DESI Dark Energy and Hubble tension

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暗物质暗能量研究现状发展趋势及对策专题研讨会

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References

2505.22369 Jia-Le Ling, Guo-Hong Du, Tian-Nuo Li, Jing-Fei Zhang, Shao-Jiang Wang, Xin Zhang
Model-independent cosmological inference after the DESI DR2 data with improved inverse distance ladder

This talk is mainly based on 2502.04212 Lu Huang (黄路), Rong-Gen Cai, Shao-Jiang Wang
The DESI DR1/DR2 evidence for dynamical dark energy is biased by low-redshift supernovae

2410.06053 Lu Huang, Rong-Gen Cai, Shao-Jiang Wang, Jian-Qi Liu, Yan-Hong Yao
Narrowing down the Hubble tension to the first two rungs of distance ladders
Sci.China Phys.Mech.Astron. 68 (2025) 8, 280405

2401.14170 Lu Huang, Shao-Jiang Wang, Wang-Wei Yu
No-go guide for the Hubble tension: Late-time or local-scale new physics
Sci.China Phys.Mech.Astron. 68 (2025) 2, 220413

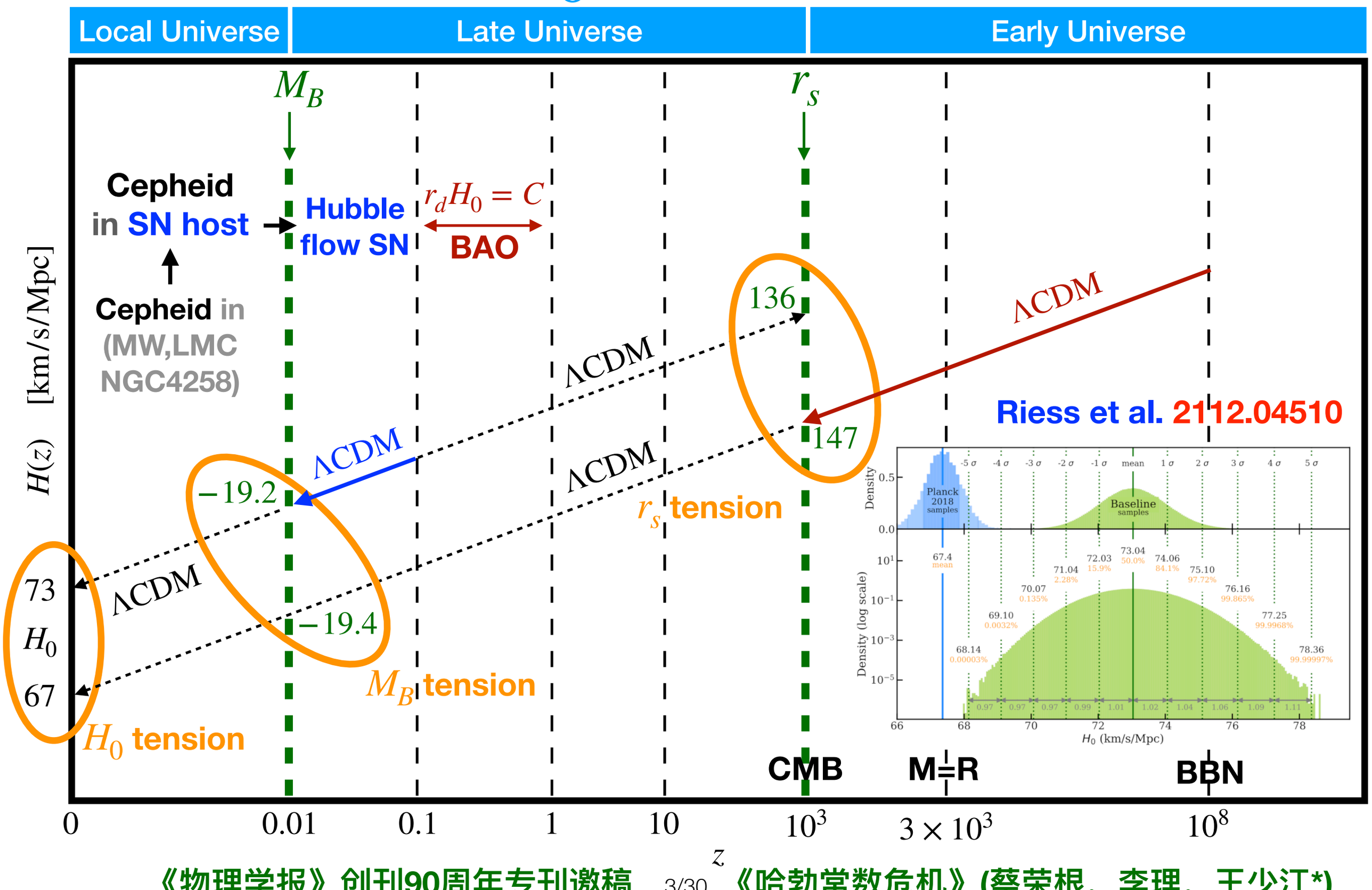
2202.12214 Rong-Gen Cai, Zong-Kuan Guo, Shao-Jiang Wang, Wang-Wei Yu, Yong Zhou
No-go guide for late-time solutions to the Hubble tension: Matter perturbations
Phys.Rev.D 106 (2022) 6, 063519

2107.13286 Rong-Gen Cai, Zong-Kuan Guo, Shao-Jiang Wang, Wang-Wei Yu, Yong Zhou
No-go guide for the Hubble tension: Late-time solutions
Phys.Rev.D 105 (2022) 2, L021301

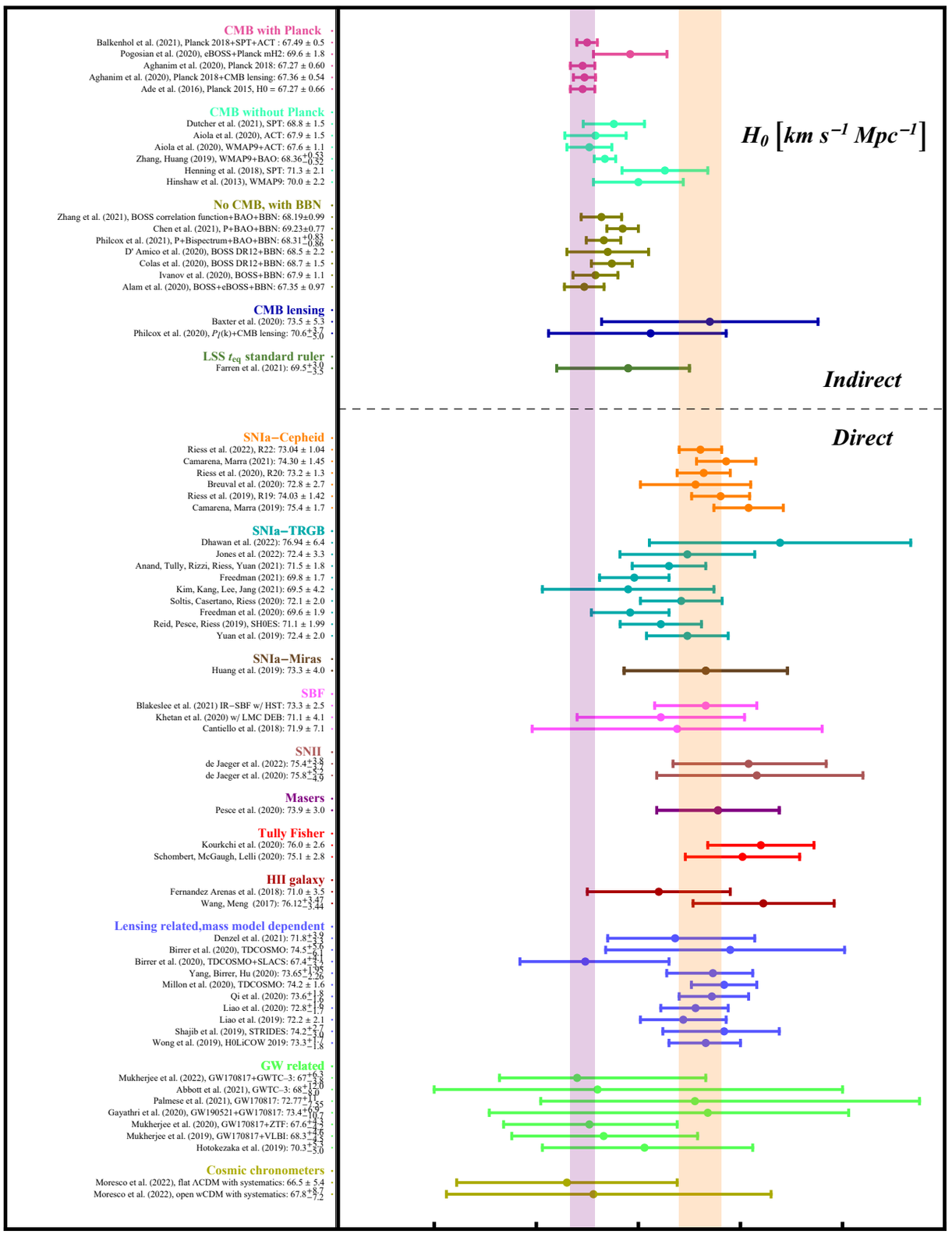
2102.02020 Rong-Gen Cai, Zong-Kuan Guo, Li Li, Shao-Jiang Wang, Wang-Wei Yu
Chameleon dark energy can resolve the Hubble tension
Phys.Rev.D 103 (2021) L121302

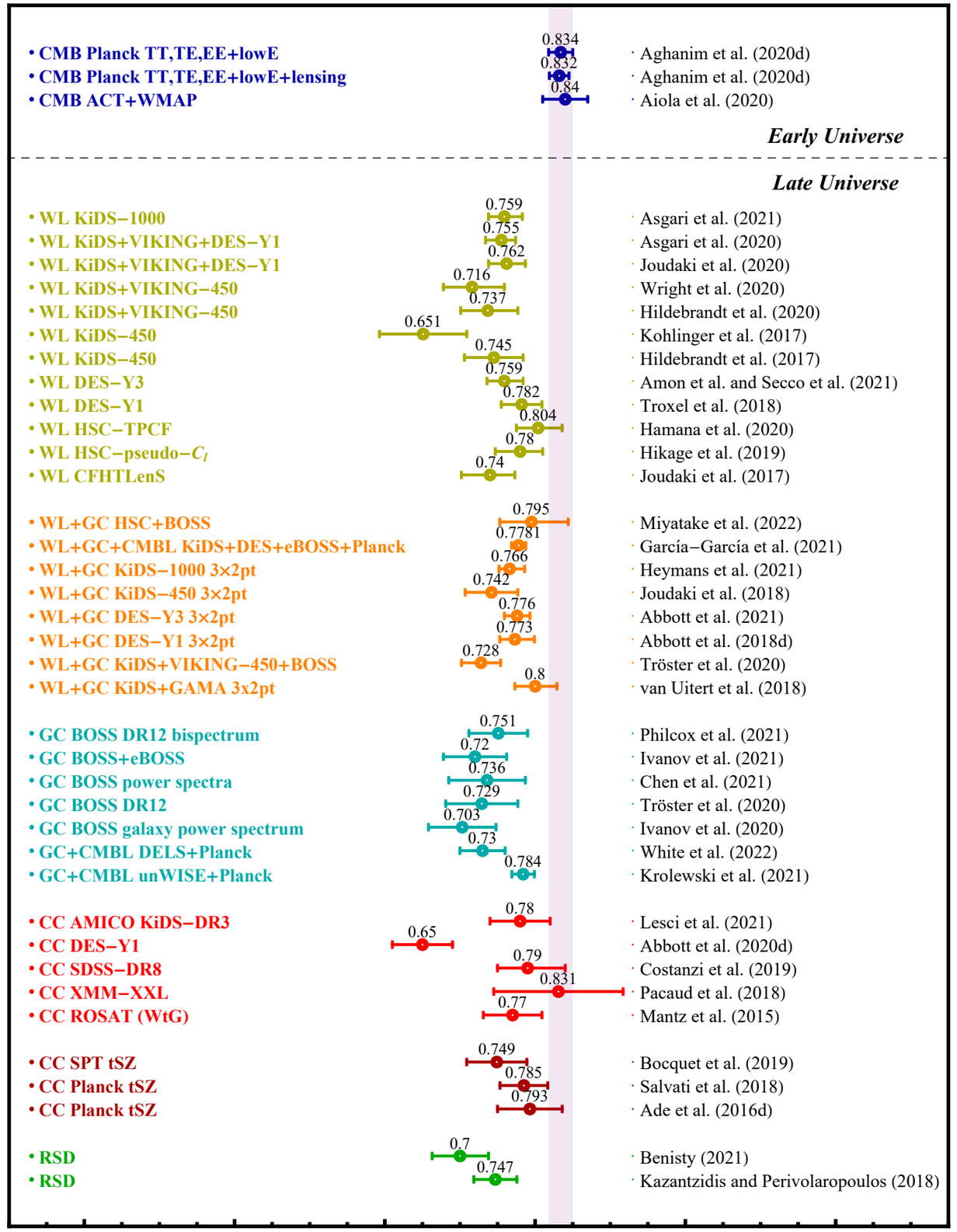
& 2209.14732 Wang-Wei Yu, Li Li, Shao-Jiang Wang First detection of the Hubble variation correlation and its scale dependence

H_0 tension

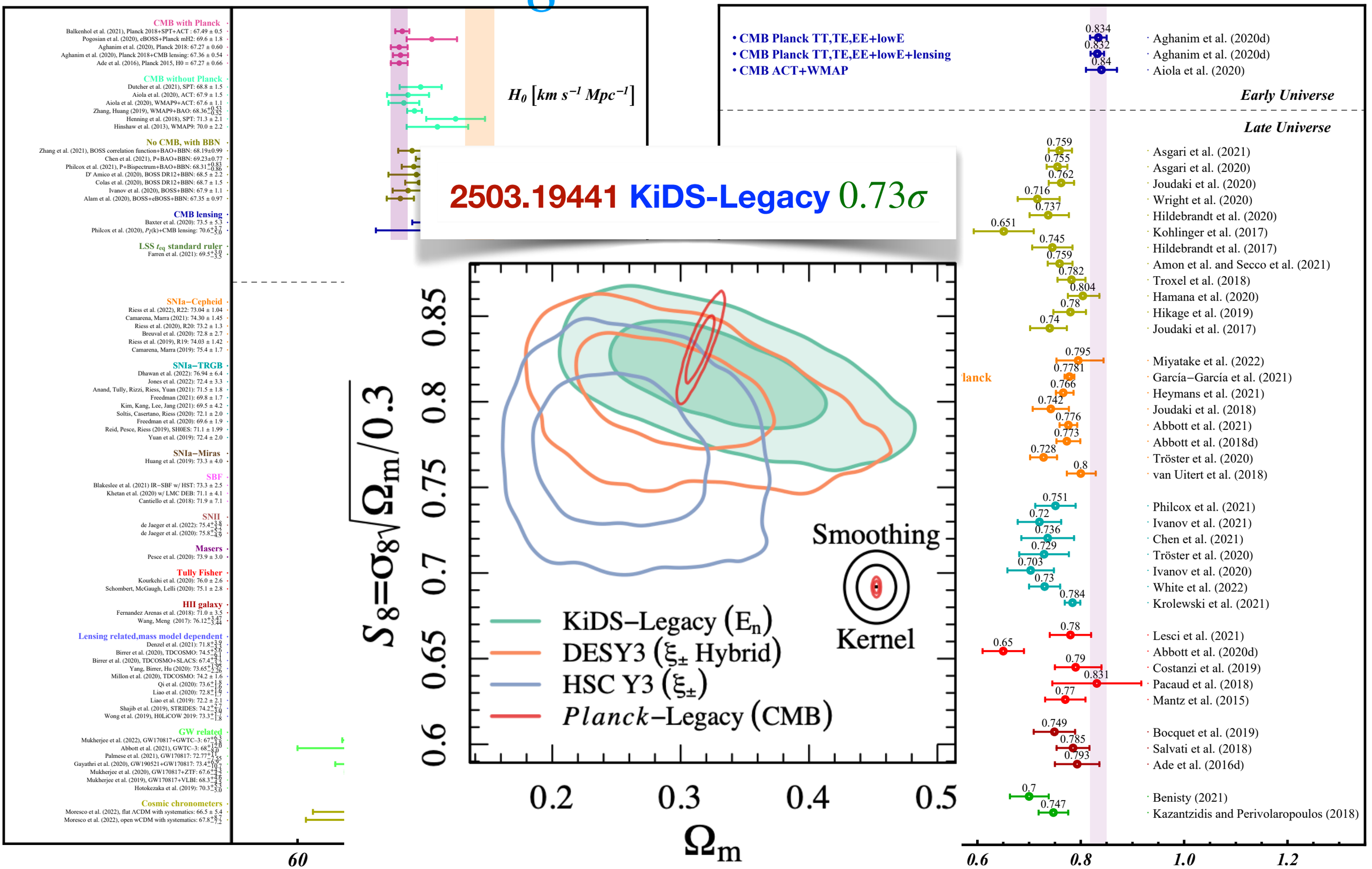

Local Universe
Late Universe
Early Universe
M_B
r_s
Cepheid in SN host
Cepheid in (MW,LMC NGC4258)
Hubble flow SN
$r_d H_0 = C$
BAO
136
ΛCDM
ΛCDM
147
ΛCDM
Riess et al. 2112.04510
ΛCDM
−19.2
−19.4
M_B tension
r_s tension
73
H_0
67
H_0 tension
CMB
M=R
BBN
$H(z)$ [km/s/Mpc]
0
0.01
0.1
1
10
10^3
3×10^3
10^8
z
Density
Planck 2018 samples
Baseline samples
-5 σ
-4 σ
-3 σ
-2 σ
-1 σ
mean
1 σ
2 σ
3 σ
4 σ
5 σ
67.4 mean
68.14 0.00003%
69.10 0.0032%
70.07 0.135%
71.04 2.28%
72.03 15.9%
73.04 50.0%
74.06 84.1%
75.10 97.72%
76.16 99.865%
77.25 99.9968%
78.36 99.99997%
0.97
0.97
0.97
0.99
1.01
1.02
1.04
1.06
1.09
1.11
Density (log scale)
H_0 (km/s/Mpc)

Early-late tension





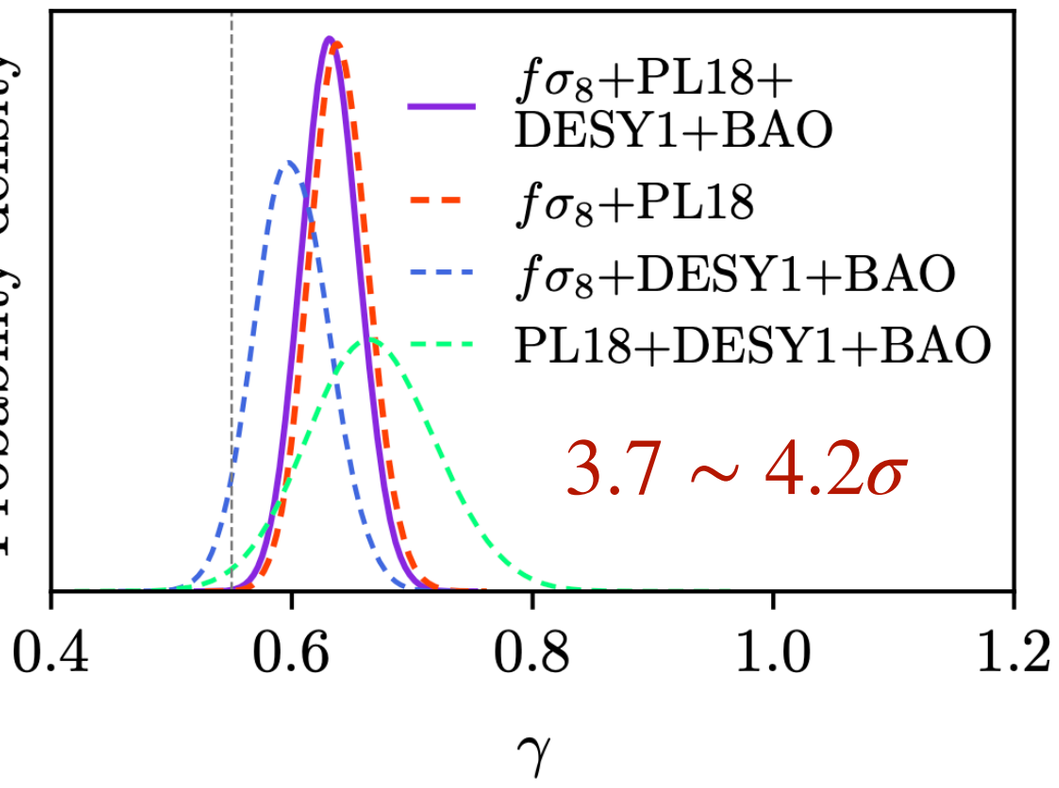
S_8 tension?

