Revealing Limitation in the Standard Cosmological Model: A Redshift-Dependent Hubble Constant from Fast Radio Bursts

Subtitle: Is the Standard Model of Cosmology Truly "Standard"?

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Introduction

Why Should We Care? The "Hubble Tension"

Hubble Tension： The discrepancy in the Hubble constant (H0) measured using two types of "cosmic rulers."

- Early-Universe (Planck18 CMB) eg., （67.4 ± 0.5） km $s^{-1}Mpc^{-1}$
- late-Universe (SH0ES distance-ladder) eg., (73.04 ± 1.04) km $s^{-1}Mpc^{-1}$

ΛCDM assumption: Hubble constant H_0 remains invariant across all redshifts.

Knowledge Gap

Is this tension due to observational systematics? Or a fundamental problem with ΛCDM?

Need independent observational probes to test this

Core Research Question

Is H_0 truly constant across different redshifts? If not, this implies a fundamental inadequacy in the ΛCDM model.

Data

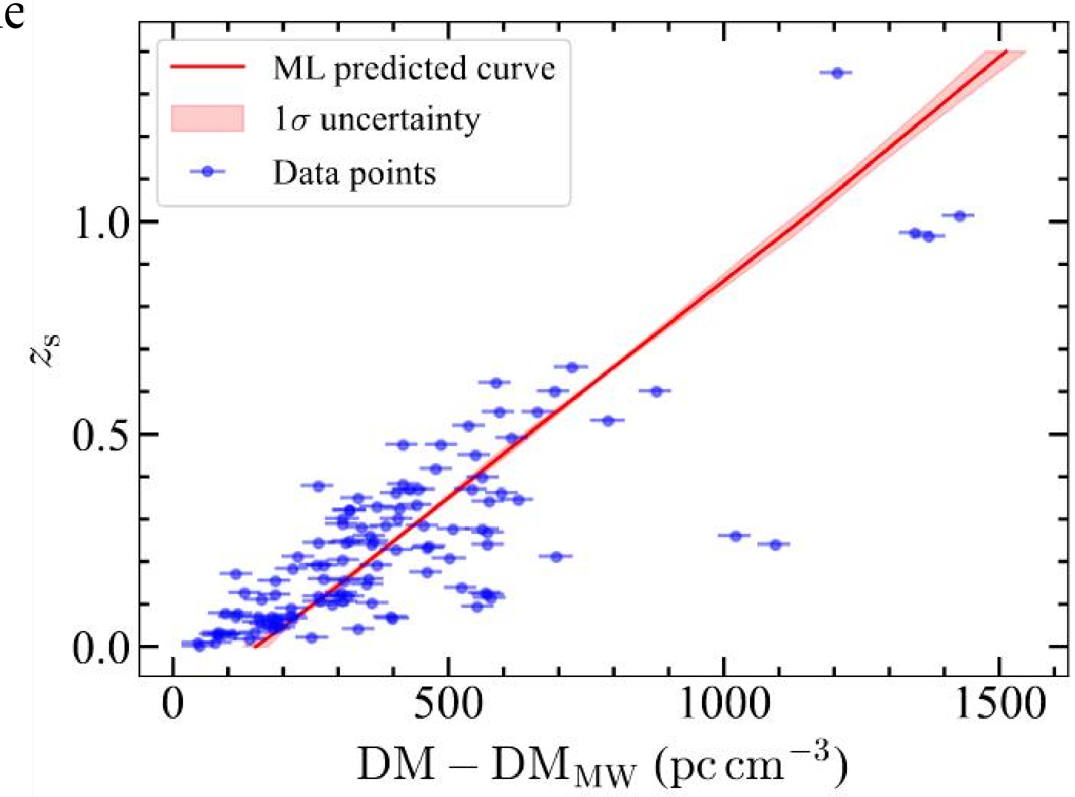
Dataset

- 114 well-localized Fast Radio Bursts (FRBs)
- Redshift range: $z \approx 0$ to $z \approx 1.35$
- Exploiting the Dispersion Measure (DM) - redshift relation

Data

First Approach: Artificial Neural Network (ANN)

- Architecture: Input layer + 2 hidden layers (100 neurons each) + Output layer
- Training: Continuous reconstruction of DM' - z relationship
- Advantage: Captures fine

