PHYSICS

On the Difficulties with Late-Time Solutions for the Hubble Tension

arXiv: 2602.0629

COSMOVERSE Journal Club

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How does a typical SNIa lileihood work?

$$\mu = 5\log_{10}(d_L) + 25$$
$$m_{app} = \mu + M_{abs}$$
$$m_{app} = 5\log_{10}(d_L) + 25 + M_{abs}$$

$$m_{app} = 5\log_{10}(H_0 d_L) - 5\log_{10} H_0 + 25 + M_{abs}$$
$$m_{app} = 5\log H_0 d_L + \mathscr{M}$$

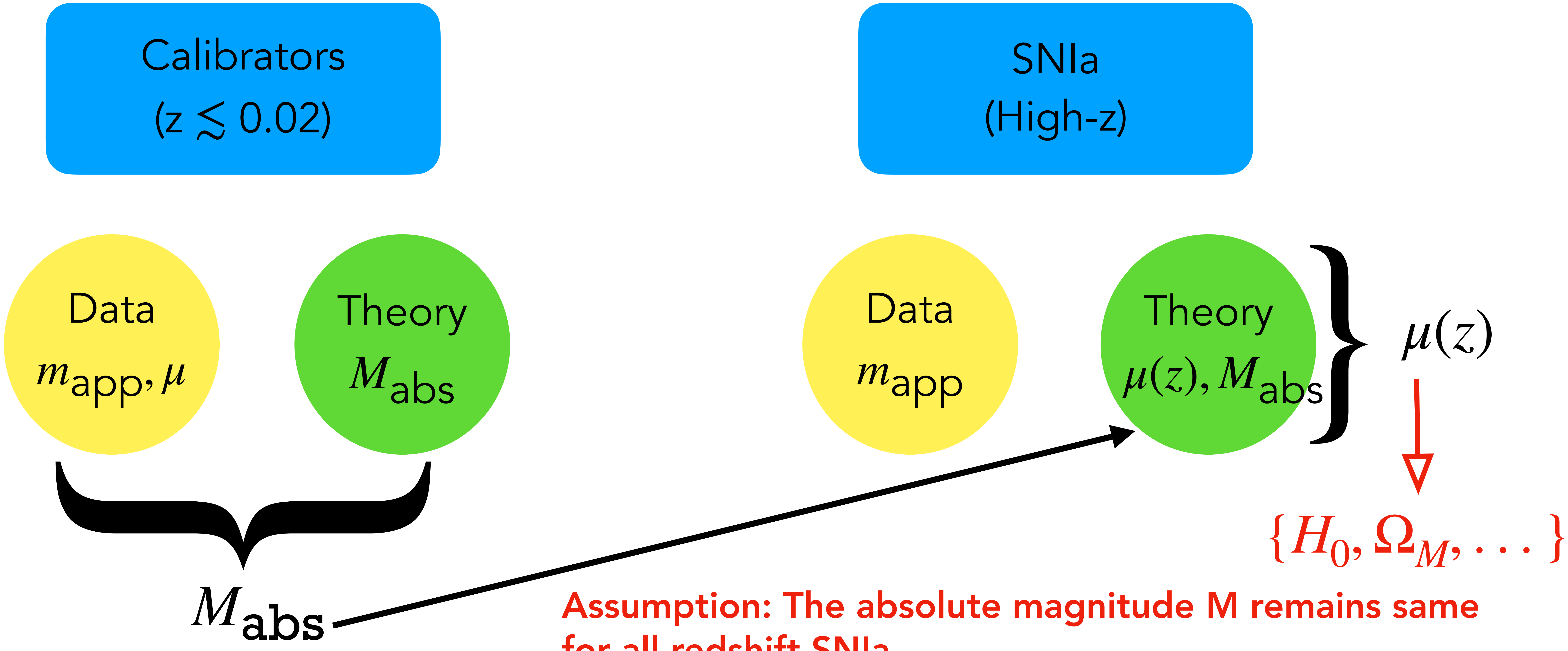
Marginalized over in std analyses

$\{$**SN Properties**$, H_0\}$

$\{\Omega_M, \Omega_K, w_0, w_a \ldots\}$

How does a typical (Calib.) SNIa lileihood work?