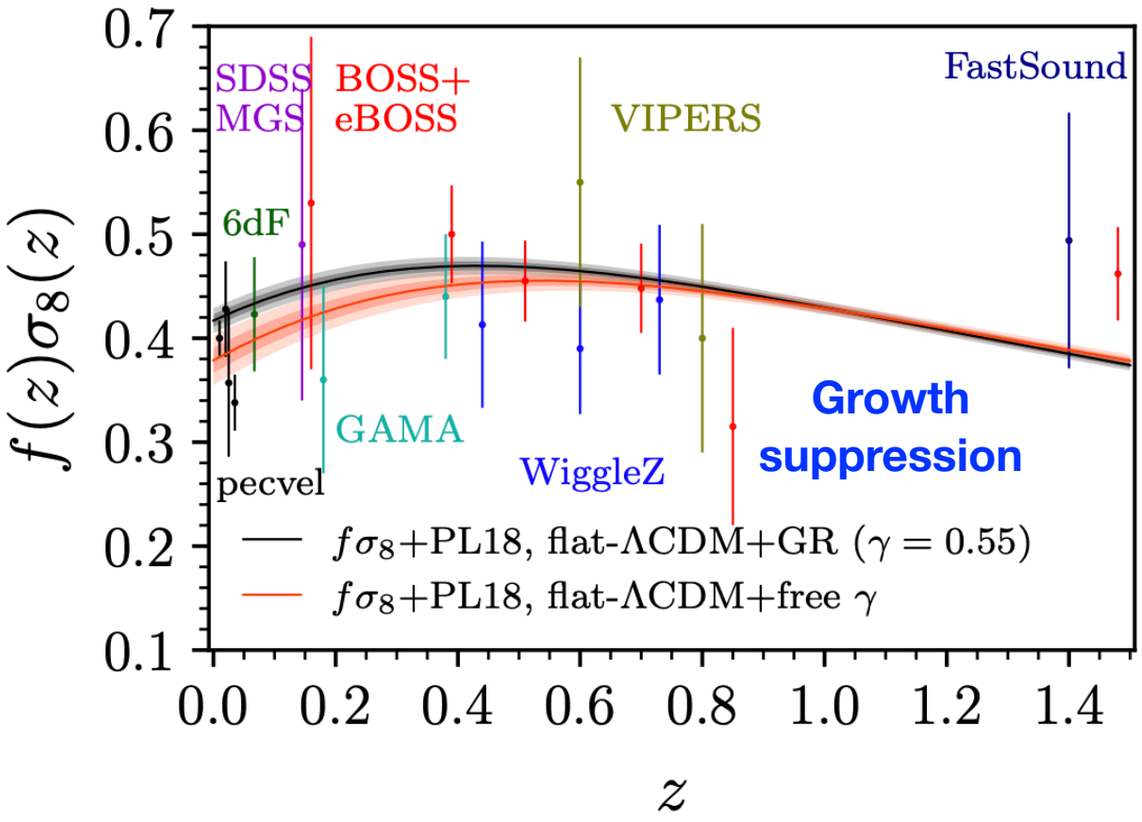

CMB with Planck
Balkenhol et al. (2021), Planck 2018+SPT+ACT : 67.49 ± 0.5
Pogosian et al. (2020), eBOSS+Planck mH2: 69.6 ± 1.8
Aghanim et al. (2020), Planck 2018: 67.27 ± 0.60
Aghanim et al. (2020), Planck 2018+CMB lensing: 67.36 ± 0.54
Ade et al. (2016), Planck 2015, H0 = 67.27 ± 0.66
CMB without Planck
Dutcher et al. (2021), SPT: 68.8 ± 1.5
Aiola et al. (2020), ACT: 67.9 ± 1.5
Aiola et al. (2020), WMAP9+ACT: 67.6 ± 1.1
Zhang, Huang (2019), WMAP9+BAO: 68.36$^{+0.53}_{-0.52}$
Henning et al. (2018), SPT: 71.3 ± 2.1
Hinshaw et al. (2013), WMAP9: 70.0 ± 2.2
No CMB, with BBN
Zhang et al. (2021), BOSS correlation function+BAO+BBN: 68.19±0.99
Chen et al. (2021), P+BAO+BBN: 69.23±0.77
Philcox et al. (2021), P+Bispectrum+BAO+BBN: 68.31$^{+0.83}_{-0.86}$
D' Amico et al. (2020), BOSS DR12+BBN: 68.5 ± 2.2
Colas et al. (2020), BOSS DR12+BBN: 68.7 ± 1.5
Ivanov et al. (2020), BOSS+BBN: 67.9 ± 1.1
Alam et al. (2020), BOSS+eBOSS+BBN: 67.35 ± 0.97
CMB lensing
Baxter et al. (2020): 73.5 ± 5.3
Philcox et al. (2020), P_l(k)+CMB lensing: 70.6$^{+3.7}_{-3.0}$
LSS t_{eq} standard ruler
Farren et al. (2021): 69.5$^{+3.0}_{-3.5}$
SNIa−Cepheid
Riess et al. (2022), R22: 73.04 ± 1.04
Camarena, Marra (2021): 74.30 ± 1.45
Riess et al. (2020), R20: 73.2 ± 1.3
Breuval et al. (2020): 72.8 ± 2.7
Riess et al. (2019), R19: 74.03 ± 1.42
Camarena, Marra (2019): 75.4 ± 1.7
SNIa−TRGB
Dhawan et al. (2022): 76.94 ± 6.4
Jones et al. (2022): 72.4 ± 3.3
Anand, Tully, Rizzi, Riess, Yuan (2021): 71.5 ± 1.8
Freedman (2021): 69.8 ± 1.7
Kim, Kang, Lee, Jang (2021): 69.5 ± 4.2
Soltis, Casertano, Riess (2020): 72.1 ± 2.0
Freedman et al. (2020): 69.6 ± 1.9
Reid, Pesce, Riess (2019), SH0ES: 71.1 ± 1.99
Yuan et al. (2019): 72.4 ± 2.0
SNIa−Miras
Huang et al. (2019): 73.3 ± 4.0
SBF
Blakeslee et al. (2021) IR−SBF w/ HST: 73.3 ± 2.5
Khetan et al. (2020) w/ LMC DEB: 71.1 ± 4.1
Cantiello et al. (2018): 71.9 ± 7.1
SNII
de Jaeger et al. (2022): 75.4$^{+3.8}_{-3.7}$
de Jaeger et al. (2020): 75.8$^{+5.2}_{-4.9}$
Masers
Pesce et al. (2020): 73.9 ± 3.0
Tully Fisher
Kourkchi et al. (2020): 76.0 ± 2.6
Schombert, McGaugh, Lelli (2020): 75.1 ± 2.8
HII galaxy
Fernandez Arenas et al. (2018): 71.0 ± 3.5
Wang, Meng (2017): 76.12$^{+3.47}_{-3.44}$
Lensing related,mass model dependent
Denzel et al. (2021): 71.8$^{+3.9}_{-3.3}$
Birrer et al. (2020), TDCOSMO: 74.5$^{+5.6}_{-6.1}$
Birrer et al. (2020), TDCOSMO+SLACS: 67.4$^{+4.1}_{-3.2}$
Yang, Birrer, Hu (2020): 73.65$^{+1.95}_{-2.26}$
Millon et al. (2020), TDCOSMO: 74.2 ± 1.6
Qi et al. (2020): 73.6$^{+1.8}_{-1.6}$
Liao et al. (2020): 72.8$^{+1.6}_{-1.9}$
Liao et al. (2019): 72.2 ± 2.1
Shajib et al. (2019), STRIDES: 74.2$^{+2.7}_{-3.0}$
Wong et al. (2019), H0LiCOW 2019: 73.3$^{+1.7}_{-1.8}$
GW related
Mukherjee et al. (2022), GW170817+GWTC−3: 67$^{+6.3}_{-5.8}$
Abbott et al. (2021), GWTC−3: 68$^{+12.0}_{-8.0}$
Palmese et al. (2021), GW170817: 72.77$^{+11.7}_{-7.55}$
Gayathri et al. (2020), GW190521+GW170817: 73.4$^{+6.9}_{-10.7}$
Mukherjee et al. (2020), GW170817+ZTF: 67.6$^{+4.3}_{-4.2}$
Mukherjee et al. (2019), GW170817+VLBI: 68.3$^{+4.6}_{-4.5}$
Hotokezaka et al. (2019): 70.3$^{+5.3}_{-5.0}$
Cosmic chronometers
Moresco et al. (2022), flat ΛCDM with systematics: 66.5 ± 5.4
Moresco et al. (2022), open wCDM with systematics: 67.8$^{+9.7}_{-7.2}$
H_0 [km s^{-1} Mpc^{-1}]
60
H_0[km/s/Mpc]
2503.19441 KiDS-Legacy 0.73σ
$S_8=\sigma_8\sqrt{\Omega_m/0.3}$
0.6
0.65
0.7
0.75
0.8
0.85
0.2
0.3
0.4
0.5
Ω_m
KiDS−Legacy (E_n)
DESY3 ($\xi_\pm$ Hybrid)
HSC Y3 ($\xi_\pm$)
Planck−Legacy (CMB)
Smoothing
Kernel
• CMB Planck TT,TE,EE+lowE
• CMB Planck TT,TE,EE+lowE+lensing
• CMB ACT+WMAP
0.834
0.832
0.84
Aghanim et al. (2020d)
Aghanim et al. (2020d)
Aiola et al. (2020)
Early Universe
Late Universe
0.759
0.755
0.762
0.716
0.737
0.651
0.745
0.759
0.782
0.804
0.78
0.74
Asgari et al. (2021)
Asgari et al. (2020)
Joudaki et al. (2020)
Wright et al. (2020)
Hildebrandt et al. (2020)
Kohlinger et al. (2017)
Hildebrandt et al. (2017)
Amon et al. and Secco et al. (2021)
Troxel et al. (2018)
Hamana et al. (2020)
Hikage et al. (2019)
Joudaki et al. (2017)
lanck
0.795
0.7781
0.766
0.742
0.776
0.773
0.728
0.8
Miyatake et al. (2022)
García−García et al. (2021)
Heymans et al. (2021)
Joudaki et al. (2018)
Abbott et al. (2021)
Abbott et al. (2018d)
Tröster et al. (2020)
van Uitert et al. (2018)
0.751
0.72
0.736
0.729
0.703
0.73
0.784
Philcox et al. (2021)
Ivanov et al. (2021)
Chen et al. (2021)
Tröster et al. (2020)
Ivanov et al. (2020)
White et al. (2022)
Krolewski et al. (2021)
0.78
0.65
0.79
0.831
0.77
Lesci et al. (2021)
Abbott et al. (2020d)
Costanzi et al. (2019)
Pacaud et al. (2018)
Mantz et al. (2015)
0.749
0.785
0.793
Bocquet et al. (2019)
Salvati et al. (2018)
Ade et al. (2016d)
0.7
0.747
Benisty (2021)
Kazantzidis and Perivolaropoulos (2018)
0.6
0.8
1.0
1.2
$S_8 \equiv \sigma_8\sqrt{\Omega_m/0.3}$

γ tension!

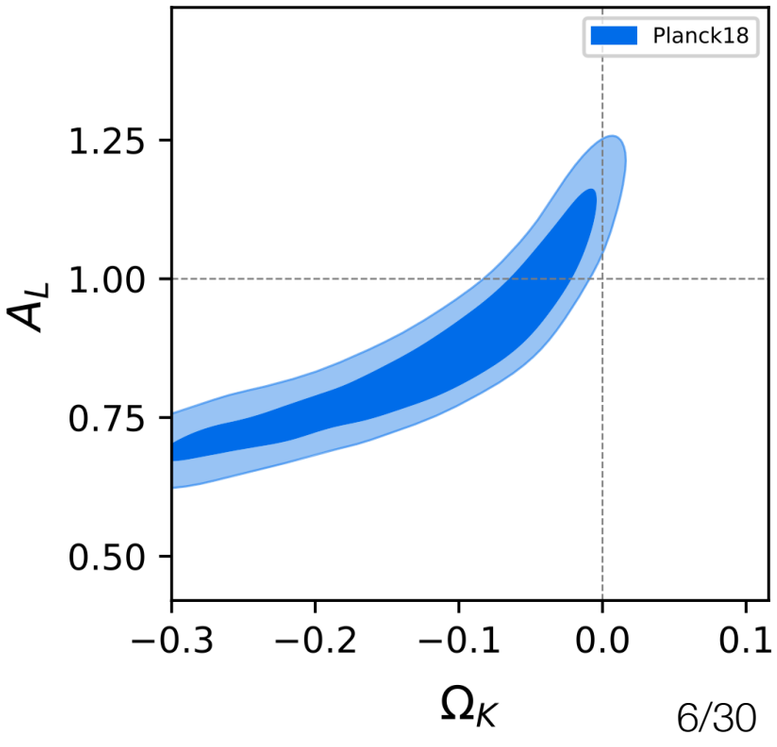
2302.01331 (PRL) growth index tension

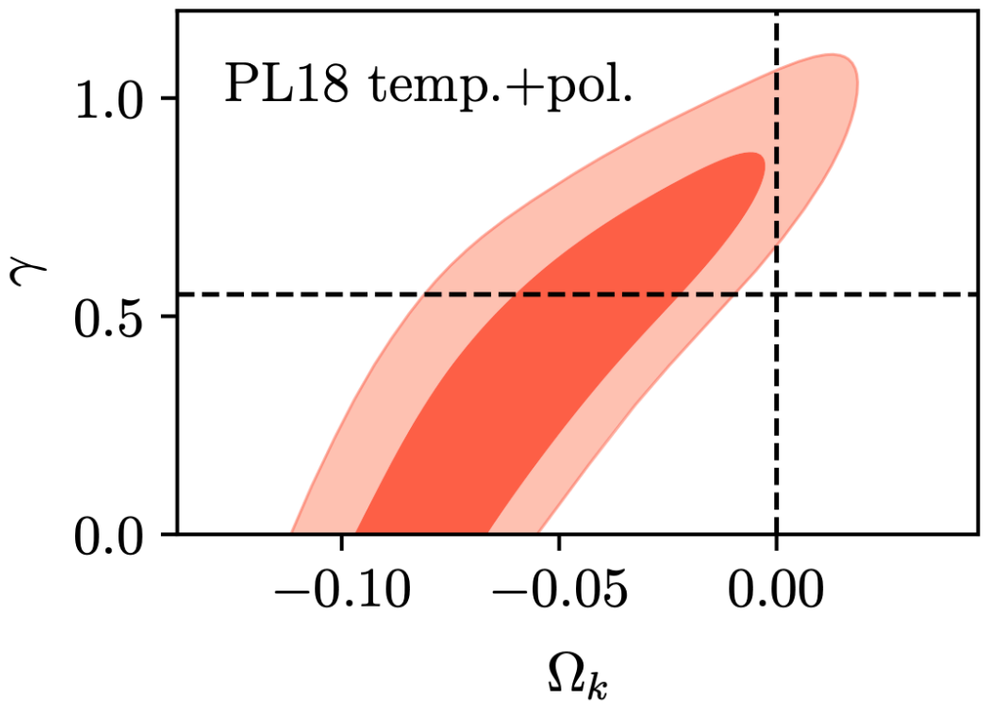
$$D(a(t)) = \delta(t)/\delta(t_0) : f(a) = d\ln D/d\ln a = \Omega_m(a)^\gamma$$





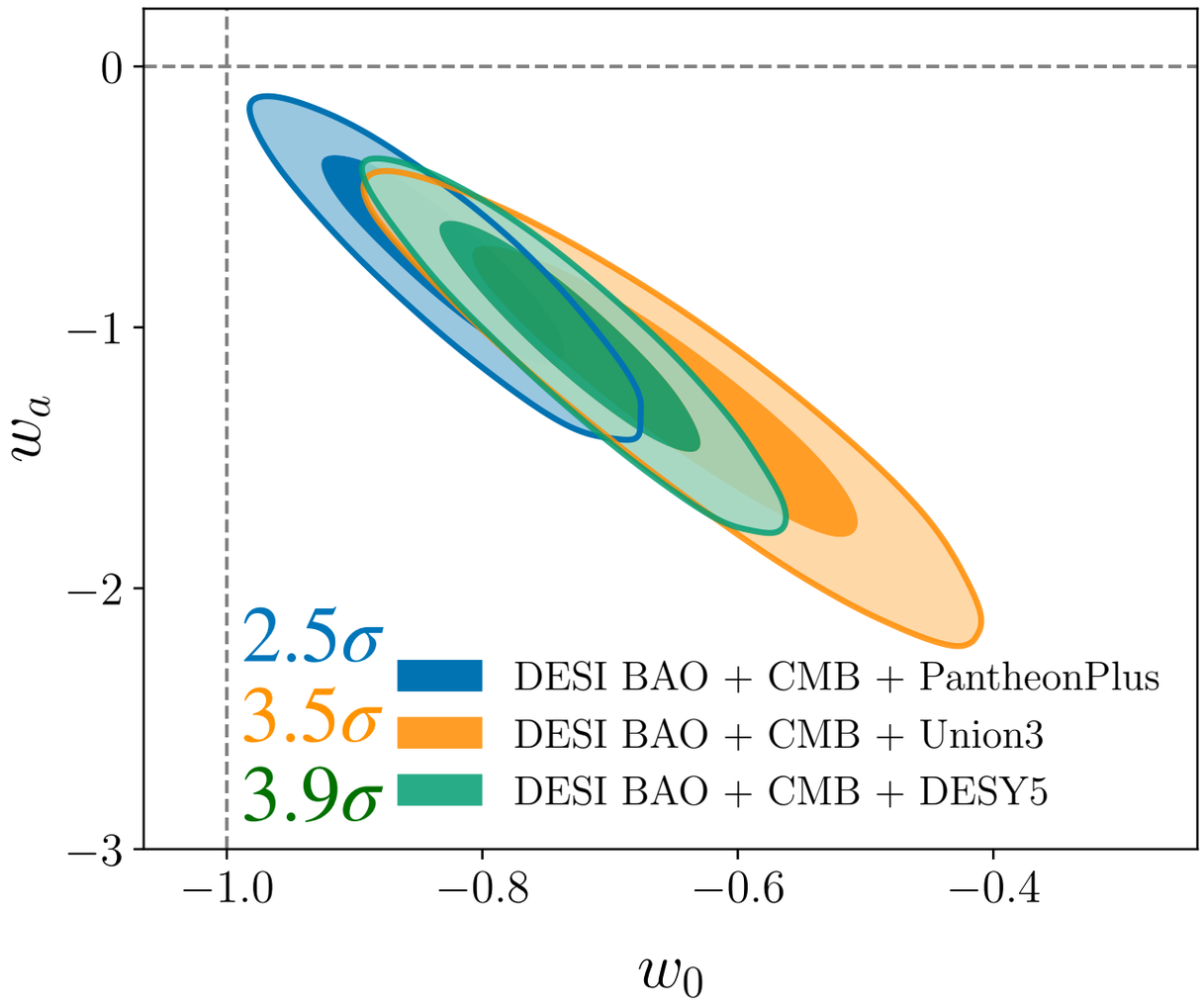
A larger γ reproduces the flat Universe that is otherwise closed with $A_L = 1$ from 1911.02087 Nature Astron