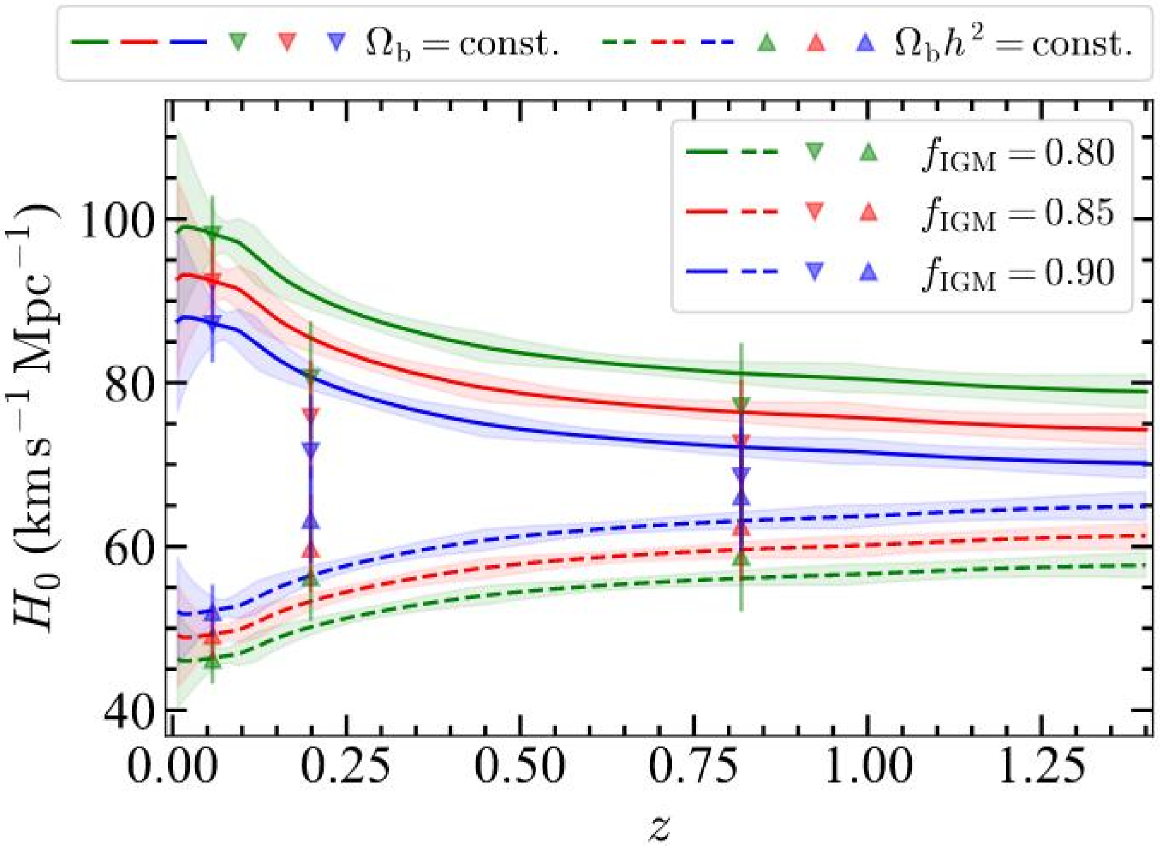


ML prediction shows DM' ≈ 150 pc cm^{-3} at z=0, corresponding to combined contribution from Galactic halo and host galaxy⇒ DM_halo≈65, DM_host≈85.

Initial Finding:

$$\langle \mathrm{DM_{IGM}}(z_s) \rangle = \frac{3c\Omega_b H_0^2}{8\pi G m_p} \int_0^{z_s} \frac{f_{\mathrm{IGM}}(z)\chi(z)(1+z)}{H(z)} \mathrm{d}z$$

The inferred H_0 was not a constant. It exhibited a systematic trend, evolving with redshift z (see sol -id lines in Fig.2).



Key Method 2 - Bayesian Validation

A Direct Test with a Bayesian Framework

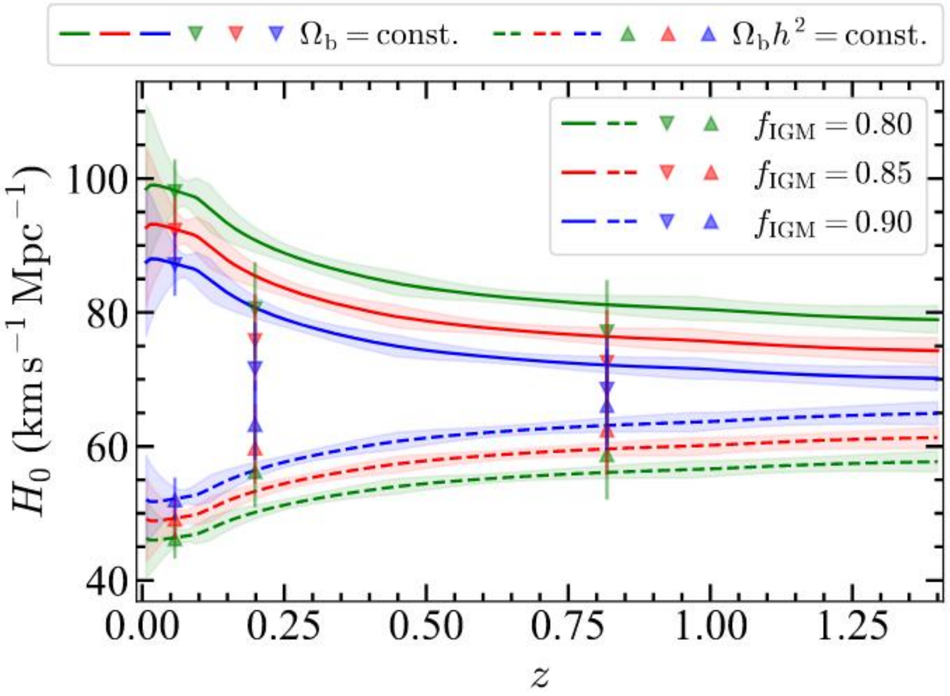
Data divided into 3 redshift bins

- Low-z: [0, 0.115], 36 samples
- Mid-z: [0.115, 0.282], 40 samples
- High-z: [0.282, 1.4], 38 samples