$$m_{app} = \mu + M_{abs}$$



Assumption: The absolute magnitude M remains same for all redshift SNIa

Hubble Tension as "M" tension

Fixing M to SHOES Best-fit value

Hubble Tension as "M" tension

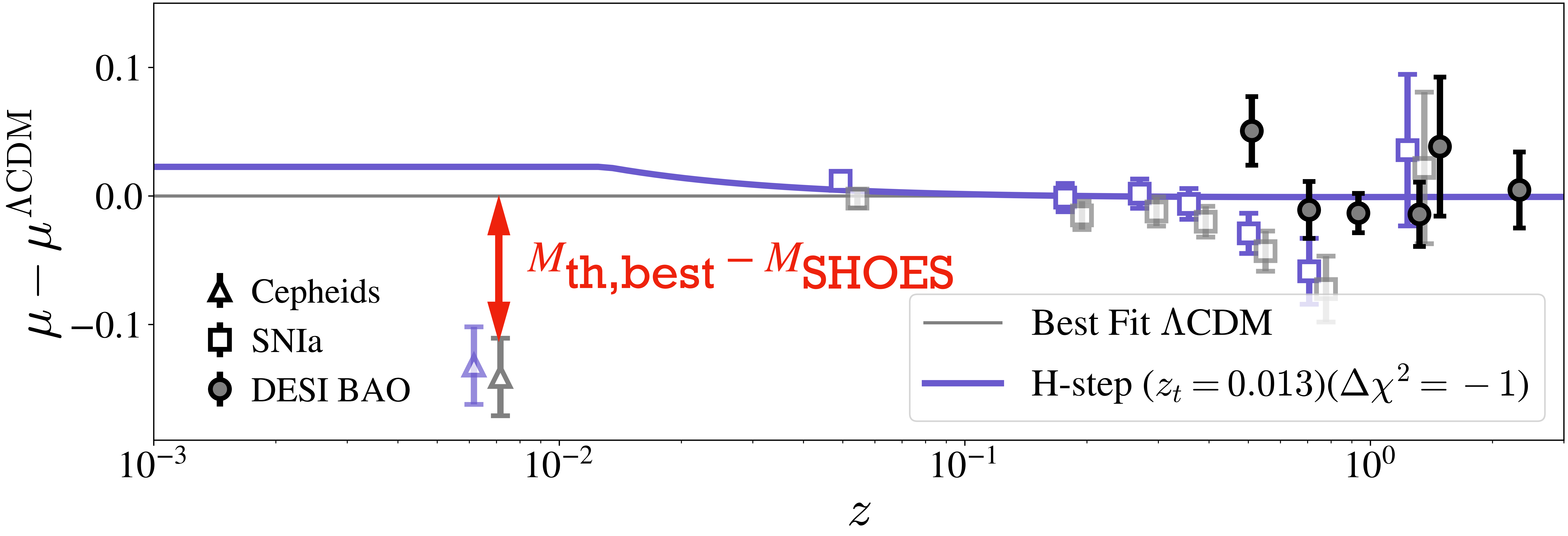
Allowing M to be a free parameter

Hubble Tension as “M” tension

Thus, a model which **solves** Hubble Tension
would give a best-fit absolute magnitude M
(in the combined fit to BAO+CMB+SNIa data)
which is consistent with the best-fit value
preferred by SHOES Cepheids (-19.25 ± 0. 027)

A simple expansion history modification cannot resolve this tension!

$$H(z) = \begin{cases} H_0 E(z), & \text{if } z \leq z_{\rm t} \\ H_0^{\rm E} E(z), & \text{if } z > z_{\rm t} \end{cases}$$