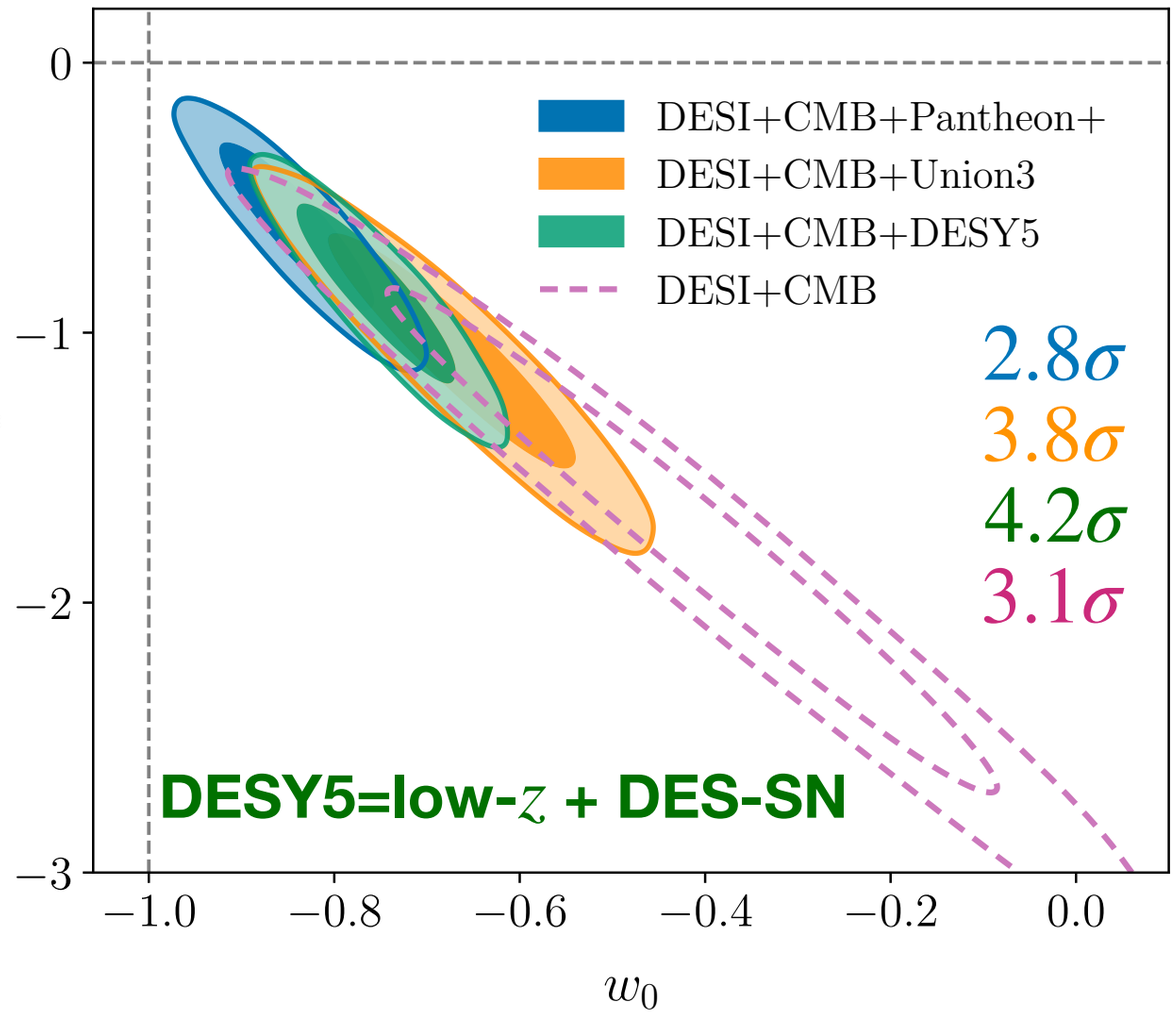


DESI-BAO+Planck-CMB+SNe

2404.03002 DESI DR1 Y1 BAO



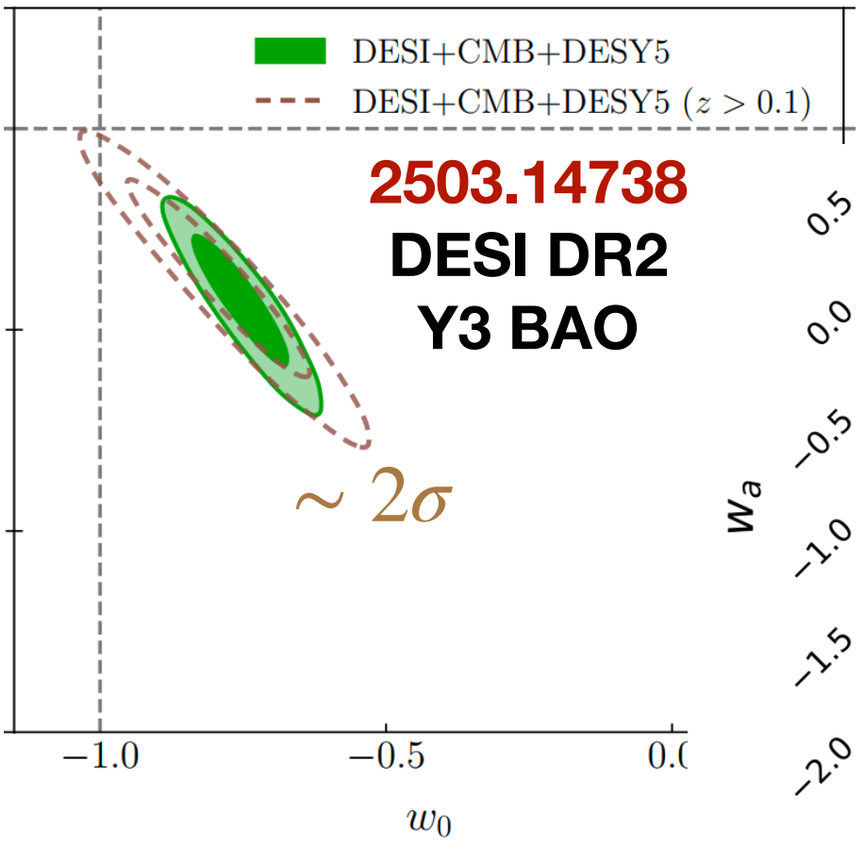
2503.14738 DESI DR2 Y3 BAO



2408.07175 George Efstathiou
"Evolving dark energy or supernovae systematics?"
MNRAS 538 (2025) 2, 875-882

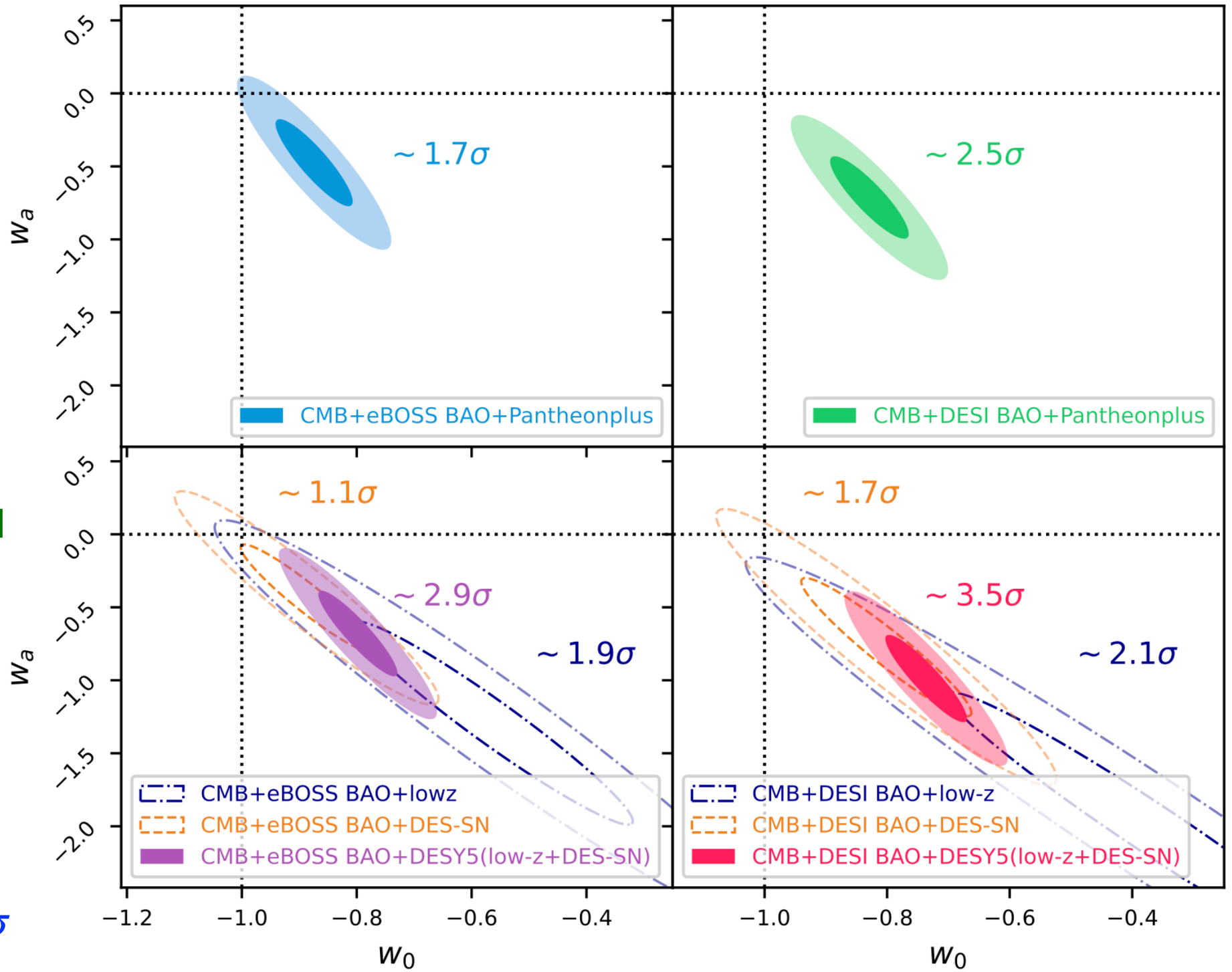
2505.02658 George Efstathiou
"Baryon Acoustic Oscillations from a Different Angle"

DESI-BAO+Planck-CMB+SNe



2503.14738
DESI DR2
Y3 BAO

2502.04212 Huang, Cai, SJW "The DESI DR1/DR2 evidence for dynamical dark energy is biased by low-redshift supernovae"



DESY5=low-z + DES-SN

Low-z sample dominates the deviation from ΛCDM

Without low-z sample, the deviation from the ΛCDM is only about 2σ

Distance ladder

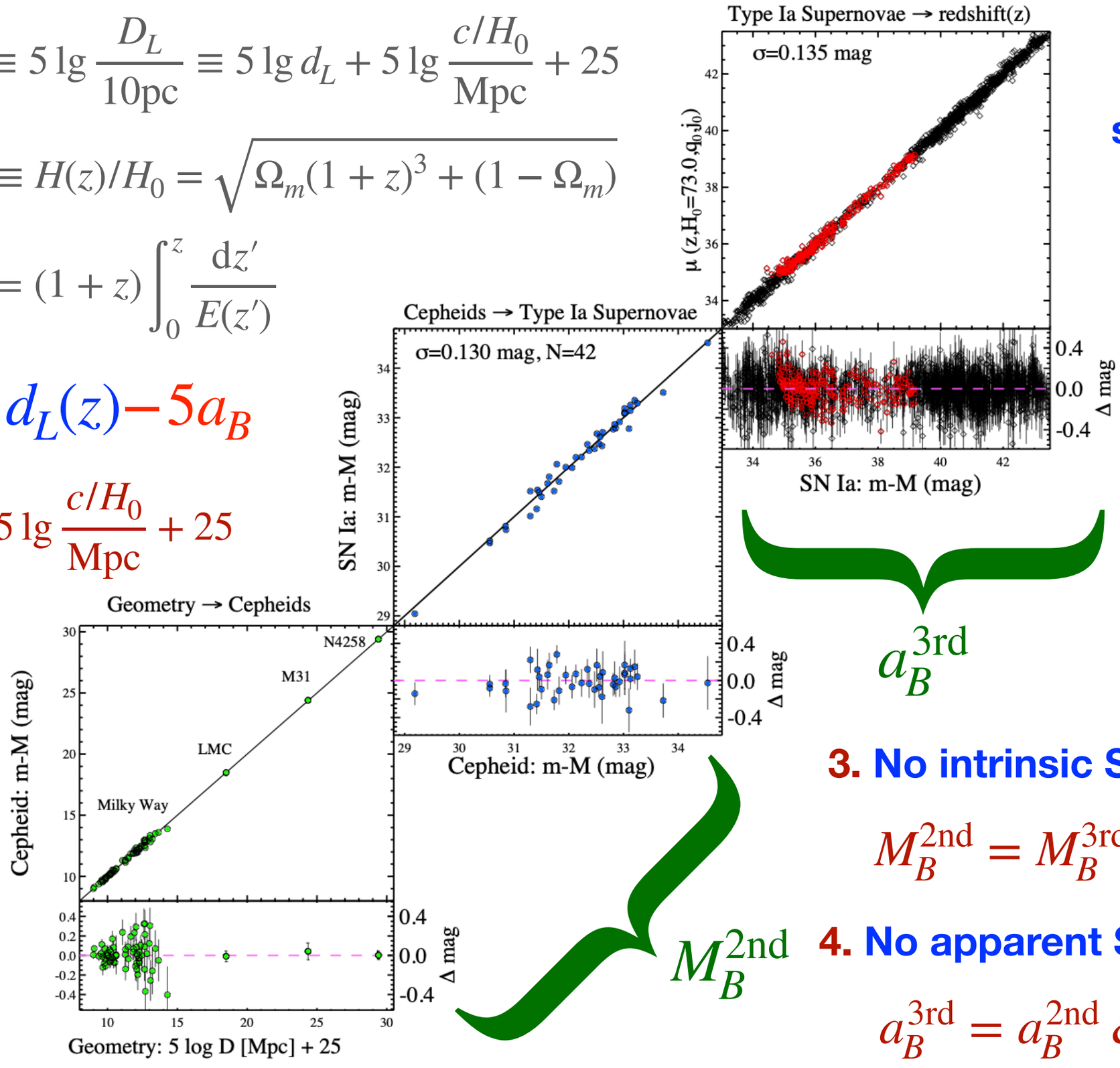
$$\mu \equiv m_B - M_B \equiv 5\lg\frac{D_L}{10\mathrm{pc}} \equiv 5\lg d_L + 5\lg\frac{c/H_0}{\mathrm{Mpc}} + 25$$

$$\Lambda\mathrm{CDM} : E(z) \equiv H(z)/H_0 = \sqrt{\Omega_m(1+z)^3 + (1-\Omega_m)}$$

$$d_L(z) = \frac{D_L(z)}{c/H_0} = (1+z)\int_0^z \frac{\mathrm{d}z'}{E(z')}$$

$$m_B = 5\lg d_L(z) - 5a_B$$

$$-5a_B \equiv M_B + 5\lg\frac{c/H_0}{\mathrm{Mpc}} + 25$$



2. 3rd-rung statistical systematics

$a_B^{3\mathrm{rd}}$

1. 1st & 2nd rungs inter-calibrations systematics

$M_B^{2\mathrm{nd}}$

3. No intrinsic SN systematics

$$M_B^{2\mathrm{nd}} = M_B^{3\mathrm{rd}} \;\&\; a_B^{3\mathrm{rd}} \Rightarrow H_0$$

4. No apparent SN systematics

$$a_B^{3\mathrm{rd}} = a_B^{2\mathrm{nd}} \;\&\; M_B^{2\mathrm{nd}} \Rightarrow H_0$$

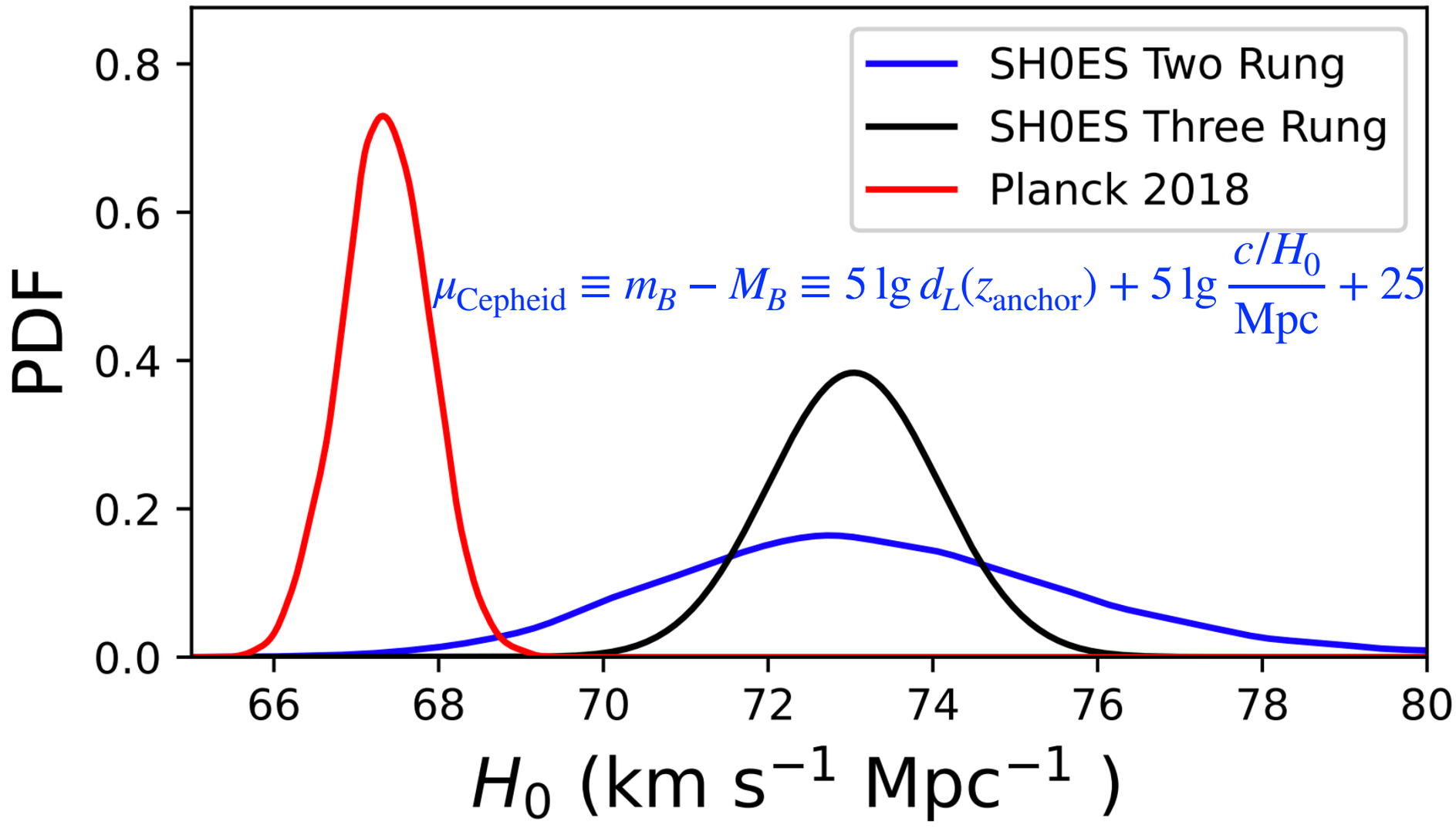
Distance ladder

The Astrophysical Journal, 935:83 (19pp), 2022 August 20 https://doi.org/10.3847/1538-4357/ac80bd

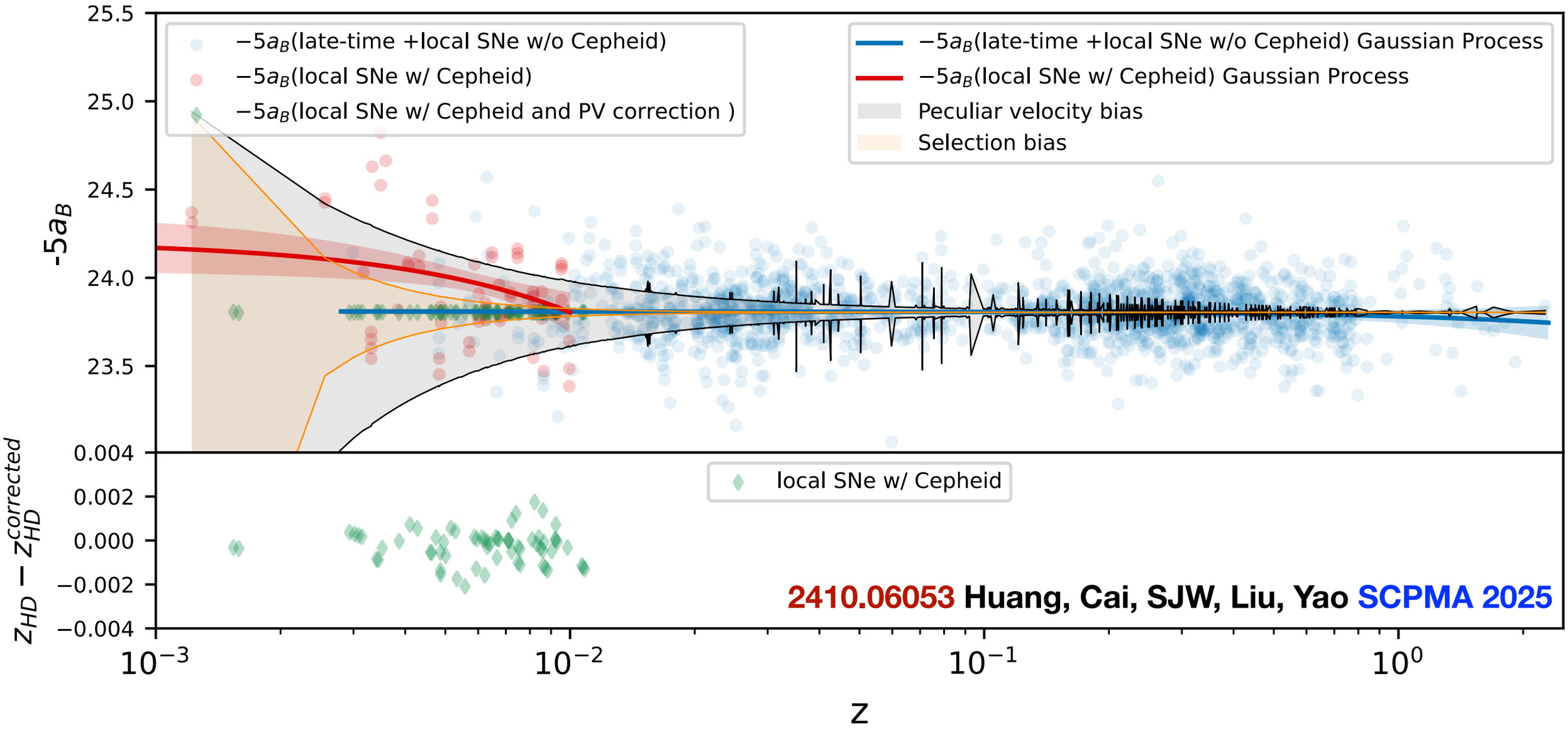
2204.10866

Measurements of the Hubble Constant with a Two-rung Distance Ladder: Two Out of Three Ain't Bad

W. D'Arcy Kenworthy[1], Adam G. Riess[1], Daniel Scolnic[2], Wenlong Yuan[1], José Luis Bernal[1], Dillon Brout[3,7], Stefano Casertano[4], David O. Jones[5,7], Lucas Macri[6], and Erik R. Peterson[2]



a_B tension around $z \sim 0.01$?



