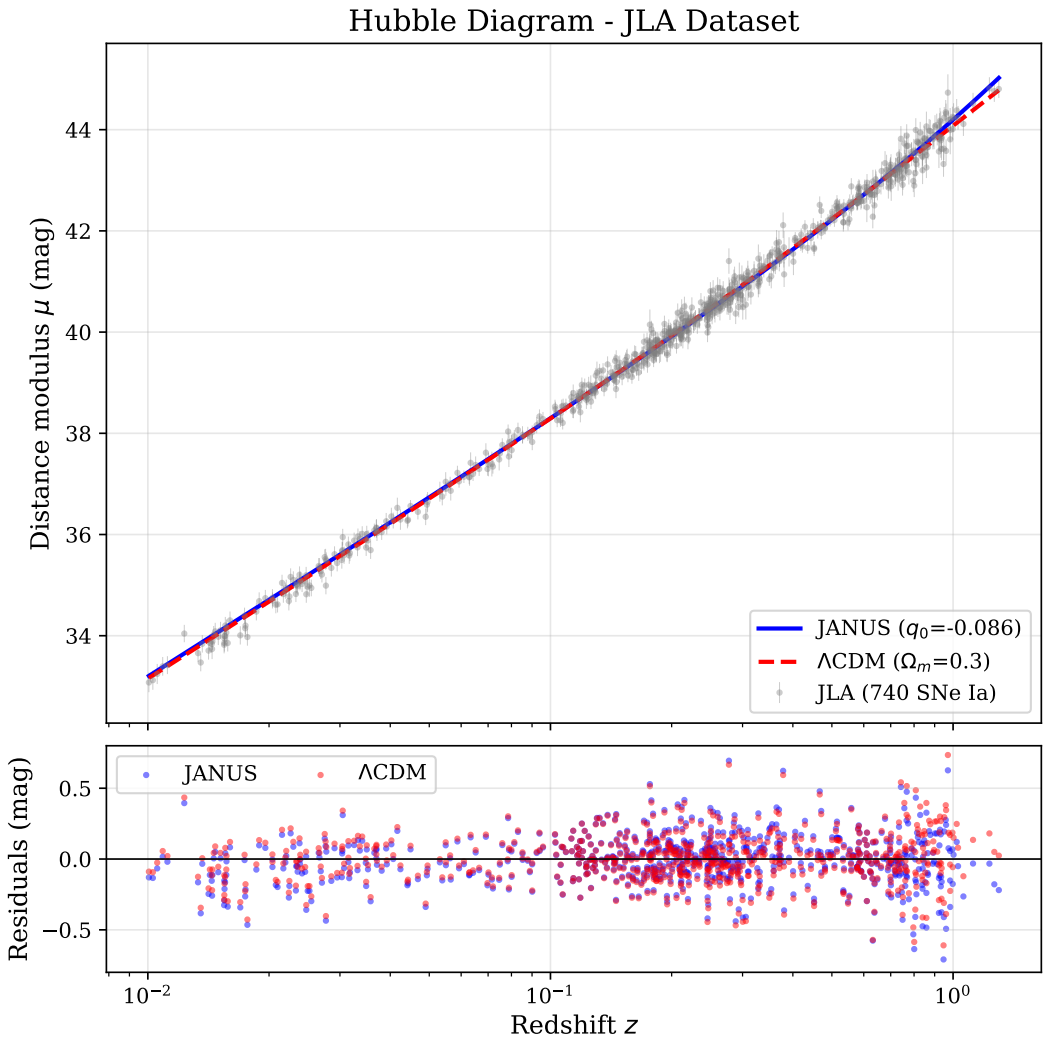

Figure 1: JLA Hubble diagram with JANUS ($q_0 = -0.086$) and ΛCDM fits.