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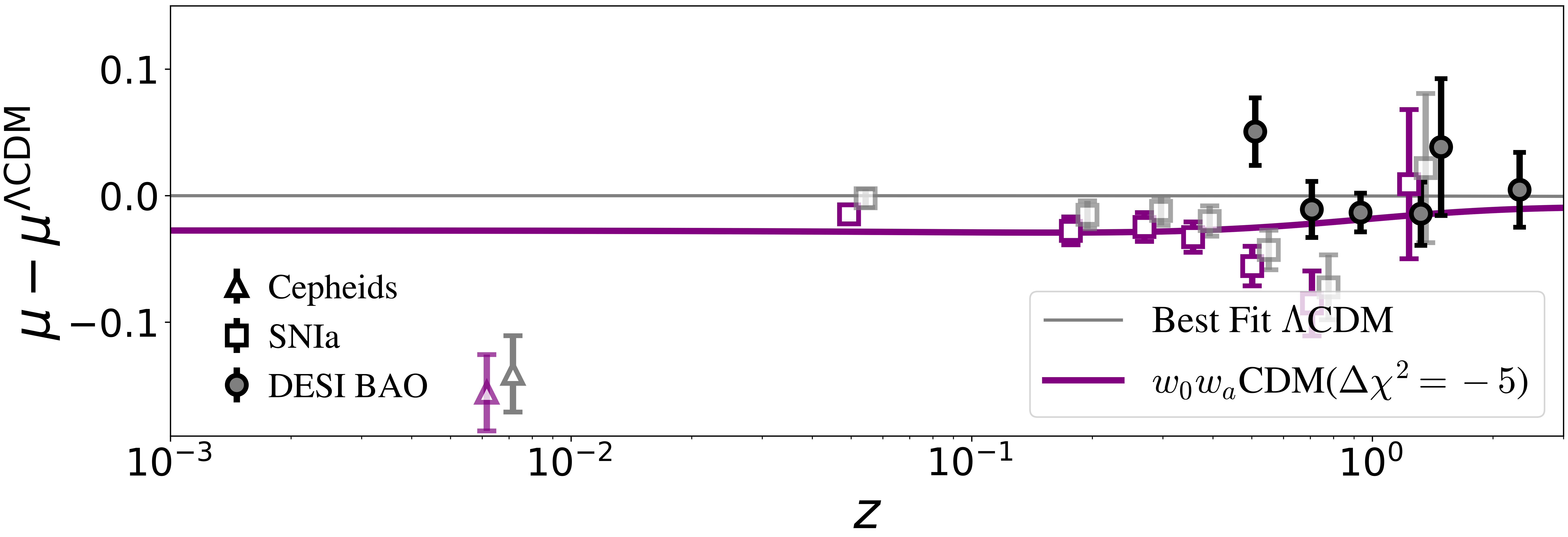
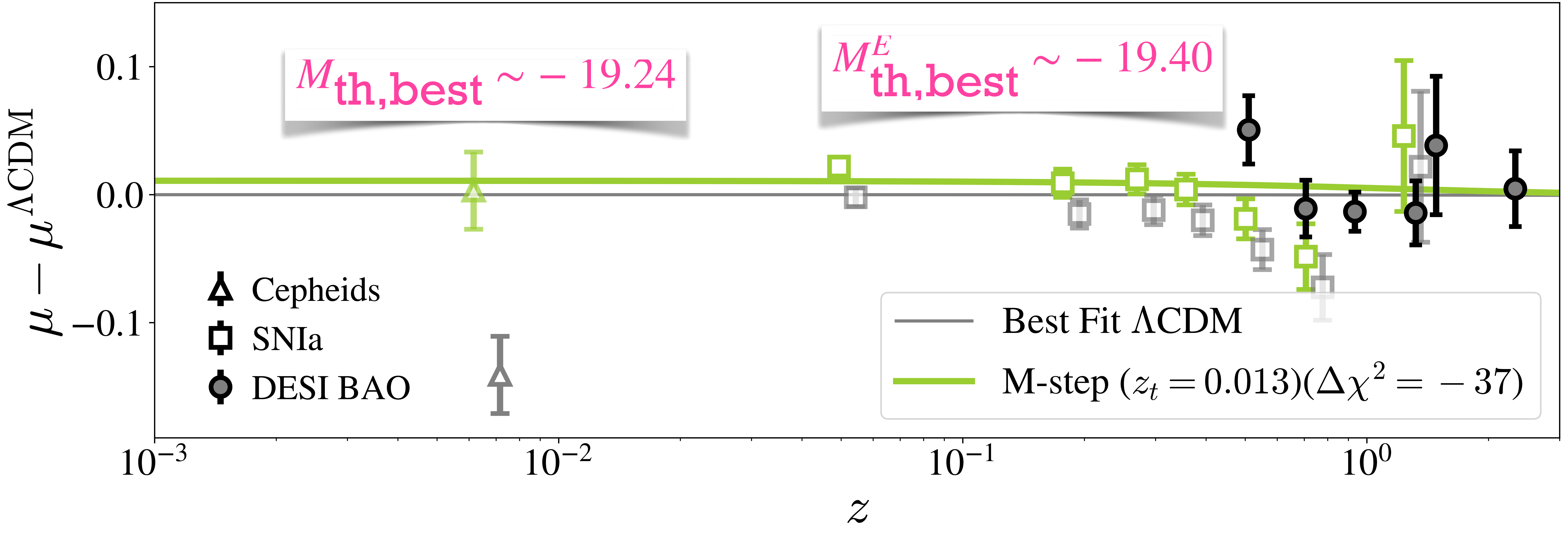