Redshift corrections for 2nd-rung SNe

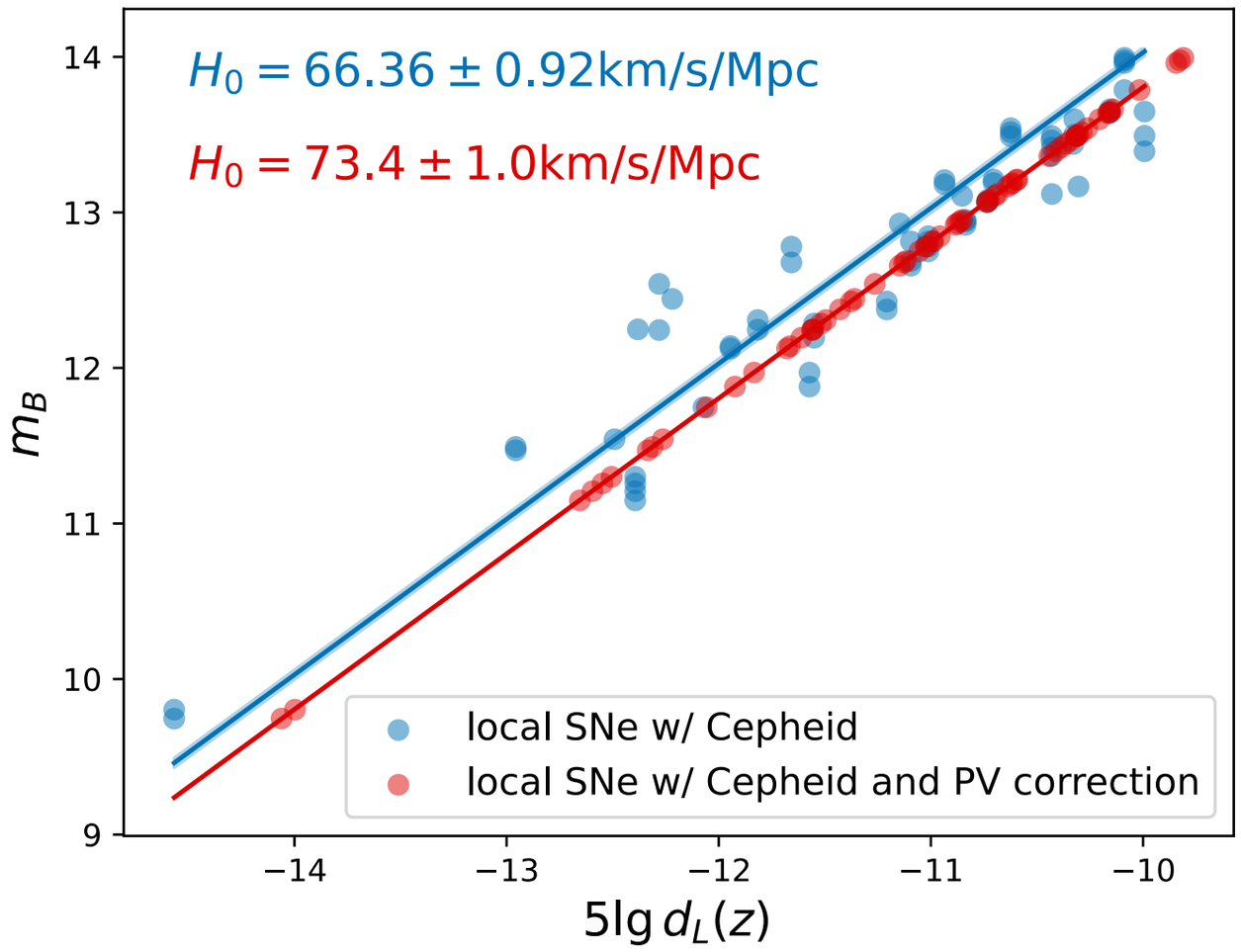
Rigorous approach: SH0ES 2204.10866

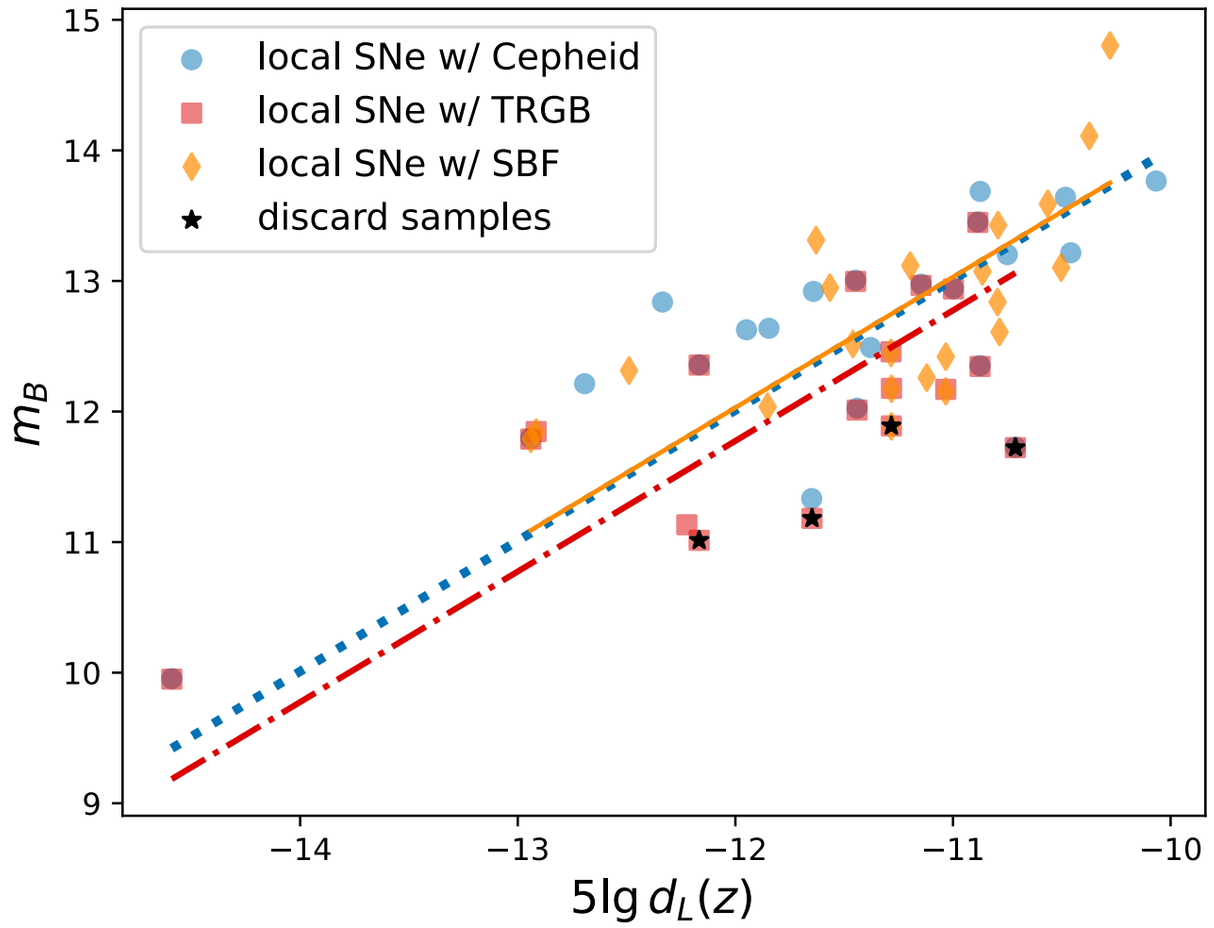
PV corrections directly from reconstructions of density field and velocity field from 2M++/2MRS

Efficient approach: Ours 2410.06053

Redshift corrected from minimizing difference of $a_{B,i} = \lg d_L(z_i) - 0.2m_{B,i}$ to Planck-calibrated late-time SNe

a_B consistency around $z \sim 0.01$





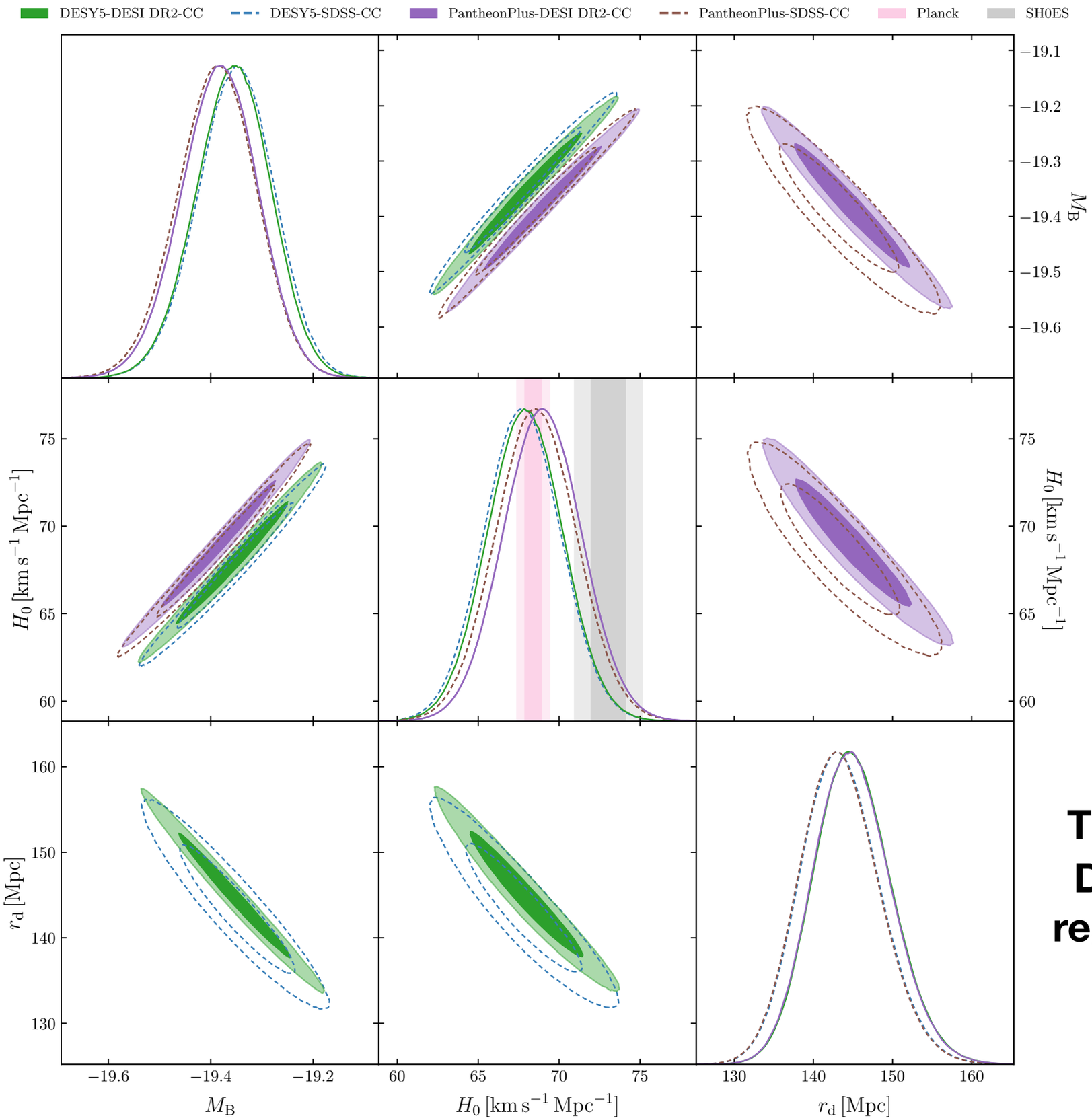
Our first two-rung distance ladder result

$$\approx \begin{cases} \textbf{SH0ES first two-rung distance ladder:} \\ \textbf{supports our redshift correction} \\ \\ \textbf{SH0ES three-rung distance ladder:} \\ \textbf{no third-rung SN systemactics} \end{cases}$$

$$H_0 = \begin{cases} 73.1 \pm 2.4 \text{ km/s/Mpc}, & z_{\text{CSP}} + \mu_{\text{Cepheid}}, \\ 74.5 \pm 3.5 \text{ km/s/Mpc}, & z_{\text{CSP}} + \mu_{\text{TRGB}}, \\ 72.1 \pm 2.3 \text{ km/s/Mpc}, & z_{\text{CSP}} + \mu_{\text{SBF}}. \end{cases}$$

There is no more disagreement between Riess and Freedman

a_B tension around $z \sim 0.1$?



2505.22369 Jia-Le Ling, Guo-Hong Du, Tian-Nuo Li, Jing-Fei Zhang, Shao-Jiang Wang, Xin Zhang

Model-independent cosmological inference after the DESI DR2 data with improved inverse distance ladder

$$m_B = 5\lg d_L(z) - 5a_B$$

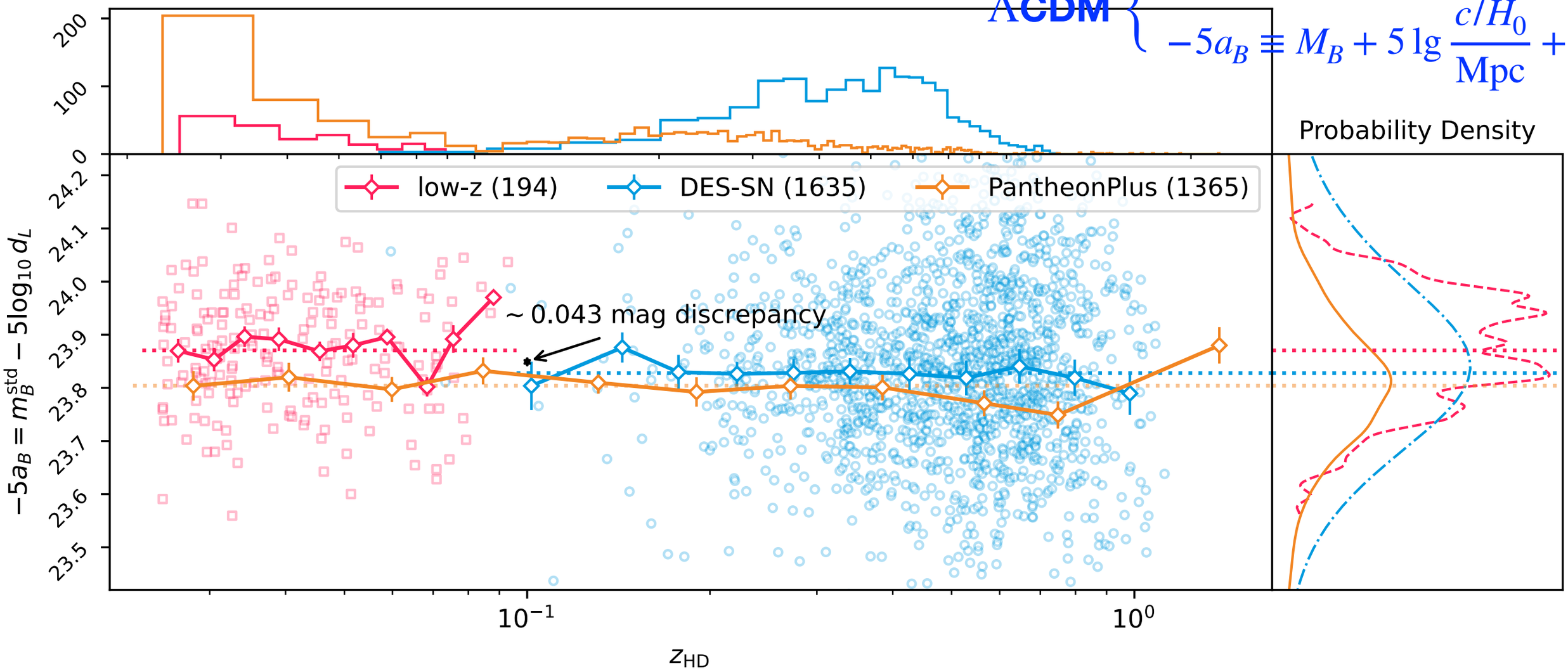
$$-5a_B \equiv M_B + 5\lg\frac{c/H_0}{\mathrm{Mpc}} + 25$$

There is an a_B tension between DESY5 and PantheonPlus SNe regardless of DESI DR2/SDSS or CMB/CC and ΛCDM/PAge !

a_B tension around $z \sim 0.1$?

2502.04212 Huang, Cai, SJW "The DESI DR1/DR2 evidence for dynamical dark energy is biased by low-redshift supernovae"

$$\Lambda\text{CDM}\begin{cases} m_{B,i}^{\text{std.}} = 5\lg \hat{d}_L(z_i) - 5a_B, \\ -5a_B \equiv M_B + 5\lg\dfrac{c/H_0}{\text{Mpc}} + 25 \end{cases}$$



Intercept $-5a_B$ is the degeneracy direction of H_0 and M_B and more sensitive to systematics in m and z

Its measured value is more reliable at high redshifts than low redshift, less affected by peculiar velocity

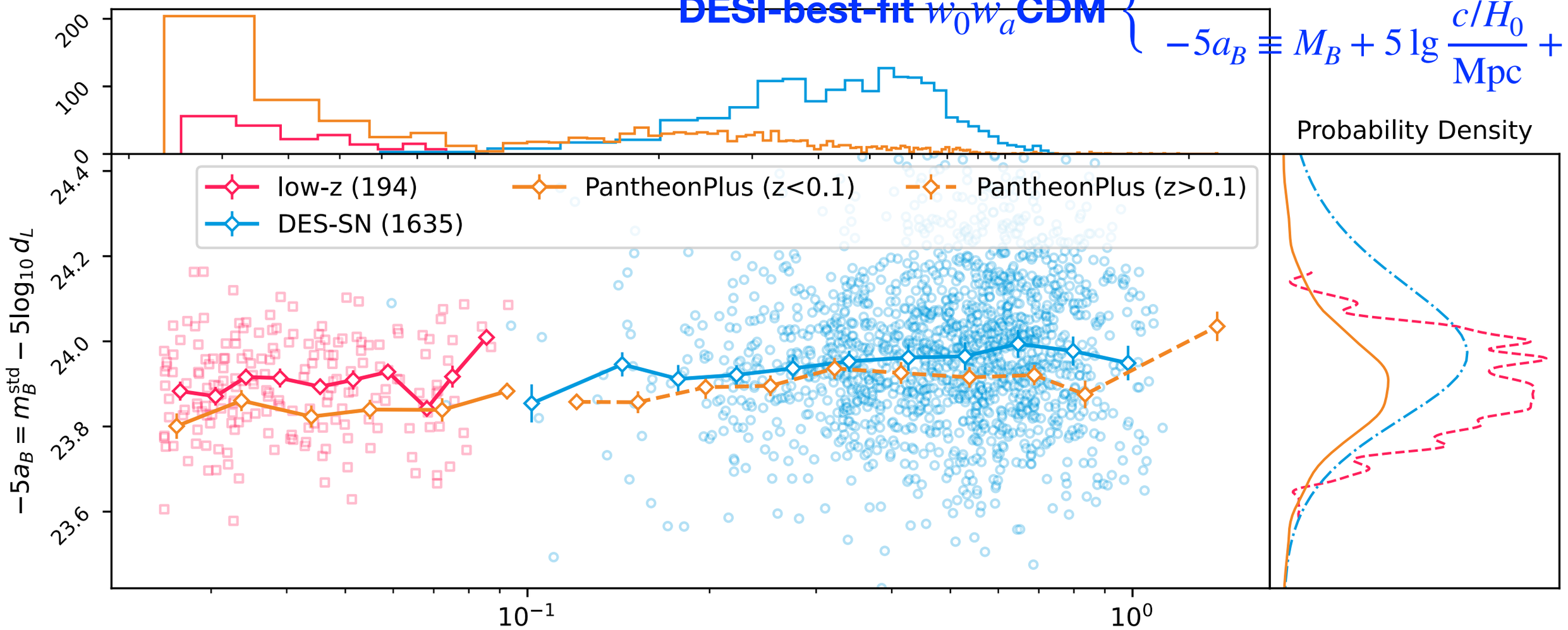
DESY5=low-z+DES-SN admits a_B discrepancy between low-z and DES-SN, unlike uniform PantheonPlus

a_B tension around $z \sim 0.1$?