Independently estimate H_0 in each bin (H_{01}, H_{02}, H_{03})

$$\langle \mathrm{DM}_{\mathrm{IGM}}(z_s)\rangle = \frac{3c\Omega_b H_{01}^2}{8\pi G m_p}\int_0^{z_1}\frac{f_{\mathrm{IGM}}(z)\chi(z)(1+z)}{H_{01}\sqrt{\Omega_m(1+z)^3+\Omega_\Lambda}}dz + \frac{3c\Omega_b H_{02}^2}{8\pi G m_p}\int_{z_1}^{z_2}\frac{f_{\mathrm{IGM}}(z)\chi(z)(1+z)}{H_{02}\sqrt{\Omega_m(1+z)^3+\Omega_\Lambda}}dz + \frac{3c\Omega_b H_{03}^2}{8\pi G m_p}\int_{z_2}^{z_s}\frac{f_{\mathrm{IGM}}(z)\chi(z)(1+z)}{H_{03}\sqrt{\Omega_m(1+z)^3+\Omega_\Lambda}}dz$$

The Bayesian analysis strongly corroborated the ML findings. We again observed a statistically significant evolution of H_0 across the different redshift bins (see scatter points in Fig. 2).



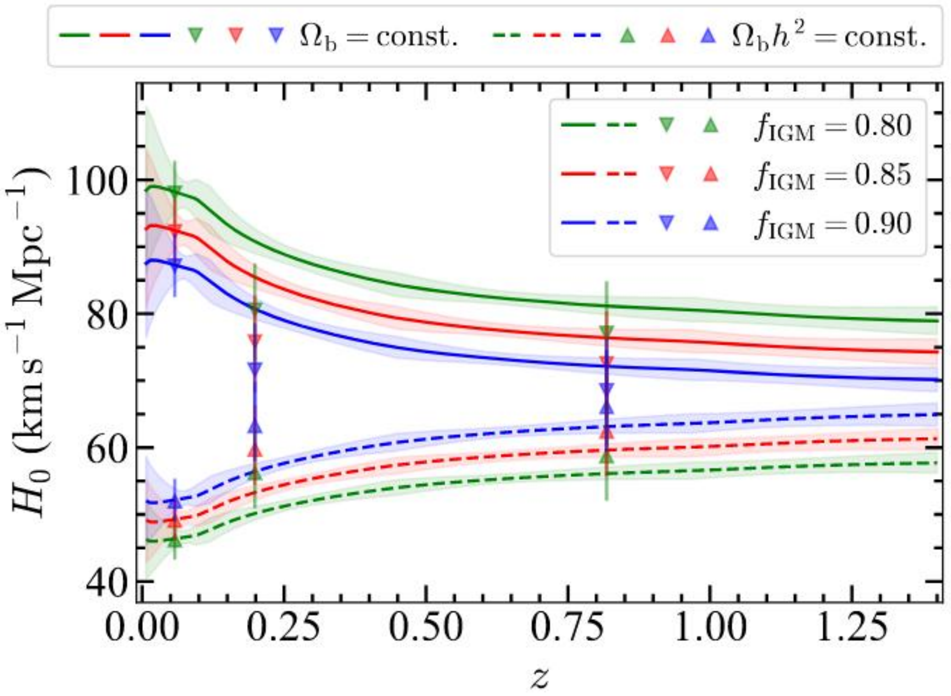
Results

The Critical Result: H_0 Varies Significantly with Redshift!

- When Fixing Ωb:H_0 decreases with redshift
- When Fixing Ωbh²:H_0 increases with redshift
- Results robust across different fIGM values (0.80, 0.85, 0.90)

Two Methods Agree

- ML continuous curves + Bayesian discrete points perfectly match
- → The core ΛCDM assumption (constant H_0) is violated!



Summary

- ➢ ΛCDM is Inadequate: Standard cosmological model cannot explain the observed H_0 redshift dependence
- ➢ New Interpretation of Hubble Tension: May not be observational errors, but a problem with the model itself
- ➢ Dark Energy May Be Dynamic: The cosmological constant Λ may be oversimplified.
- ➢ Further Test: $w_0 w_a$CDM Model, H_0 can remain constant within more flexible dark energy frameworks!

Thanks for your listening!

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