So what type of solutions can work?

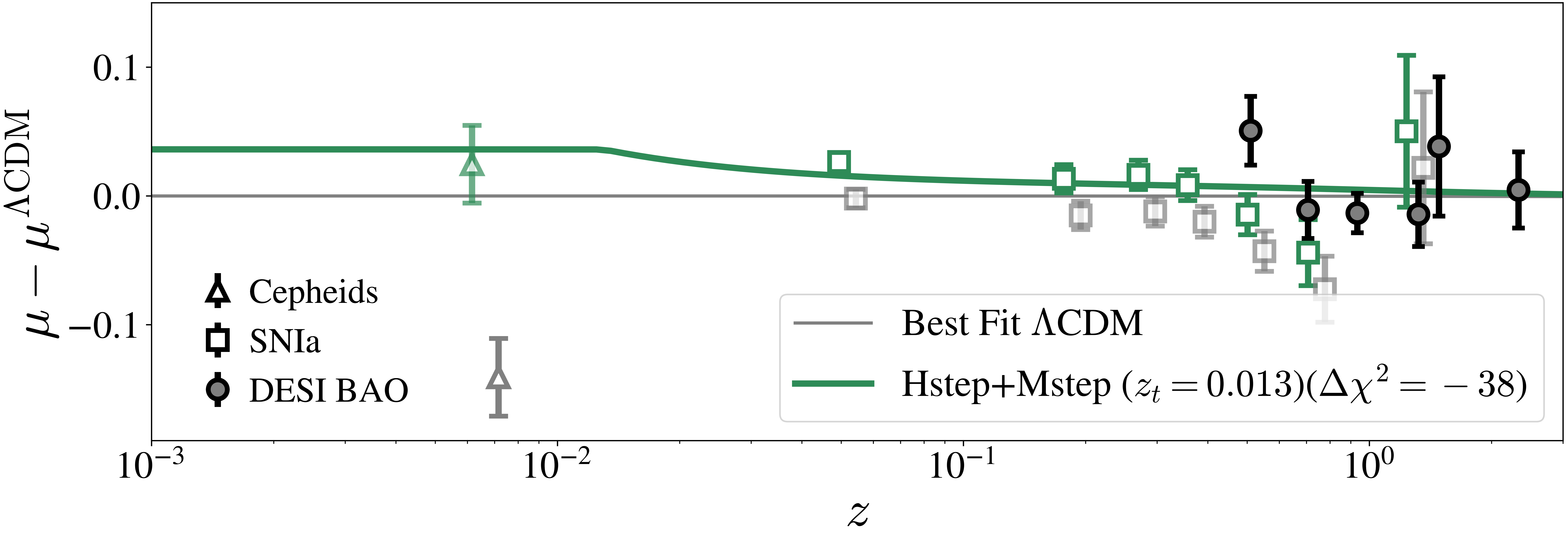
1. Allowing for a break in SNIa absolute magnitude significantly improves the $\Delta\chi^2$