2502.04212 Huang, Cai, SJW "The DESI DR1/DR2 evidence for dynamical dark energy is biased by low-redshift supernovae"

$$m_{B,i}^{\rm std.} = 5\lg \hat{d}_L(z_i) - 5a_B,$$

$$-5a_B \equiv M_B + 5\lg\frac{c/H_0}{\rm Mpc} + 25$$



ΛCDM:

DESY5=low-z+DES-SN

PantheonPlus

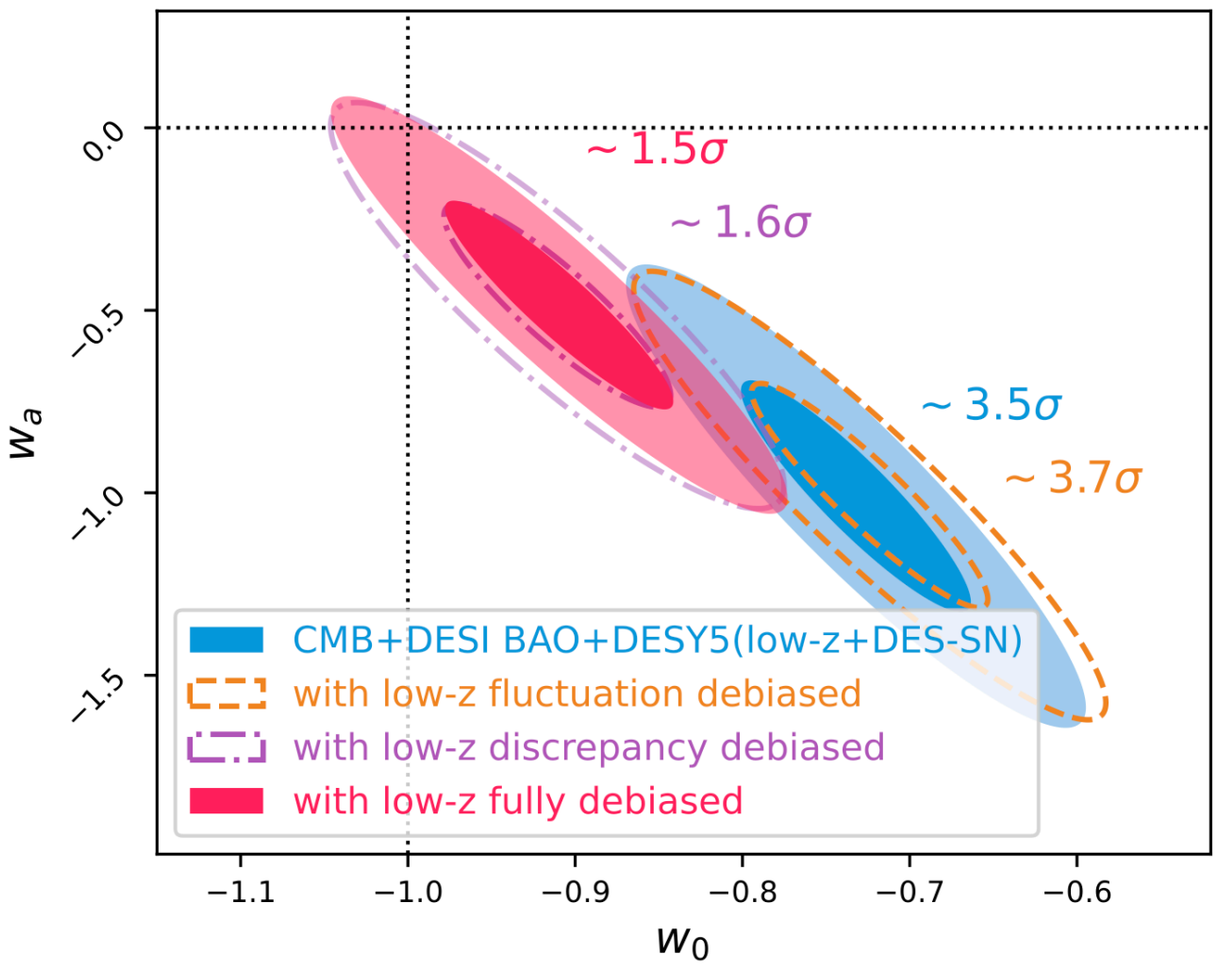
Other model:

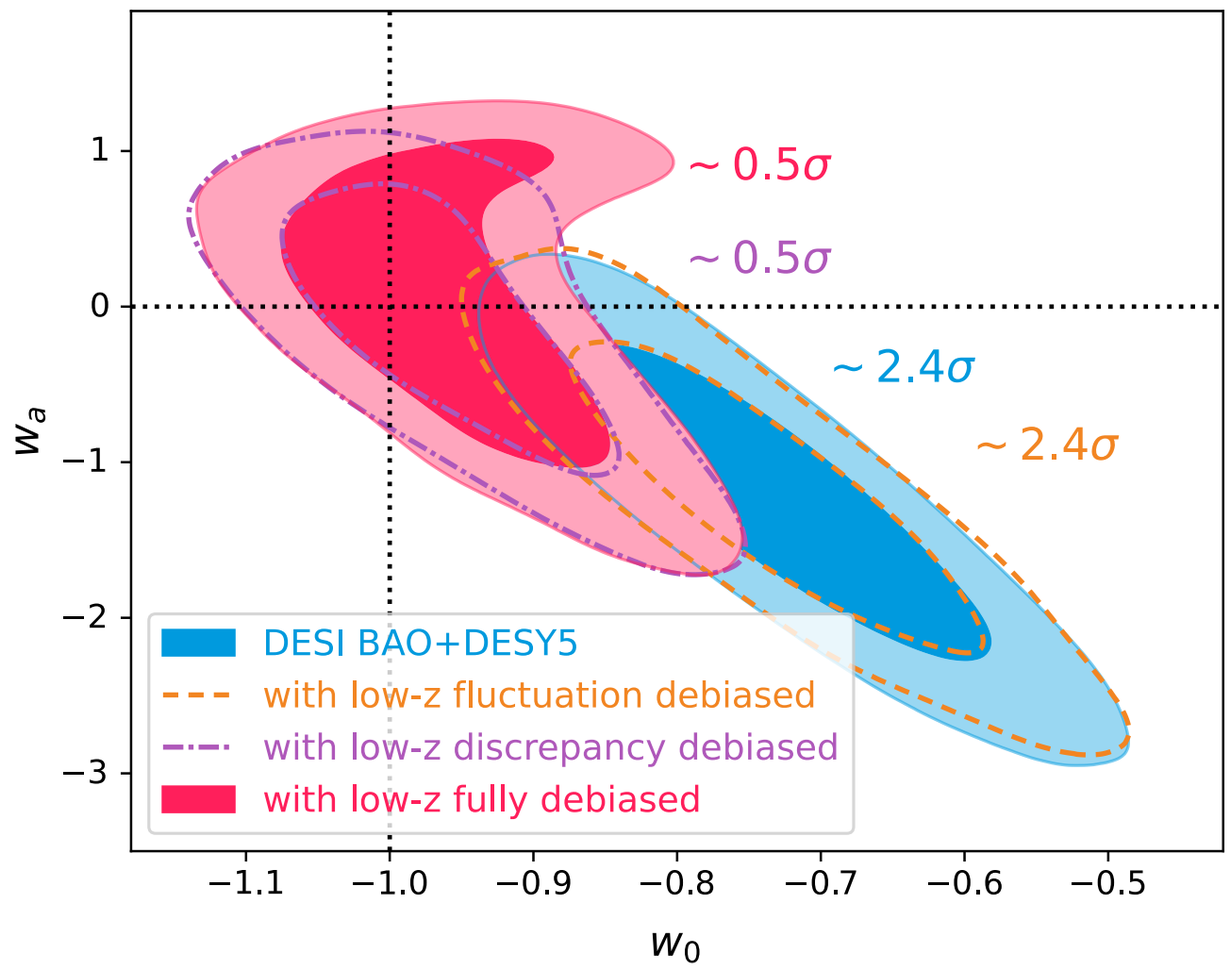
DESY5=low-z+DES-SN

PantheonPlus

a_B consistency around $z \sim 0.1$

2502.04212 Huang, Cai, SJW "The DESI DR1/DR2 evidence for dynamical dark energy is biased by low-redshift supernovae"





The DDE evidence from Planck-CMB+DESI Y1 BAO+DESY5(low-z+DES-SN) is reduced from 3.5σ to 1.5σ after our bias correction, and the pure late-Universe data without Planck-CMB deviates from ΛCDM only at 0.5σ

a_B consistency around $z \sim 0.1$

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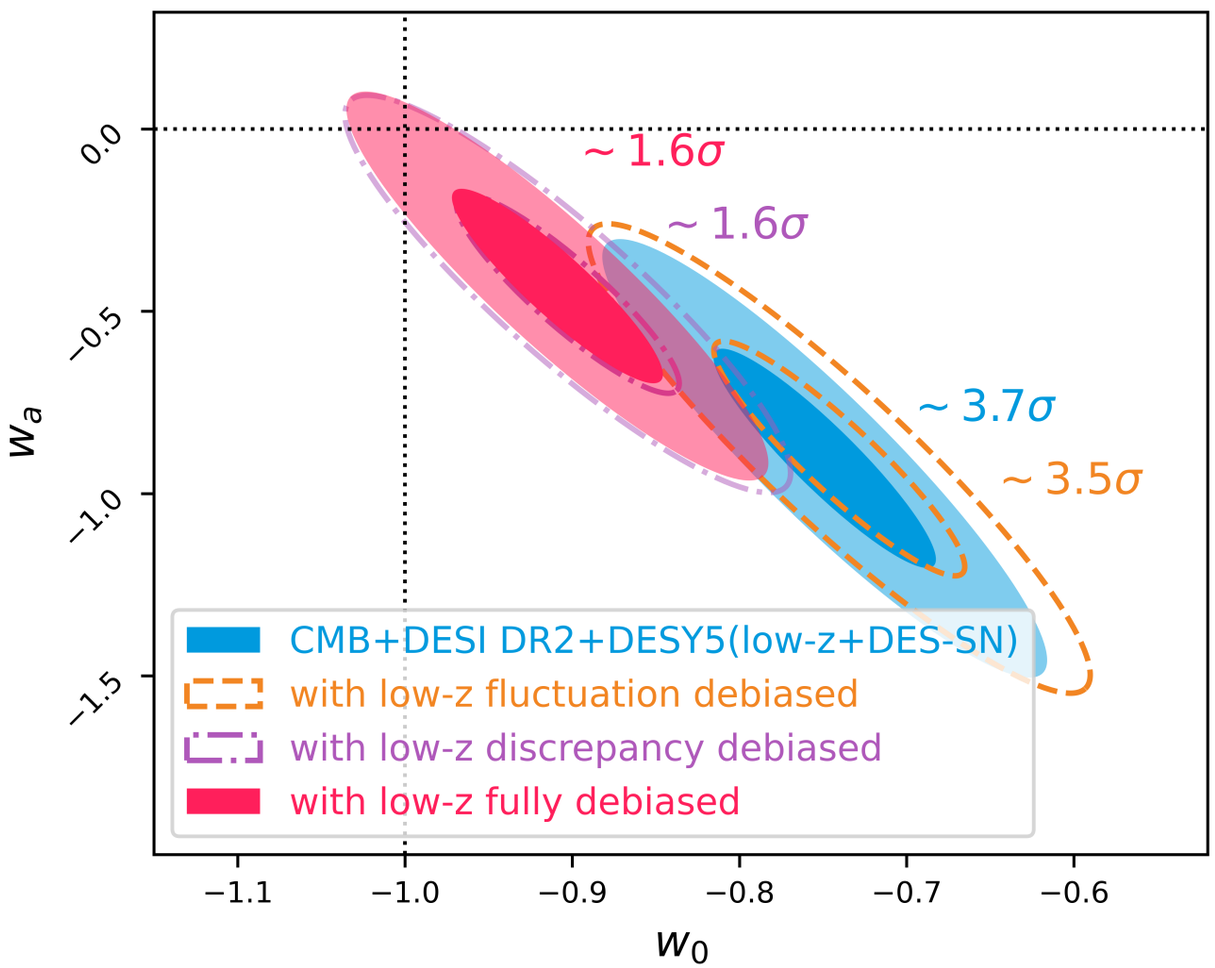
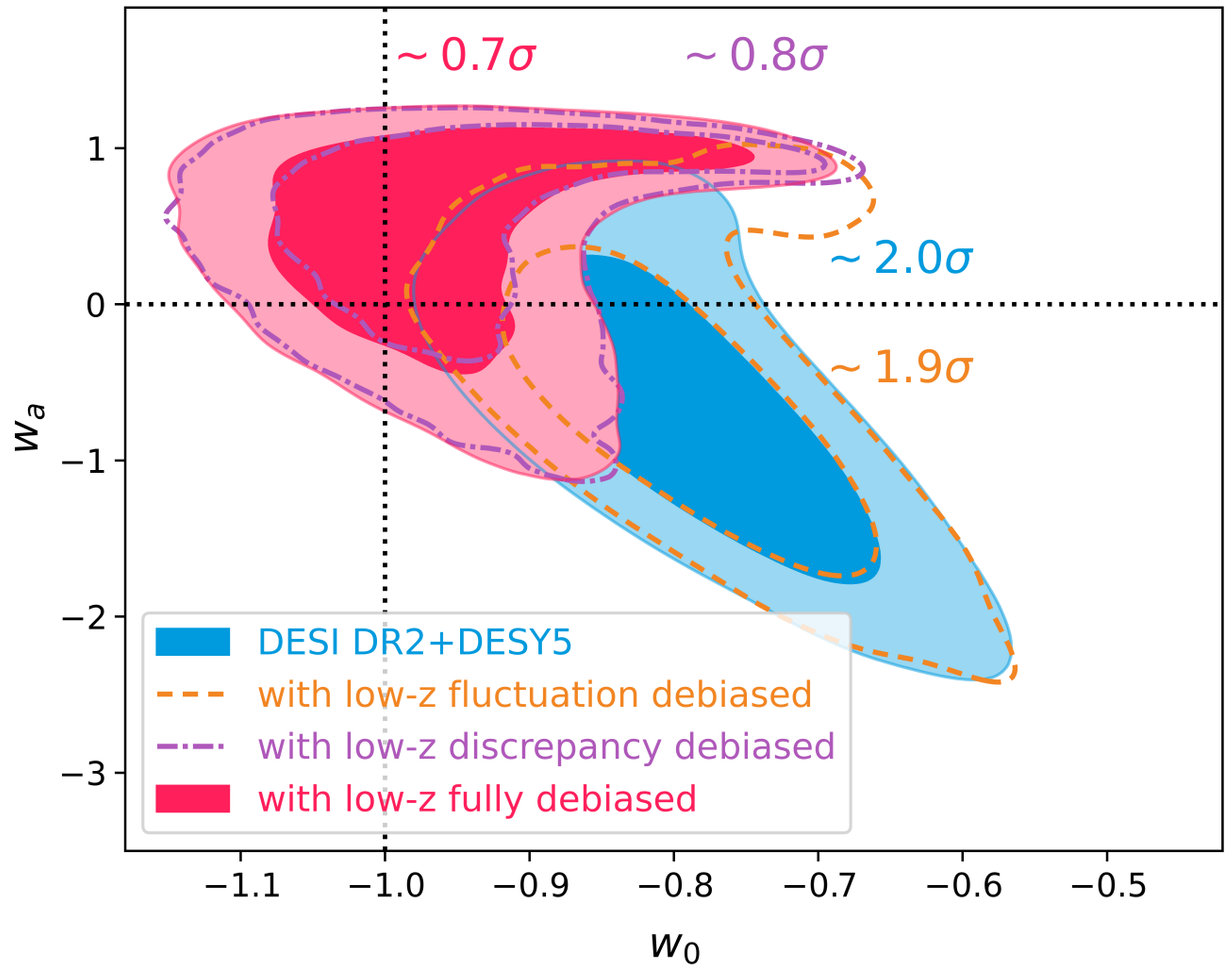
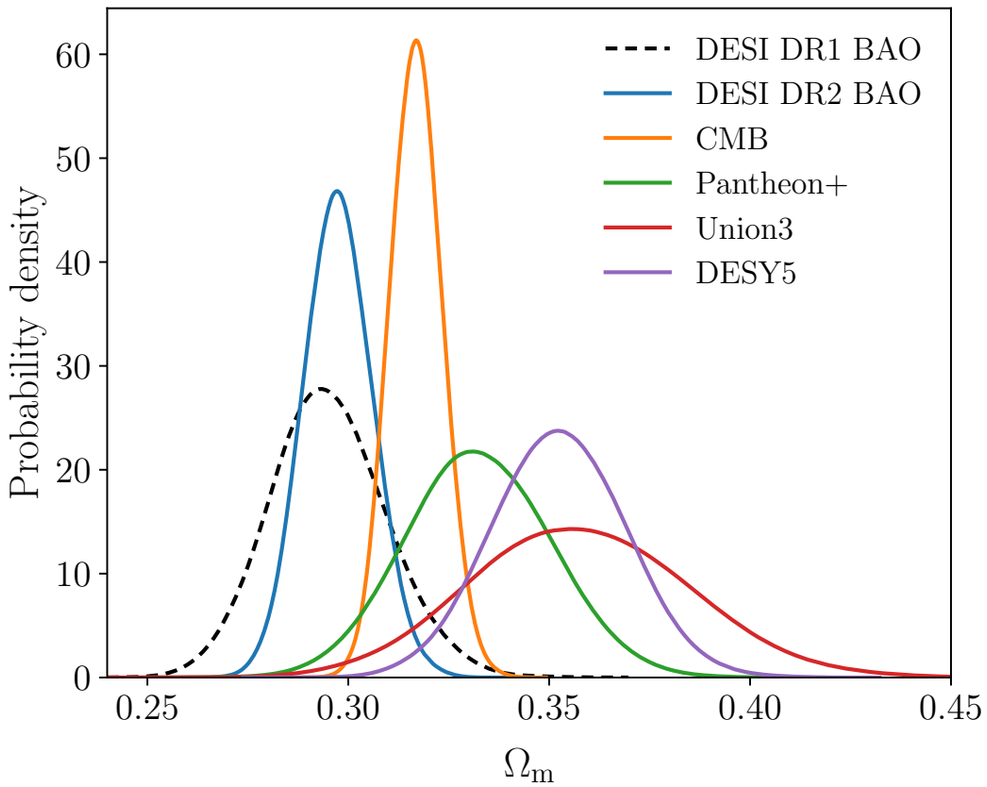


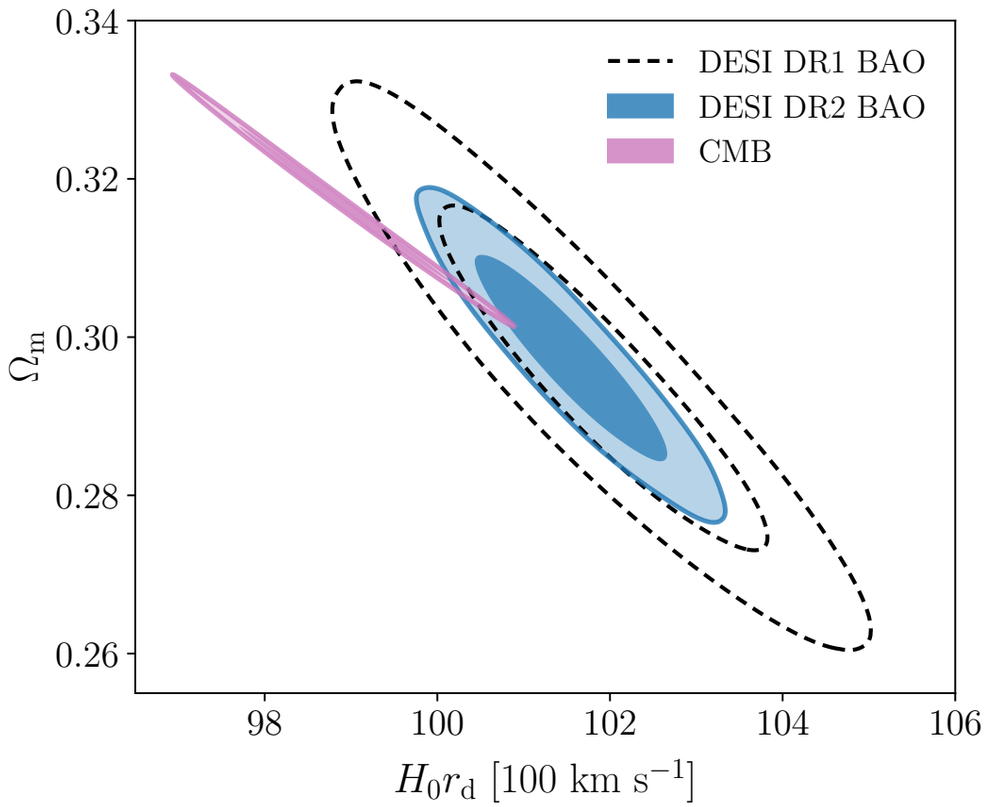


The DDE evidence from Planck-CMB+DESI Y3 BAO+DESY5(low-z+DES-SN) is reduced from 3.7σ to 1.6σ after our bias correction, and the pure late-Universe data without Planck-CMB deviates from ΛCDM only at 0.7σ