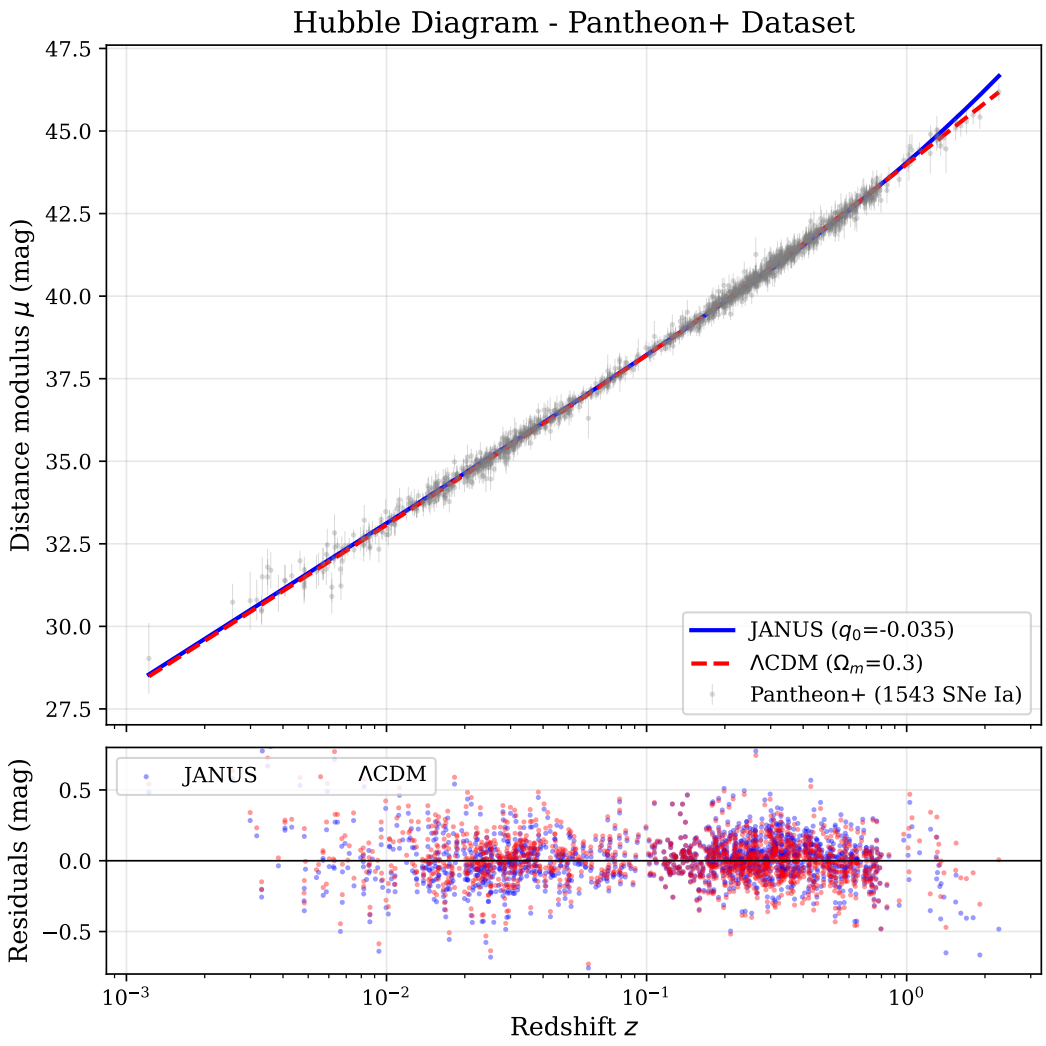

Figure 2: Pantheon+ Hubble diagram with JANUS ($q_0 = -0.035$) and ΛCDM fits.

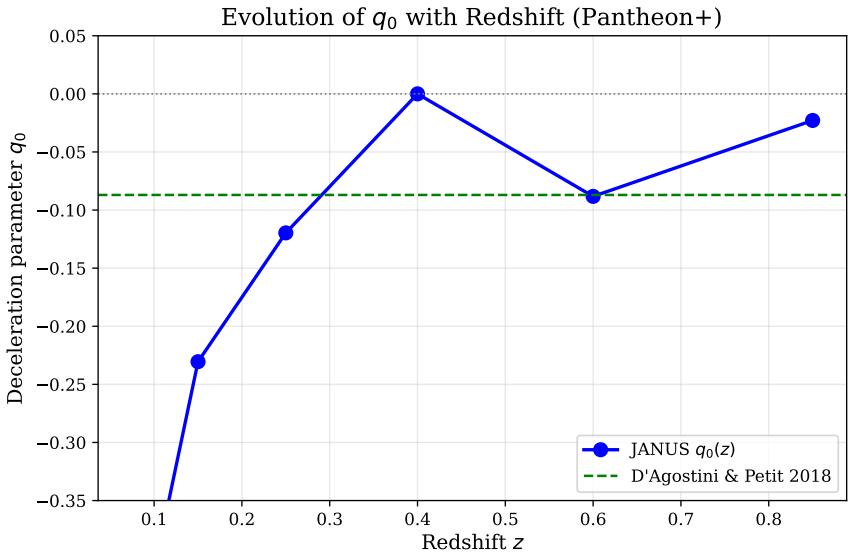

Figure 3: $q_0(z)$ evolution from Pantheon+ subsamples. Dashed: 2018 value.

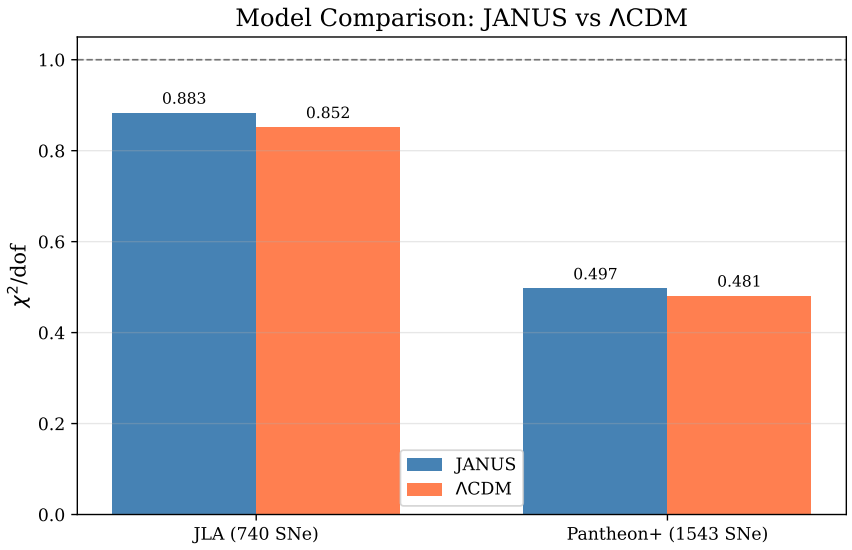

Figure 4: χ^2/dof comparison: JANUS vs ΛCDM.