$$m(z) = \begin{cases} \mu(z) + M, & \text{if } z \leq z_{\rm t} \\ \mu(z) + M^{\rm E}, & \text{if } z > z_{\rm t} \end{cases}$$



2. A break in absolute magnitude along with a modified expansion history also works

$$m(z) = \begin{cases} \mu(z) + M, & \text{if } z \leq z_\mathrm{t} \\ \mu(z) + M^\mathrm{E}, & \text{if } z > z_\mathrm{t} \end{cases} \qquad H(z) = \begin{cases} H_0 E(z), & \text{if } z \leq z_\mathrm{t} \\ H_0^\mathrm{E} E(z), & \text{if } z > z_\mathrm{t} \end{cases}$$



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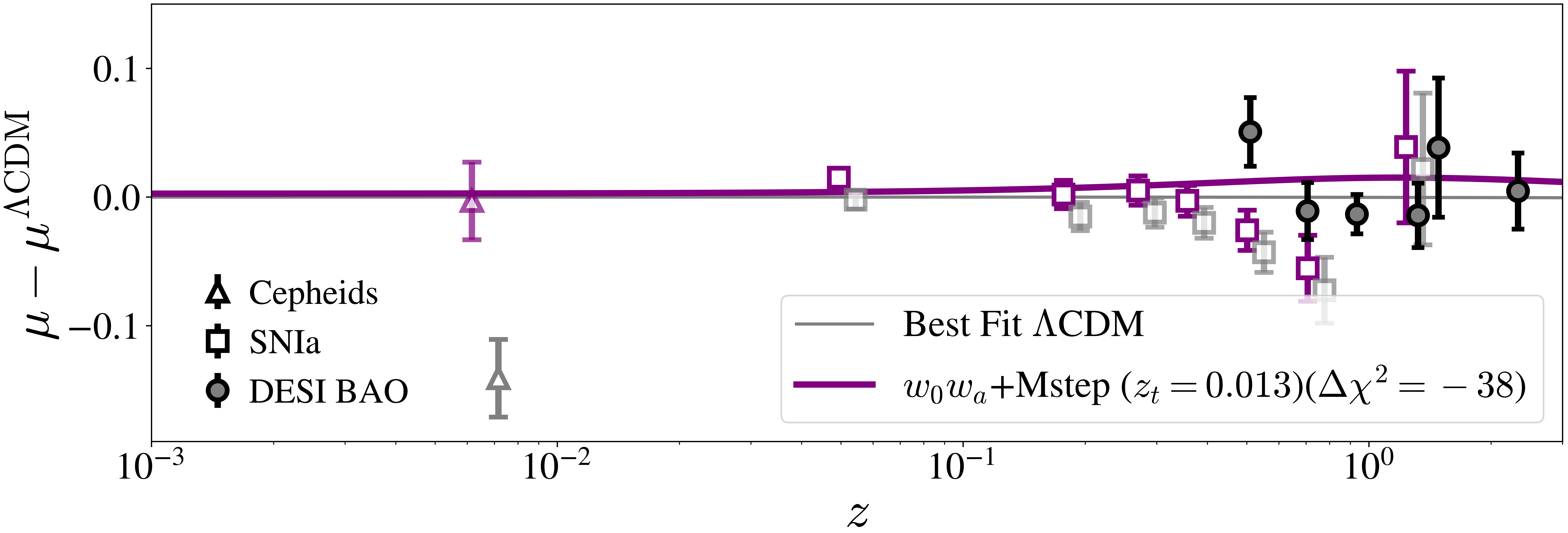
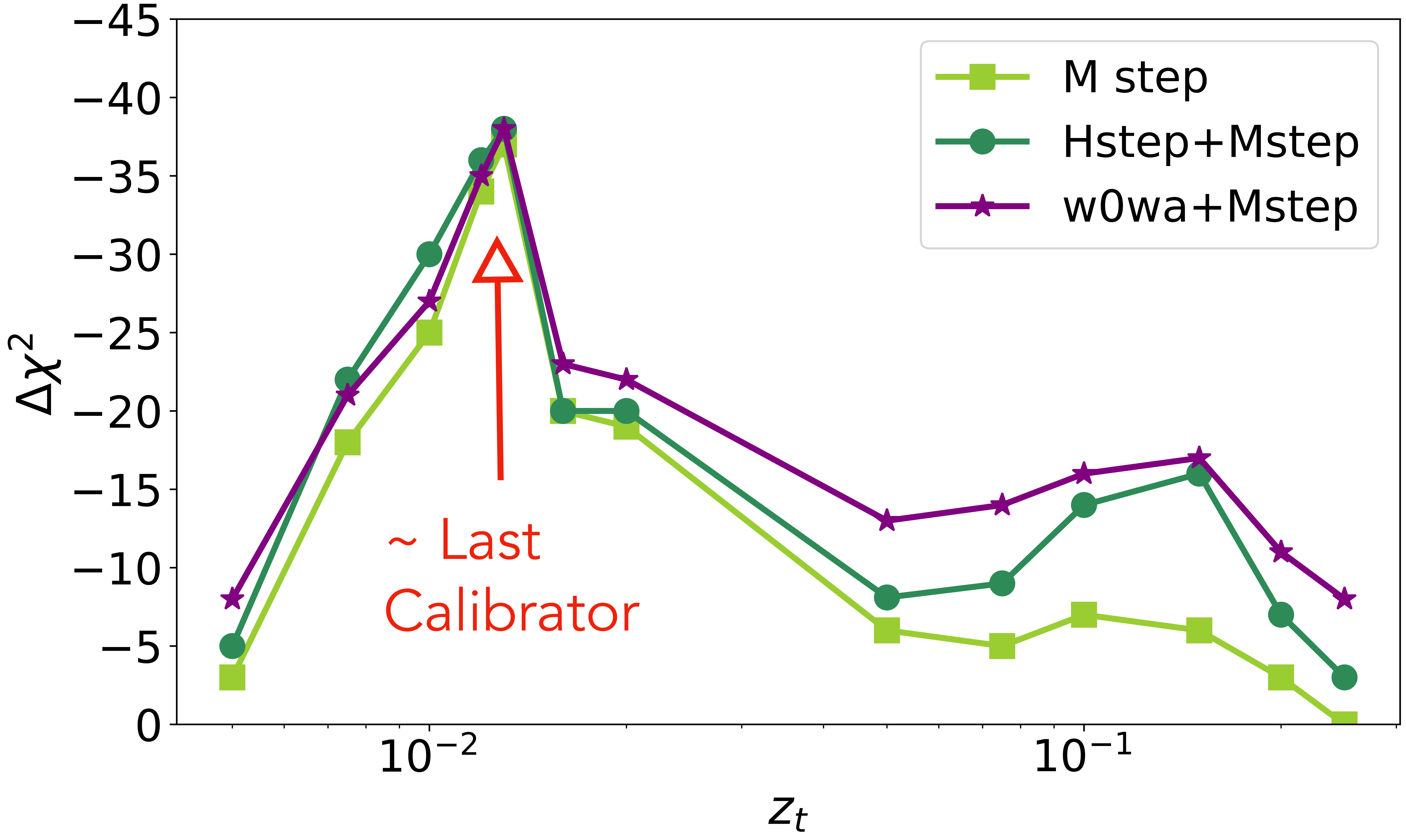
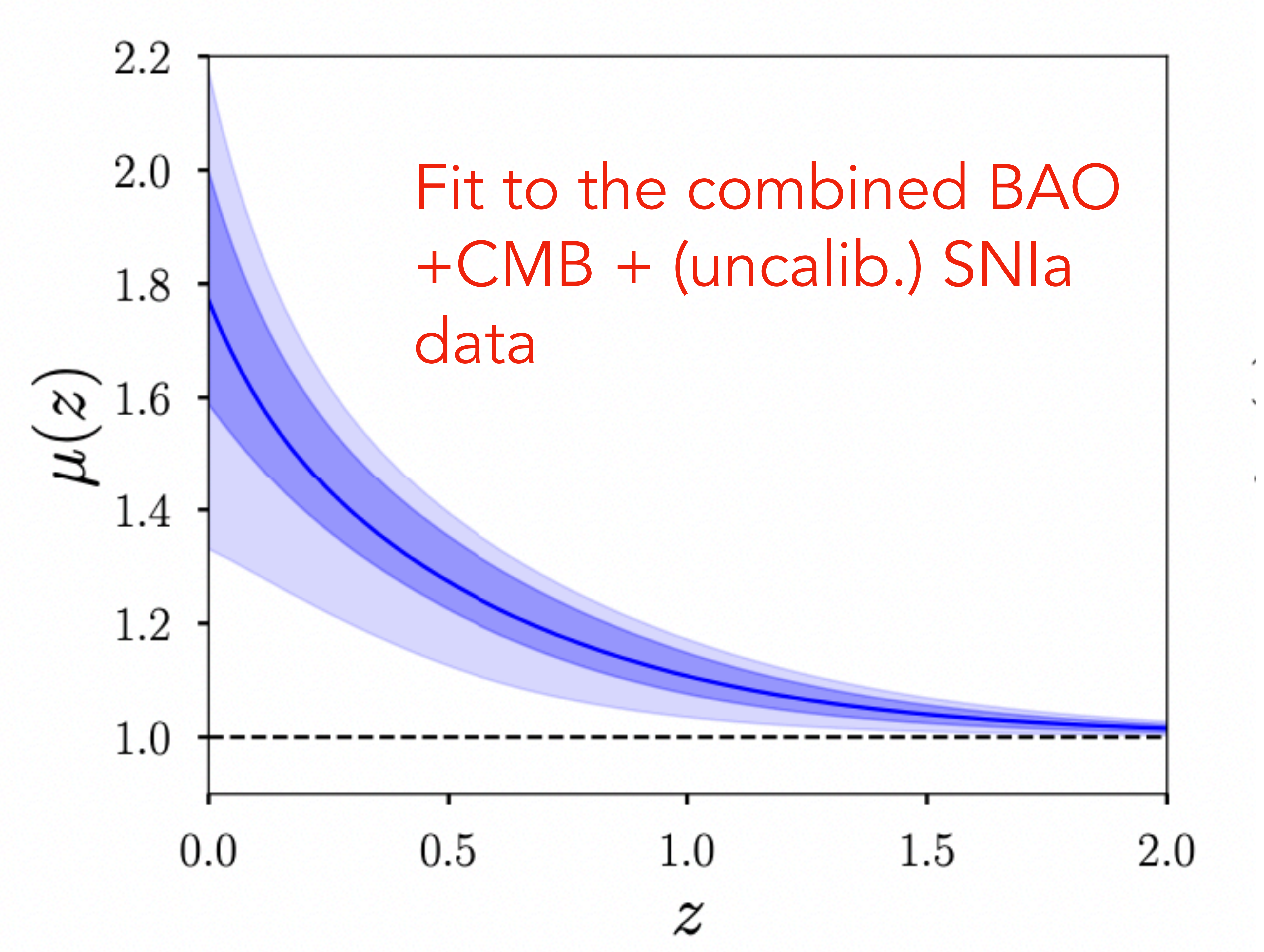