DESI-BAO VS Planck-CMB

2503.14738 DESI DR2 Y3 BAO **What DESI DR2 truly want to tell us is Ω_m tension with Planck-CMB within ΛCDM**

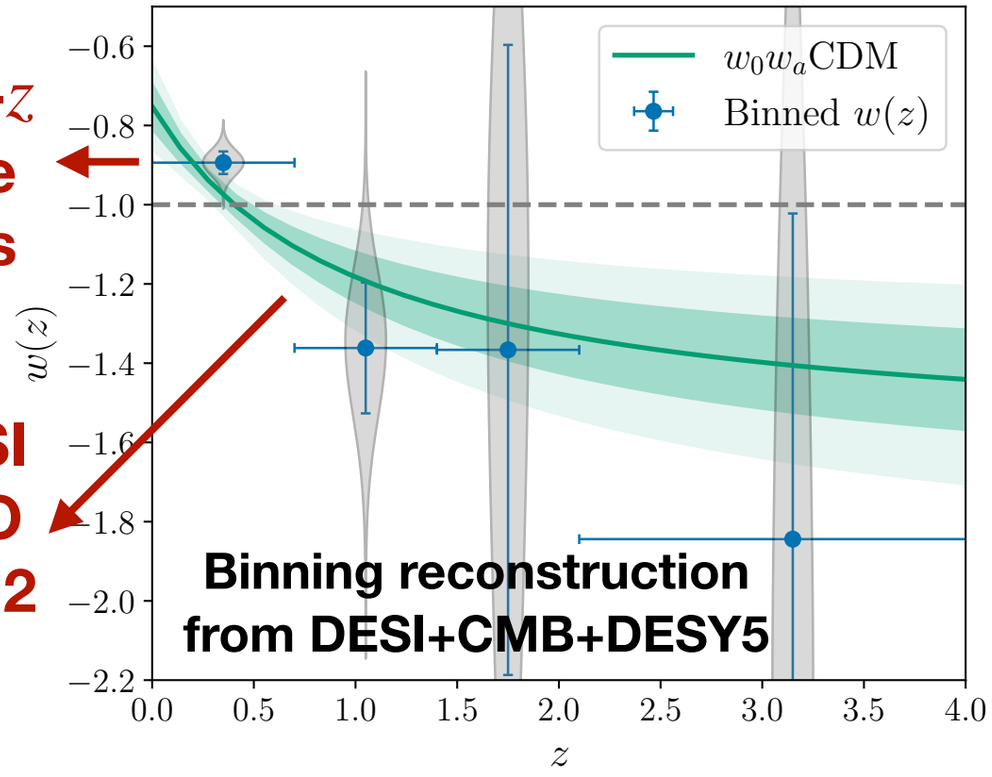




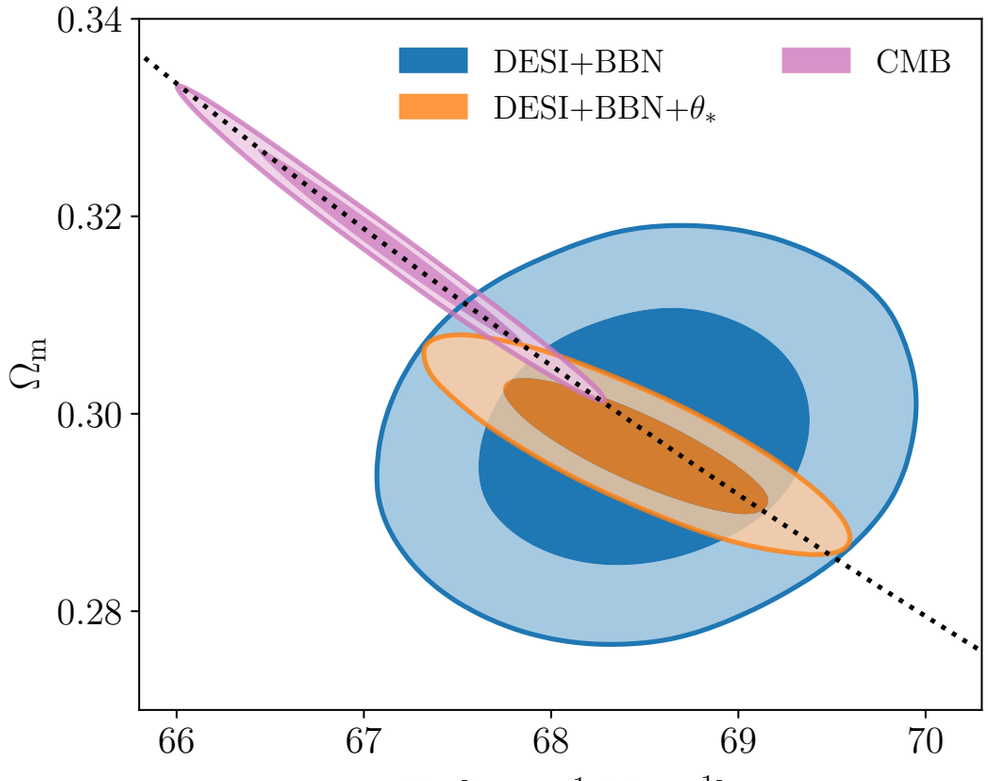
Ω_m tension!

low-z SNe bias

DESI BAO LRG2

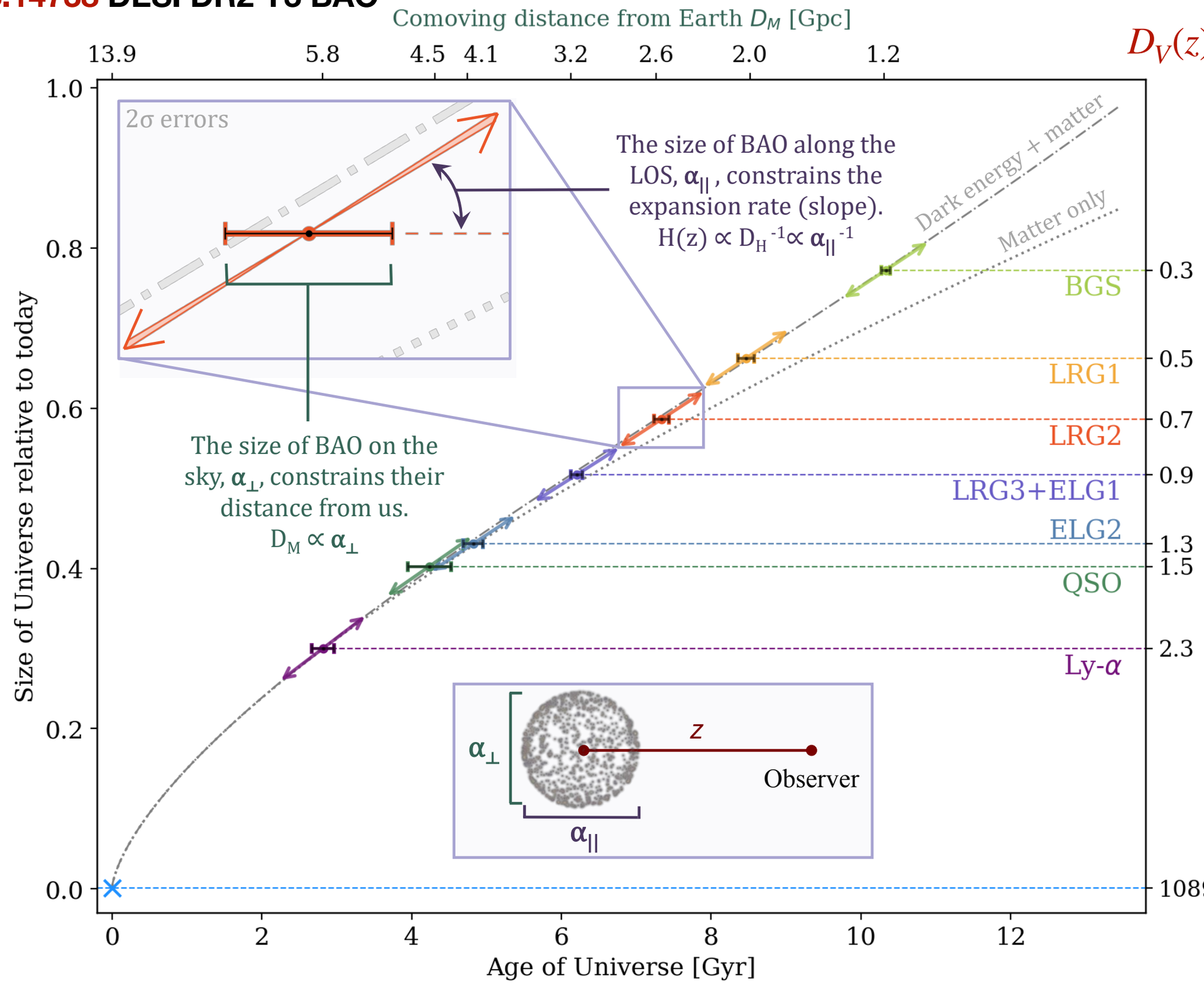


Dynamical dark energy with phantom crossing



DESI BAO

2503.14738 DESI DR2 Y3 BAO



$$D_V(z) = (zD_M^2(z)D_H(z))^{1/3}$$

$$D_H(z) = \frac{c}{H(z)}$$

$$D_M(z) = \int_0^{z'} \frac{c\mathrm{d}z'}{H(z')}$$

$$r_d = \int_{z_d}^{\infty} \frac{c_s(z)\mathrm{d}z}{H(z)}$$

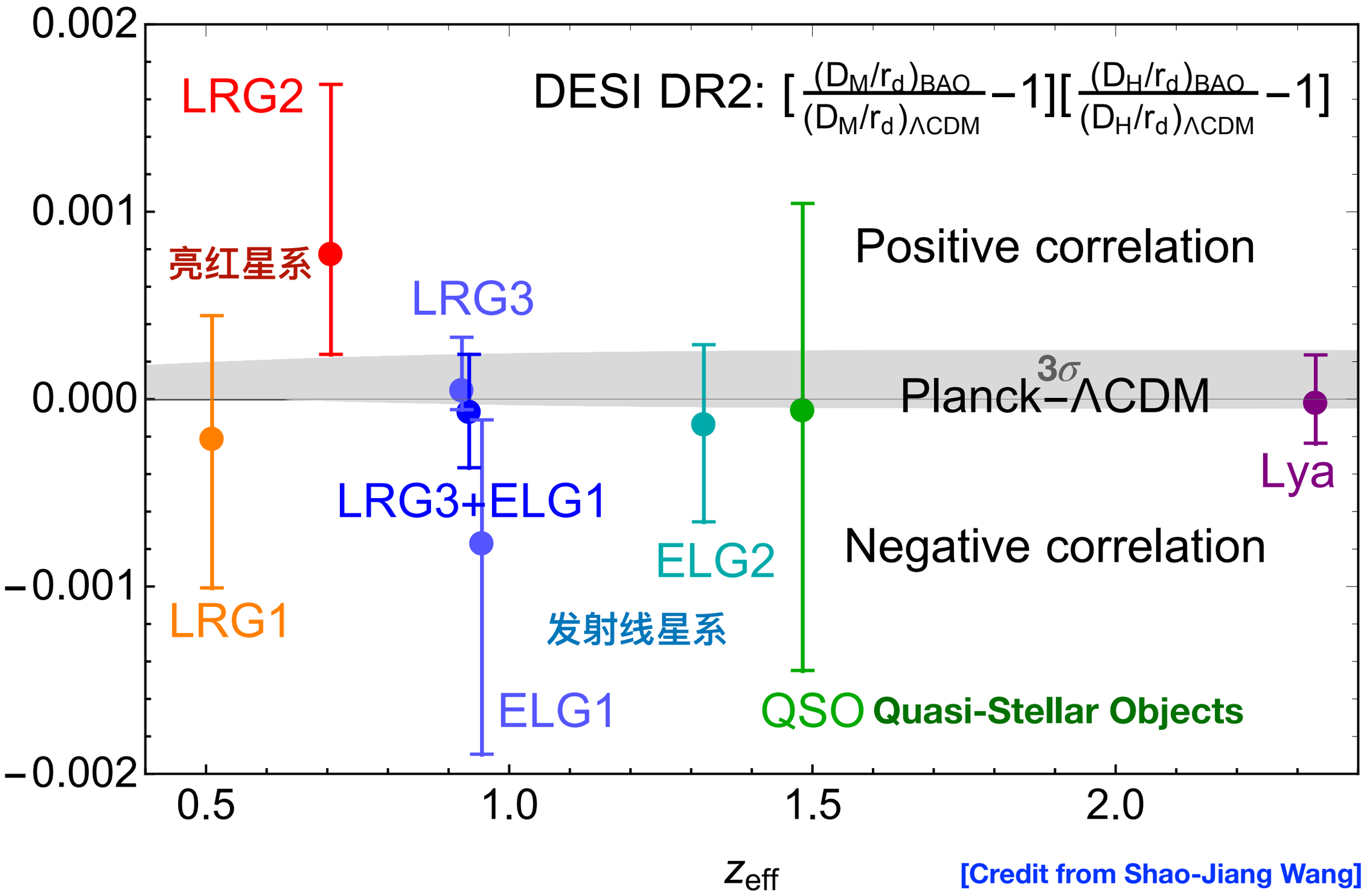
$$\alpha_{||}(z) = \frac{D_H(z)/r_d}{D_H^{\mathrm{fid}}(z)/r_d^{\mathrm{fid}}}$$

$$\alpha_\perp(z) = \frac{D_M(z)/r_d}{D_M^{\mathrm{fid}}(z)/r_d^{\mathrm{fid}}}$$

$$\alpha_{\mathrm{iso}} = (\alpha_{||}\alpha_\perp^2)^{1/3}$$

$$\alpha_{\mathrm{AP}} = \alpha_{||}/\alpha_\perp$$

DESI BAO

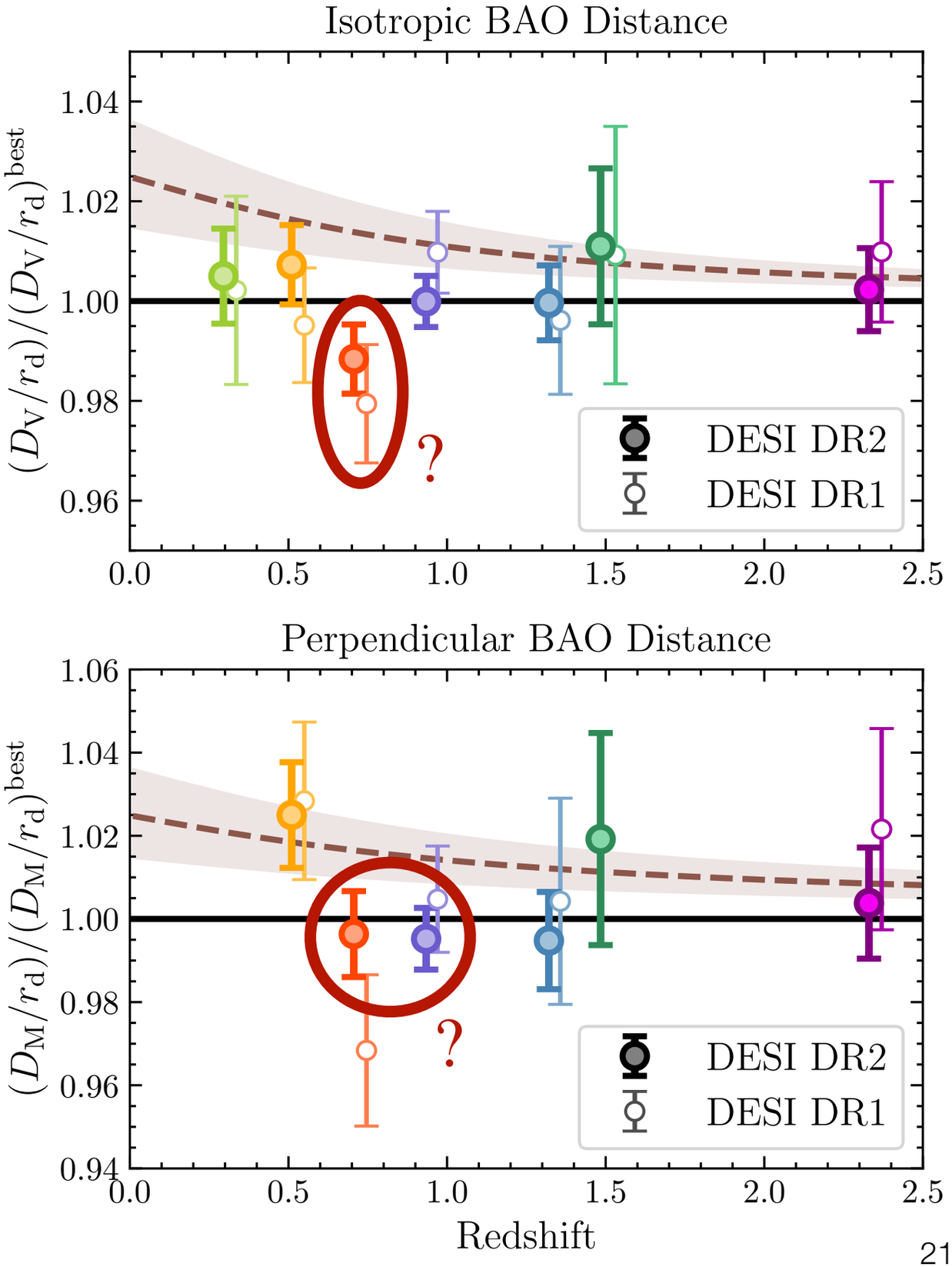


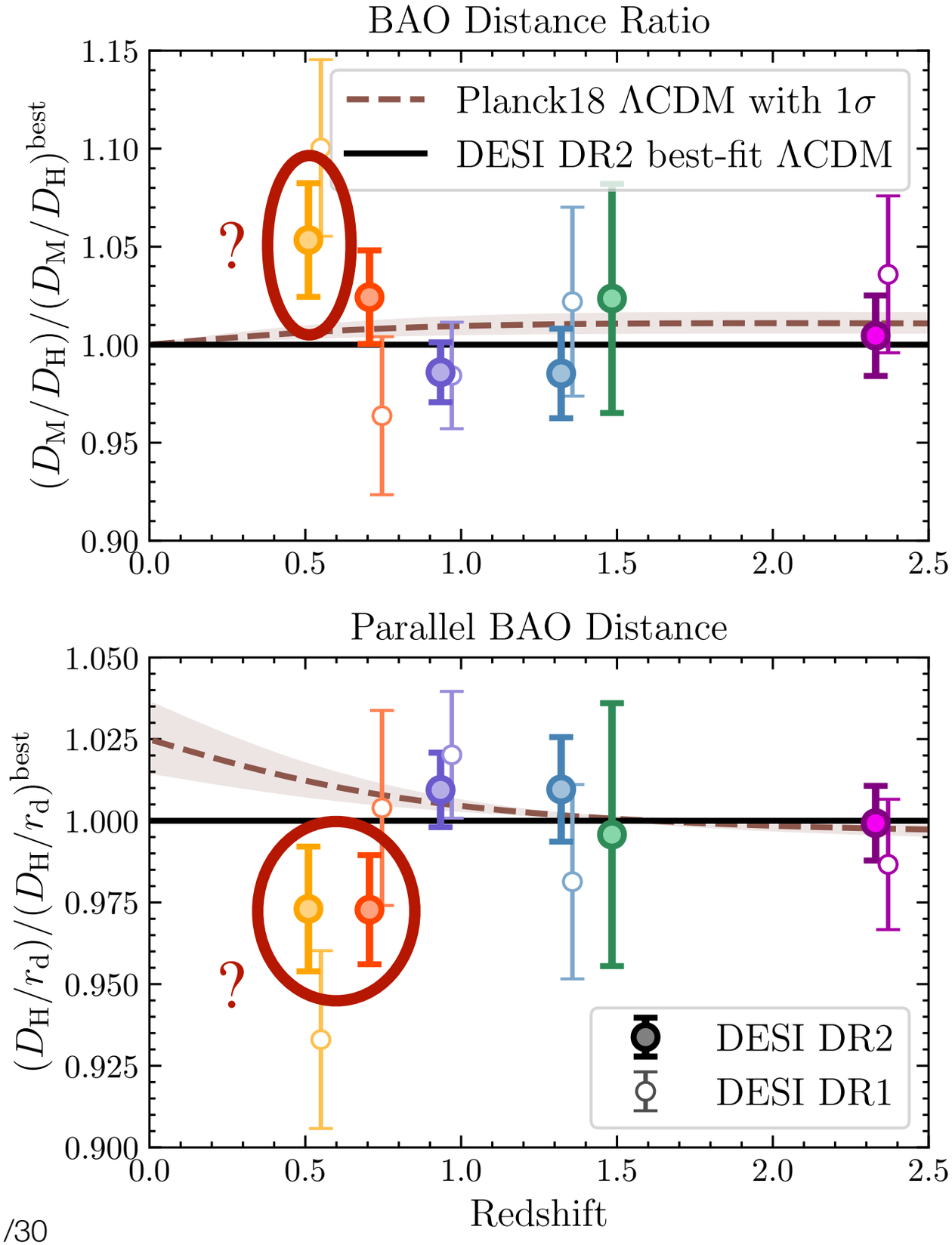
[Credit from Shao-Jiang Wang]

LRG2 is among the largest deviation from ΛCDM for a positive correlation between D_M/r_d and D_H/r_d

DESI BAO

2503.14738 DESI DR2 Y3 BAO





DESI BAO

2503.14738 DESI DR2 Y3 BAO

DESI BAO seems to indeed imply a phantom-to-quintessence transition to lower redshifts

$$D_M(z) = \int_0^{z'} \frac{c\mathrm{d}z'}{H(z')}$$

$$D_H(z) = \frac{c}{H(z)}$$

So that the integral of $D_H(z)$ within LRG could be lifted up at low-z

$$D_M^{\mathrm{DESI}}(z_{\mathrm{LRG1}}) > D_M^{\Lambda\mathrm{CDM}}(z_{\mathrm{LRG1}})$$

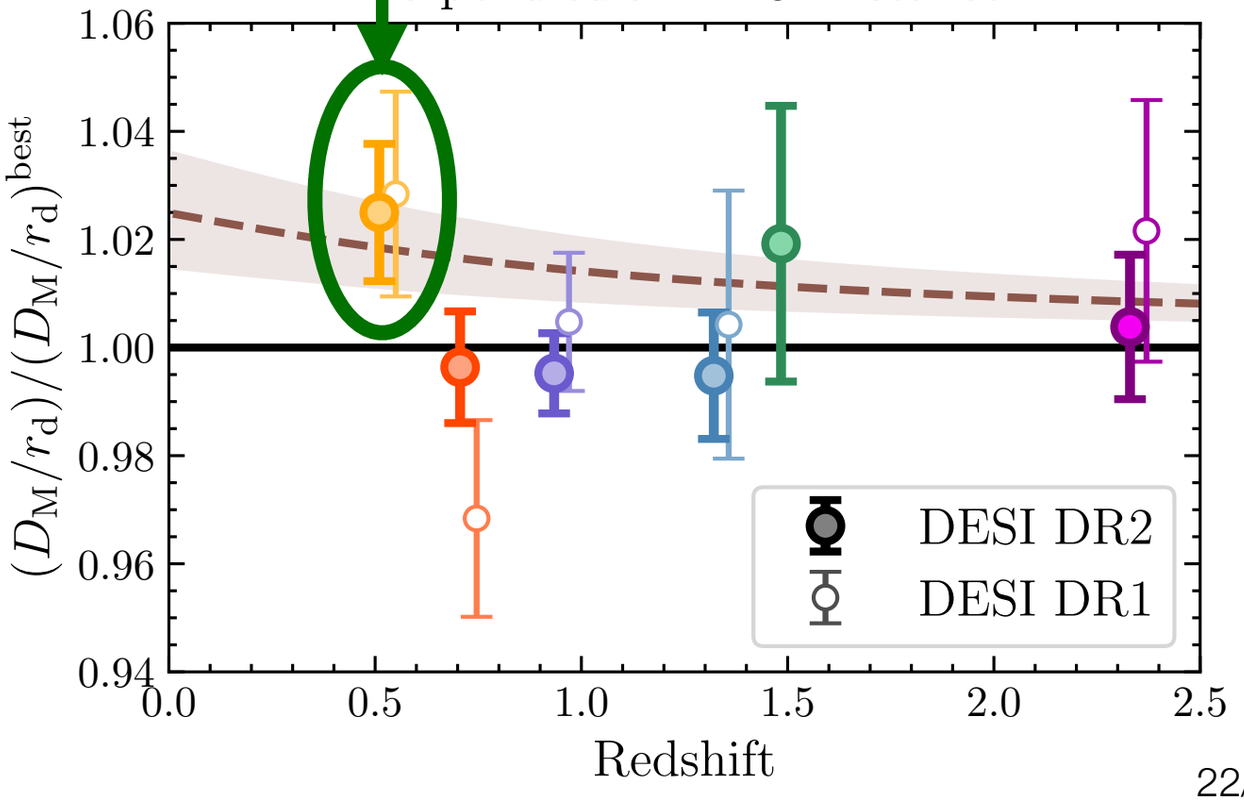
Quintessential DE at low redshifts

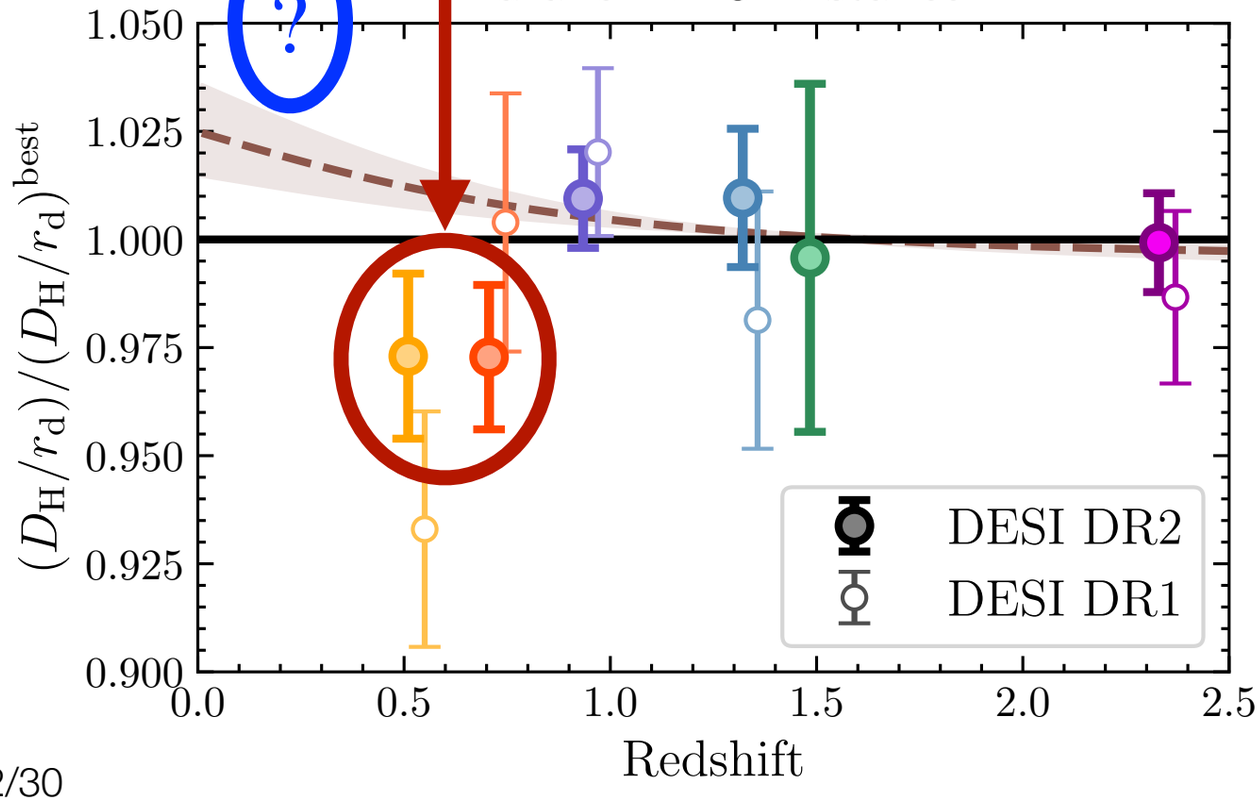
$$D_H^{\mathrm{QDE}}(z_{\mathrm{low}}) > D_H^{\Lambda\mathrm{CDM}}(z_{\mathrm{low}})$$

Phantom DE at high redshifts

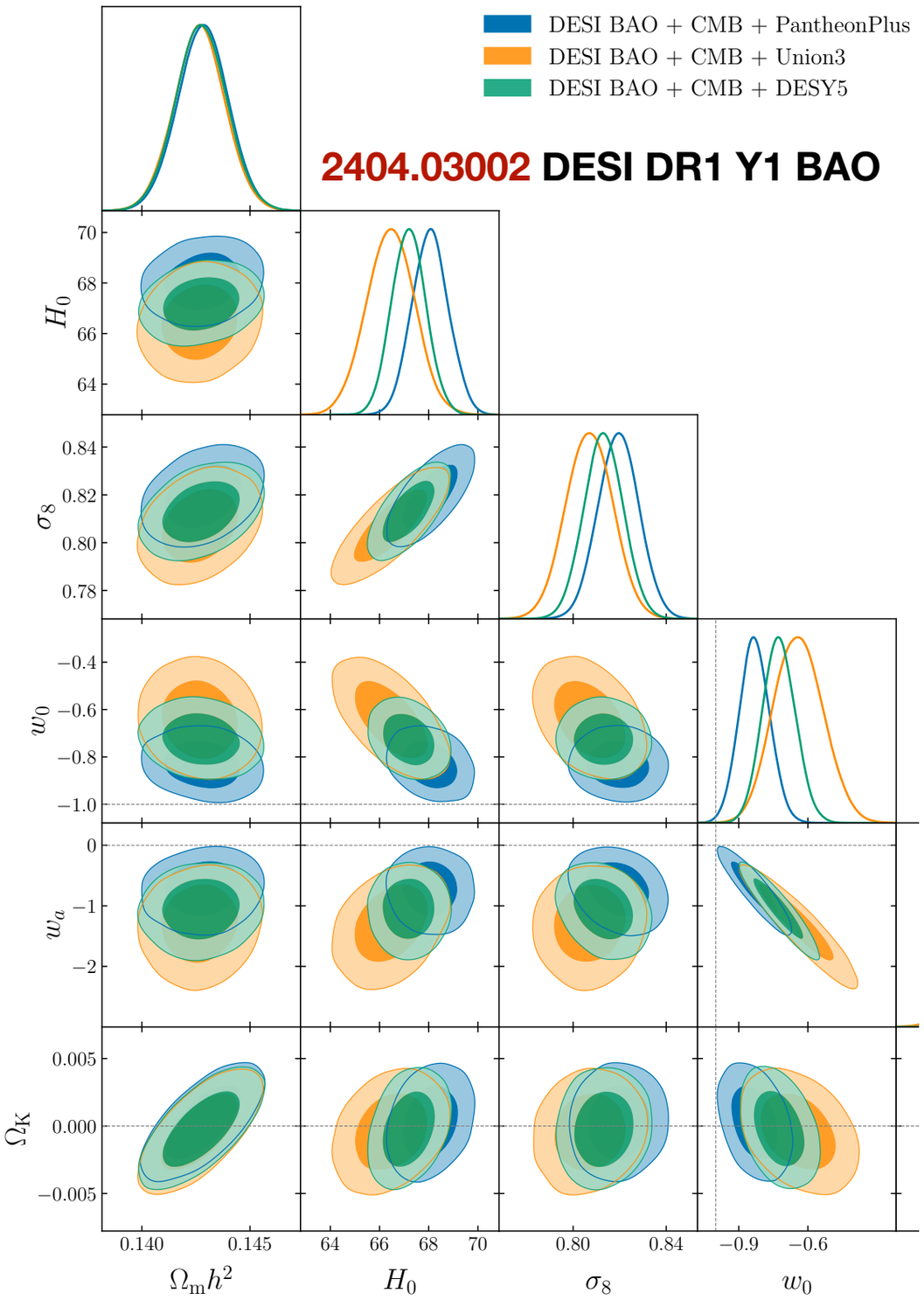
$$D_H^{\mathrm{PDE}}(z_{\mathrm{high}}) < D_H^{\Lambda\mathrm{CDM}}(z_{\mathrm{high}})$$

?





DESI tension with Hubble tension



2404.03002 DESI DR1 Y1 BAO

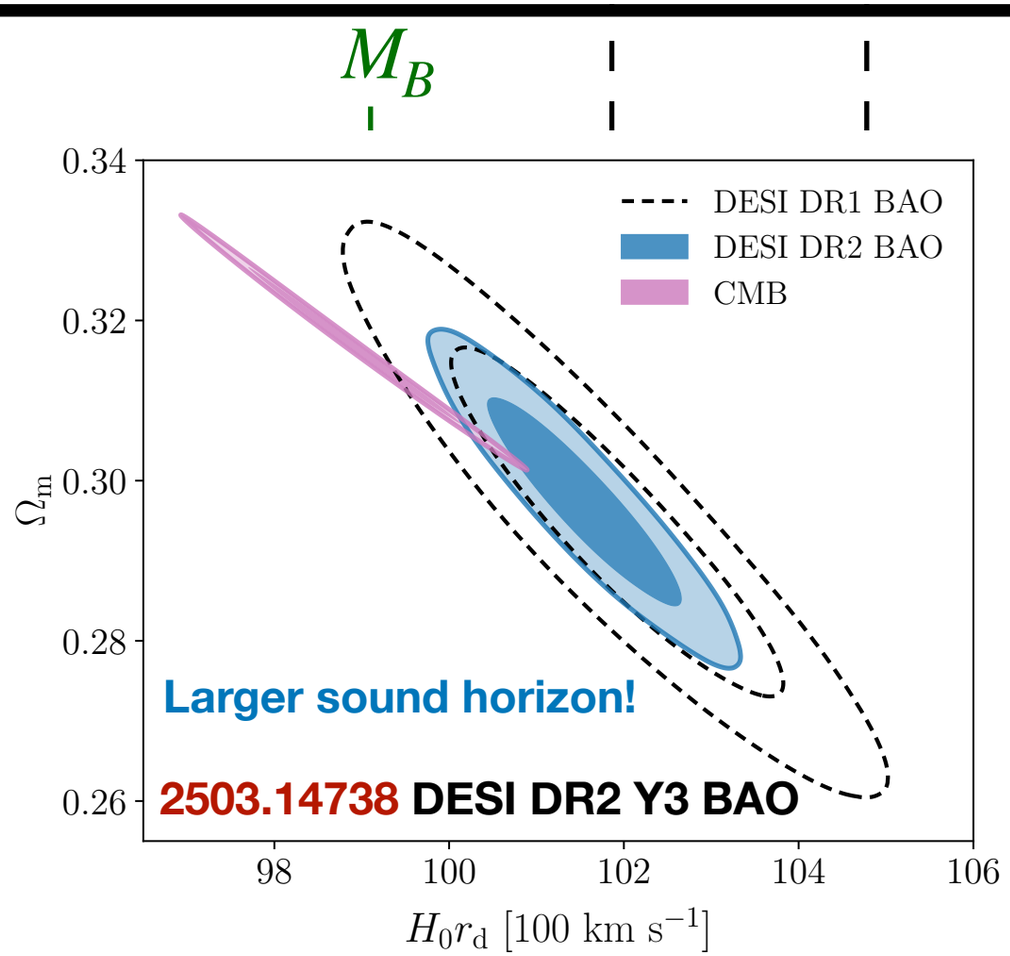
Model/Dataset	Ω_m	H_0 [km s^{-1} Mpc^{-1}]
ΛCDM	**2503.14738 DESI DR2 Y3 BAO**	
CMB	0.3169 ± 0.0065	67.14 ± 0.47
DESI	0.2975 ± 0.0086	—
DESI+BBN	0.2977 ± 0.0086	68.51 ± 0.58
DESI+BBN+θ_*	0.2967 ± 0.0045	68.45 ± 0.47
DESI+CMB	0.3027 ± 0.0036	68.17 ± 0.28
w_0w_aCDM	**2503.14738 DESI DR2 Y3 BAO**	
CMB	$0.220^{+0.019}_{-0.078}$	83^{+20}_{-6}
DESI	$0.352^{+0.041}_{-0.018}$	—
DESI+Pantheon+	$0.298^{+0.025}_{-0.011}$	—
DESI+Union3	$0.328^{+0.019}_{-0.014}$	—
DESI+DESY5	$0.319^{+0.017}_{-0.011}$	—
DESI+$(\theta_*, \omega_b, \omega_{bc})_{CMB}$	0.353 ± 0.022	$63.7^{+1.7}_{-2.2}$
DESI+CMB (no lensing)	0.352 ± 0.021	$63.7^{+1.7}_{-2.1}$
DESI+CMB	0.353 ± 0.021	$63.6^{+1.6}_{-2.1}$
DESI+CMB+Pantheon+	0.3114 ± 0.0057	67.51 ± 0.59
DESI+CMB+Union3	0.3275 ± 0.0086	65.91 ± 0.84
DESI+CMB+DESY5	0.3191 ± 0.0056	66.74 ± 0.56
DESI+DESY3 (3×2pt)+Pantheon+	0.3140 ± 0.0091	—
DESI+DESY3 (3×2pt)+Union3	0.333 ± 0.012	—
DESI+DESY3 (3×2pt)+DESY5	0.3239 ± 0.0092	—

Hubble tension is worsen!