Does the redshift of this step in magnitude also matter?



Is there any "physical" way to achieve this magnitude transition?

A "tweaked" non-minimally coupled scalar field



$$\nabla^2\Phi = 4\pi G\mu_{MG}\rho$$

Assuming, a power law variation of Chandrashekhar mass, and hence peak SNIa luminosity,

$$M(z) = M^E + n\log[\mu_{MG}(z)]$$

Wolf *et.al. Phys. Rev. Lett. 135, 081001*

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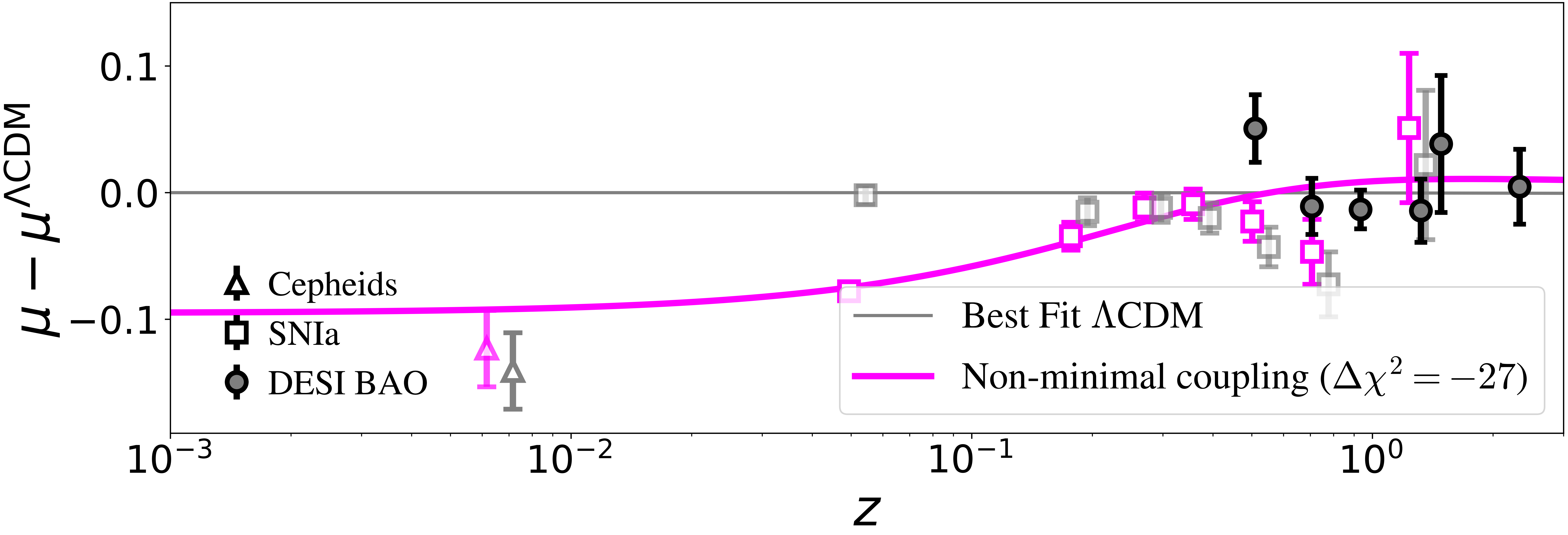
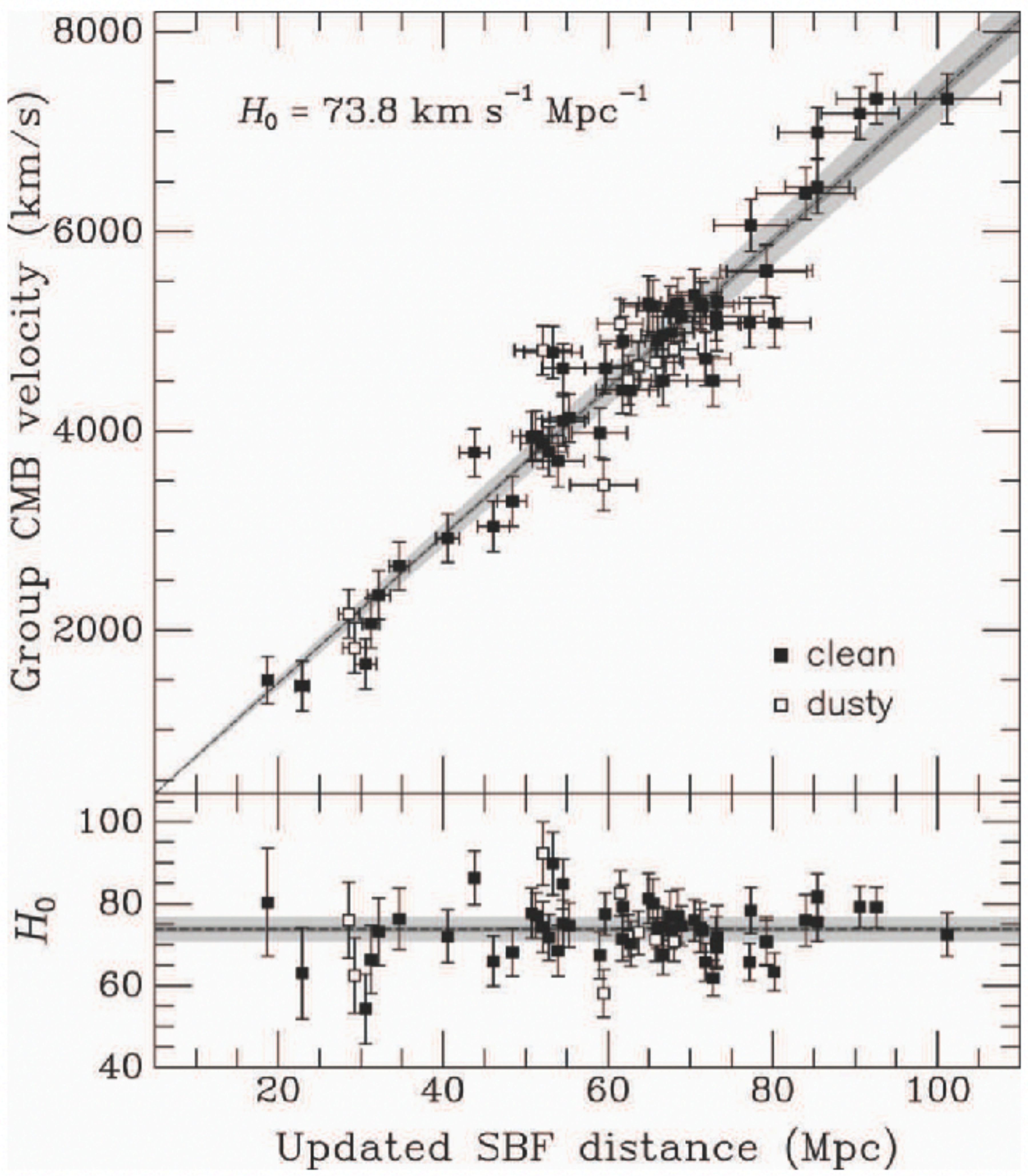


Including Surface Brightness Fluctuation (SBF) Distance Measurements



$$H_0 = 73.8 \pm 0.8\,\mathbf{(stat)}\ \pm 2.3\,\mathbf{(sys)}$$

Low-z sample extending to z $\lesssim$ 0.02

Jensen *et.al. 2025 ApJ 987 87*

Including Surface Brightness Fluctuation (SBF) Distance Measurements

Baseline+SBF (zero-point uncertainty ignored)						
Model	χ^2_{total}	$\Delta\chi^2$	$\chi^2_{\mathrm{BAO+CMB}}$	$\chi^2_{\mathrm{Panth+SH0ES}}$	χ^2_{SBF}	ΔDOF
LCDM	1645	0	32	1478	135	0
LCDM (SBF only)	–	–	–	–	97	0
HStep	1630	−15	24	1498	108	2
MStep	1614	−31	26	1446	142	2
HStep+MStep ($z_{\mathrm{tH}} = z_{\mathrm{tM}}$)	1596	−49	19	1465	112	3

Baseline+SBF+$\mathcal{Z}_{\mathrm{SBF}}$ (zero-point uncertainty included)						
Model	χ^2_{total}	$\Delta\chi^2$	$\chi^2_{\mathrm{BAO+CMB}}$	$\chi^2_{\mathrm{Panth+SH0ES}}$	χ^2_{SBF}	ΔDOF
LCDM	1574	0	18	1483	73	0
LCDM (SBF only)	–	–	–	–	71	0
HStep	1571	−3	18	1482	71	2
MStep	1533	−41	17	1444	72	2
HStep+MStep ($z_{\mathrm{tH}} = z_{\mathrm{tM}}$)	1530	−44	17	1442	71	3

SBFs at their current precision cannot rule out the M-transition type solutions

On the issue of M prior

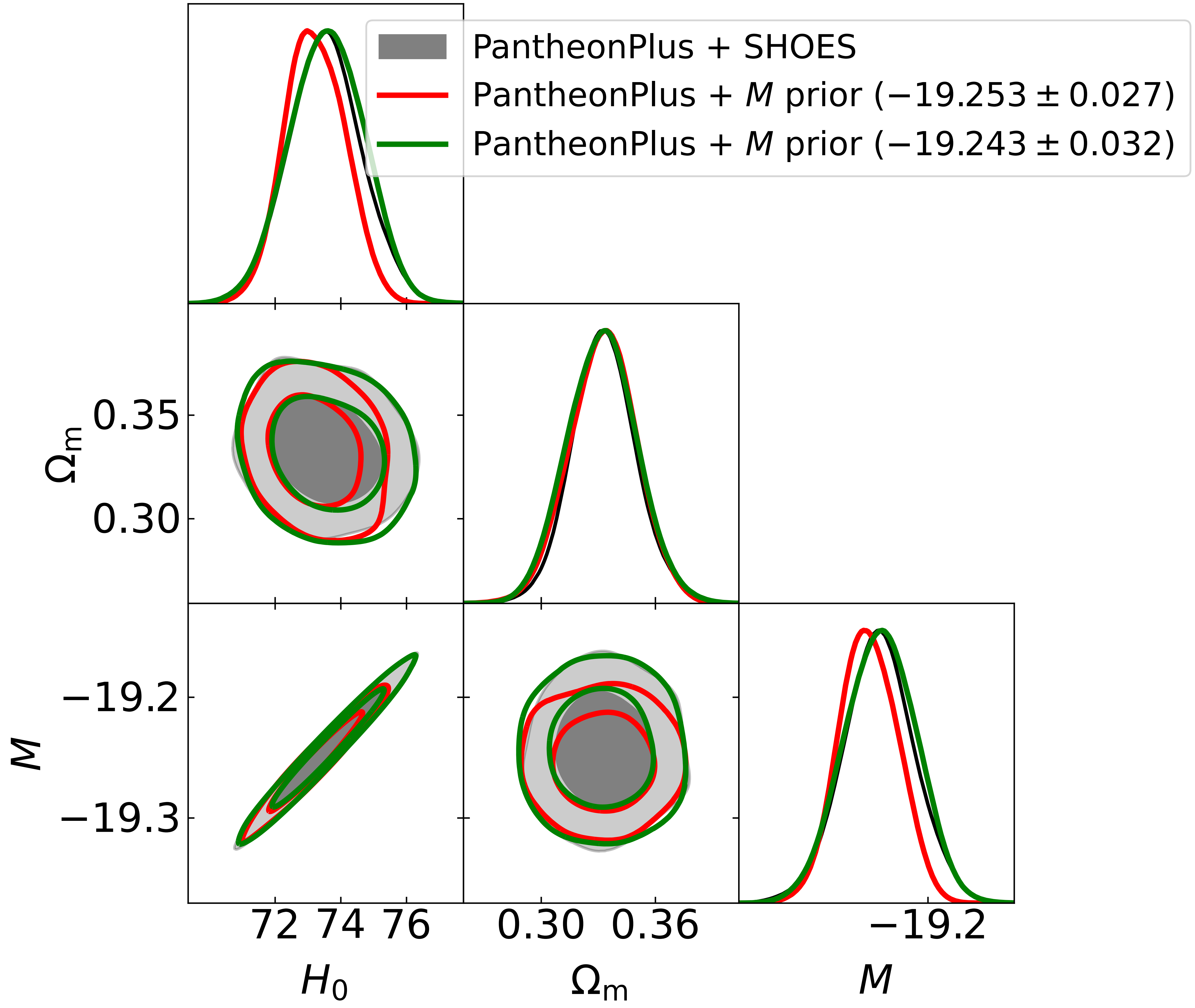
The std PantheonPlus+SHOES analysis reports H_0 and M_{abs} by considering the low-z calibrators along with SNIa **uptil redshift 0.15**

Care must be taken while employing an "M_{abs}" prior instead of full treatment using calibrators, to avoid double counting information

Correct M prior to use:

$M_{\text{abs}} = -19.243 \pm 0.032$

(Camarena & Marra 2021)



Summary

The only type of late-time solutions that work for Hubble Tension, must do one of the following

1. A late time transition in SNIa absolute magnitude M
2. A late time transition in SNIa absolute magnitude M along with a modification in expansion history
3. Violating Distance Duality Relation $(d_L = (1+z)^n d_A \ ; n \neq 2)$

See eg. Teixeira et.al. Phys. Rev. D 112, 023515

Thank You!
Questions?