DESI tension with early Hubble solutions

Local Universe | Late Universe | Early Universe

M_B r_s



$H(z)$ [km/s/Mpc]

73
H_0
67

H_0 tension

-19.4

136

147

r_s tension

Shrinking soud horizon

EDE

ΛCDM

修改早期宇宙解决哈勃常数危机需要在CMB之前减小声学视界，但这与DESI偏好的更大声学视界不符！

如果先在CMB之前减小声学视界，然后在CMB之后再增大声学视界，那么要求CMB之后暗能量比Planck-ΛCDM的要弱，但这又与DESI所偏好的先强后弱的暗能量不符！

CMB M=R BBN

0 0.01 0.1 1 10 10^3 3×10^3 10^8

z

DESI tension with late Hubble solutions

Local Universe	Late Universe	Early Universe

M_B r_s

修改晚期宇宙解决哈勃常数危机问题要求在
宇宙晚期膨胀得比Planck-ΛCDM的要快，
但这与DESI偏好的从强到弱的暗能量不符！

$H(z)$ [km/s/Mpc]

136

1

$b(z)$

−19.2

−19.4

Phantom Transition

73

H_0

67

H_0 tension

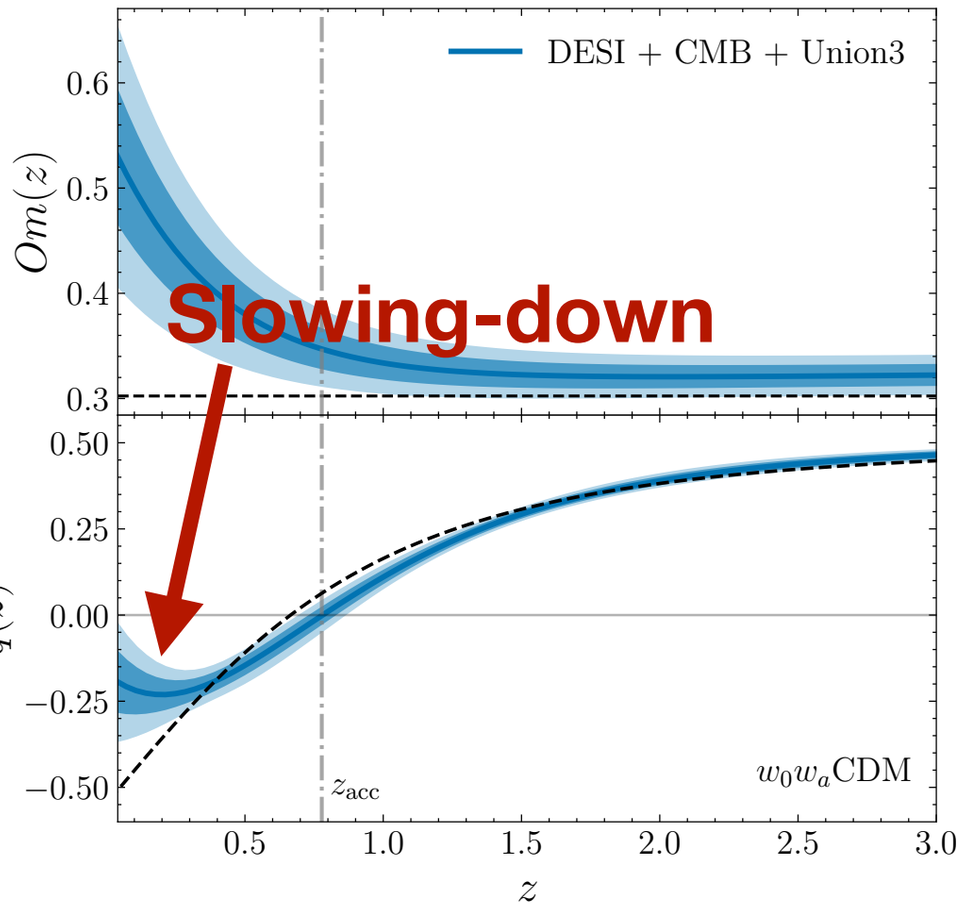
M_B tension

$$m_i = 5\lg d_L(z_i) + M_B + 5\lg\frac{c}{H_0\cdot \mathrm{Mpc}} + 25$$

CMB M=R BBN

0 0.01 0.1 1 10 10^3 3×10^3 10^8

z



DESI tension with γ tension

2302.01331 (PRL) growth index tension

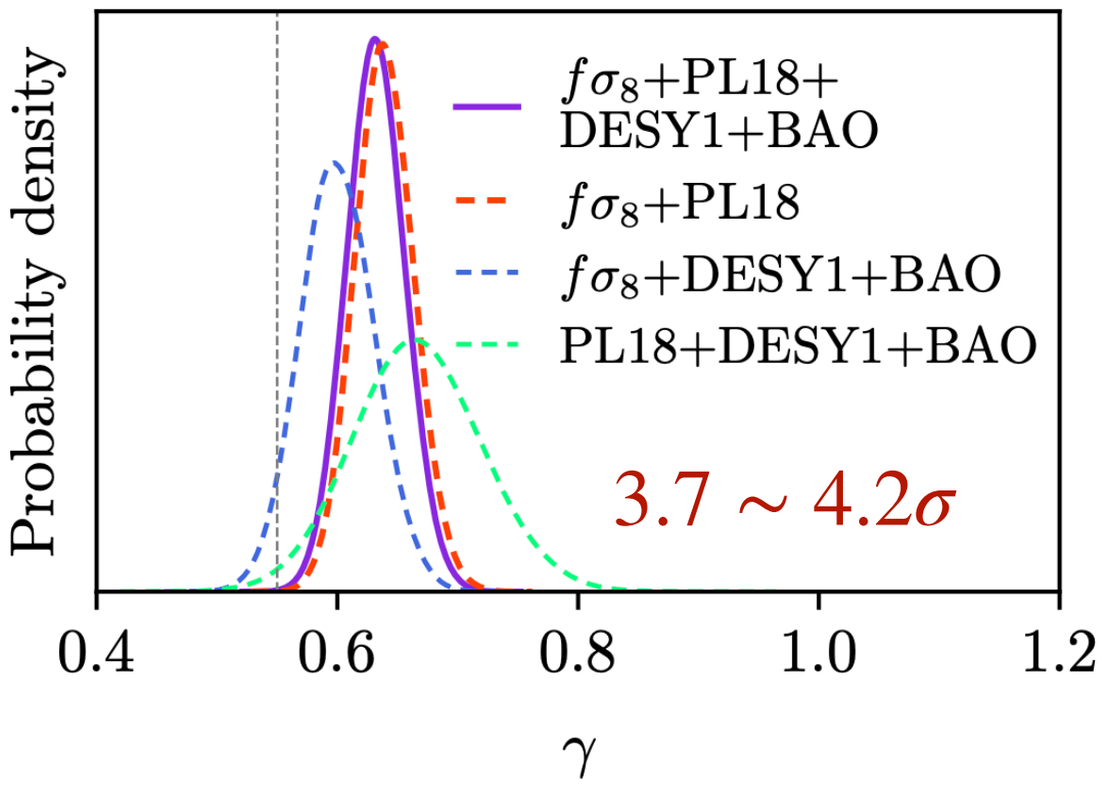
GR + linear $\delta \equiv \dfrac{\rho - \bar{\rho}}{\rho} \ll 1$ **regime**

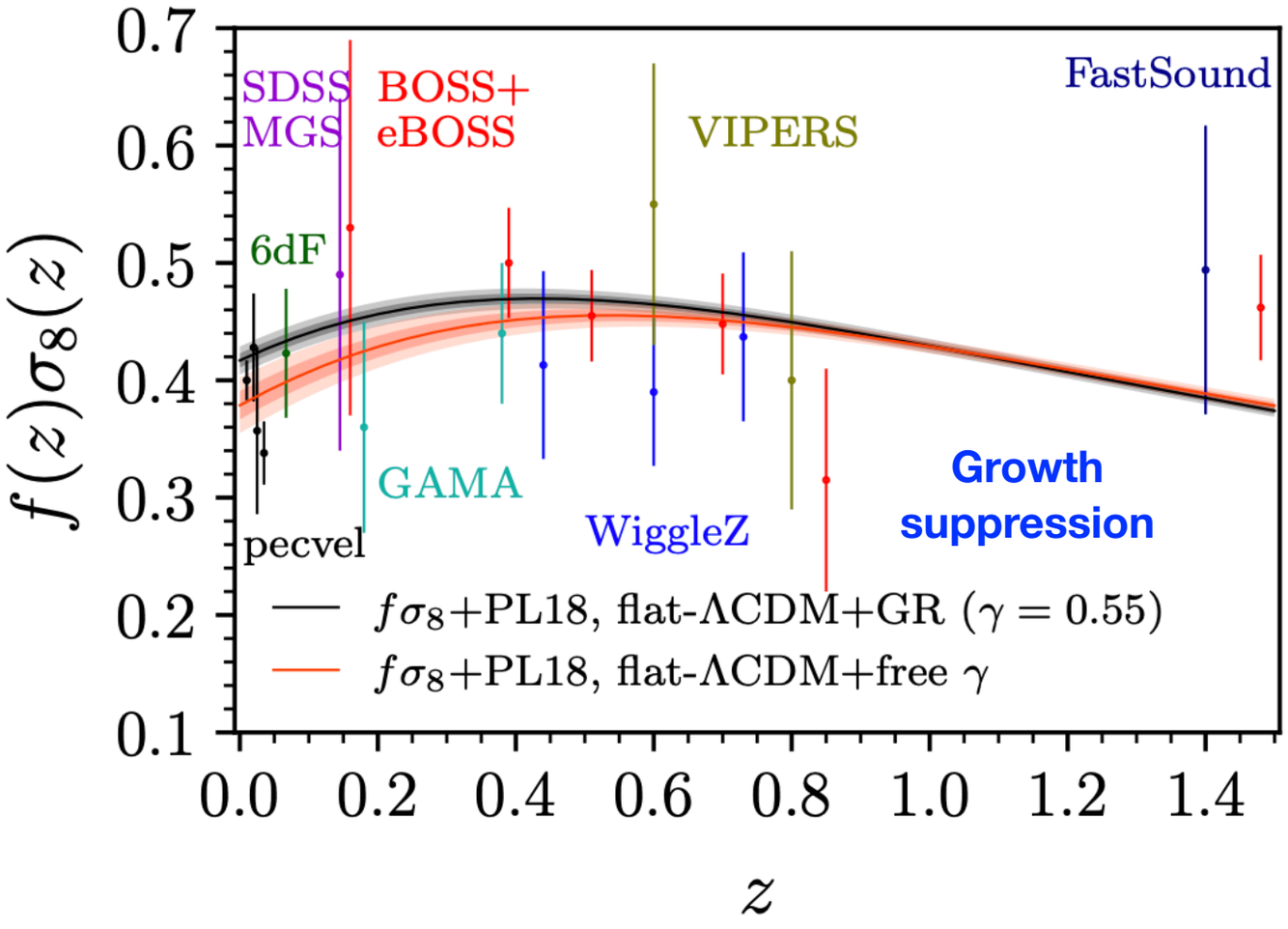
$$0.0003h/\mathrm{Mpc} \simeq H_0 \lesssim k \lesssim 0.1h/\mathrm{Mpc}$$

$$\ddot{\delta}(\mathbf{k},t) + 2H\dot{\delta}(\mathbf{k},t) - 4\pi G\bar{\rho}\delta(\mathbf{k},t) = 0$$

$$D(t) \equiv \frac{\delta(t)}{\delta(t_0)}, \quad f(a) \equiv \frac{\mathrm{d}\ln D(a)}{\mathrm{d}\ln a}$$

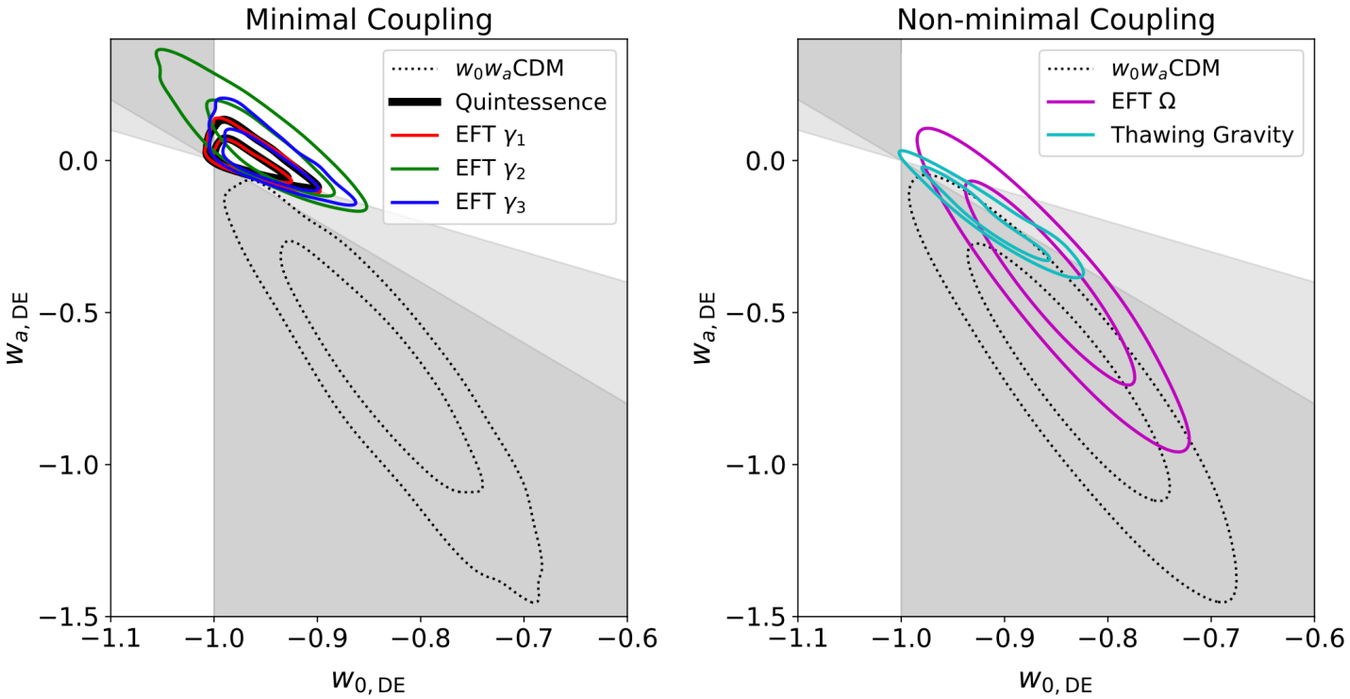
$$f(a) = \Omega_m^{\gamma}(a), \quad \gamma \approx 0.55, \quad \mathrm{flat}\Lambda\mathrm{CDM}$$





Since the Hubble expansion suppresses the matter perturbation growth, a weakening DE compared to the cosmological constant will less suppress matter perturbation growth, leading to faster growth than ΛCDM

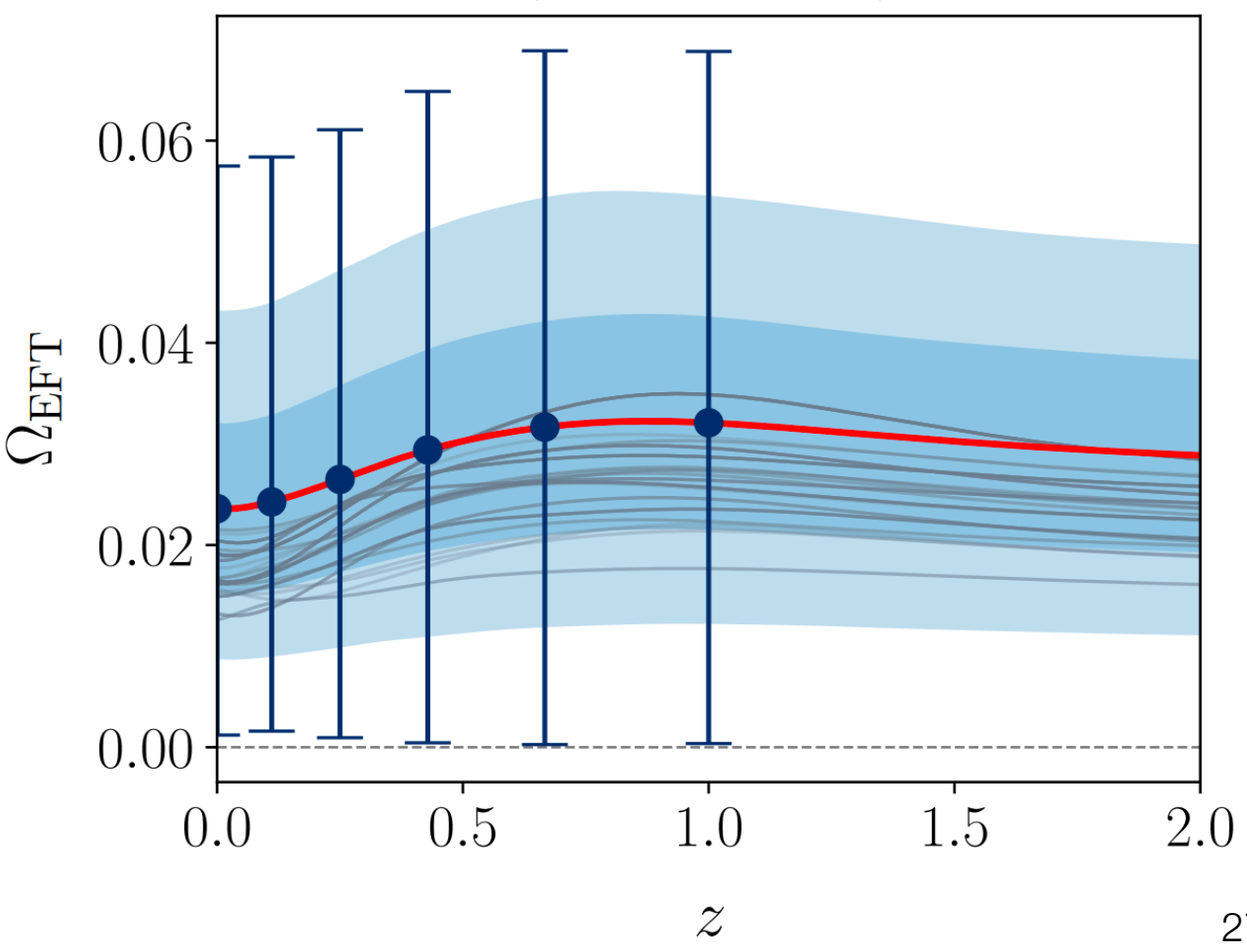
Non-minimal coupling

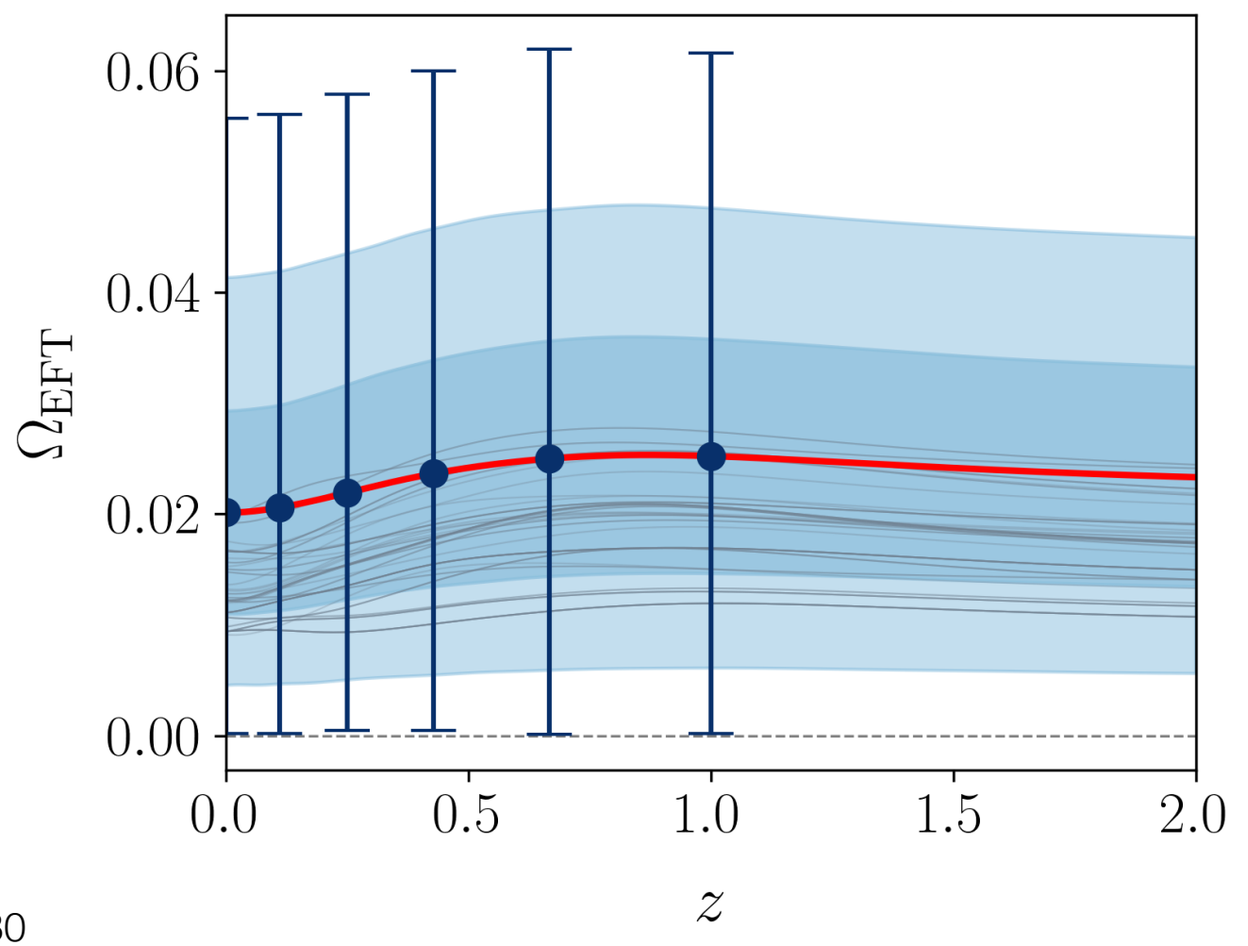


2407.15832 Gen Ye, Matteo Martinelli, Bin Hu, Alessandra Silvestri, "Non-minimally coupled gravity as a physically viable fit to DESI 2024 BAO" PRL 134 (2025) 181002

均偏好一个非最小耦合的引力

2503.19898 Jiaming Pan, Gen Ye, "Non-minimally coupled gravity constraints from DESI DR2 data"





Non-minimal coupling

$$S=\int \mathrm{d}^4x\sqrt{-g}\left[\frac{M_{\rm Pl}^2}{2}(R-2\Lambda)-\frac{1}{2}g^{\mu\nu}\nabla_\mu\phi\nabla_\nu\phi-V(\phi)+\mathscr{L}_{\rm SM}[g_{\mu\nu},\psi_{\rm SM}]\right]+\int \mathrm{d}^4x\sqrt{-\tilde{g}}\mathscr{L}_{\rm DM}[\tilde{g}_{\mu\nu}\equiv\Omega(\phi)^2 g_{\mu\nu},\psi_{\rm DM}]$$

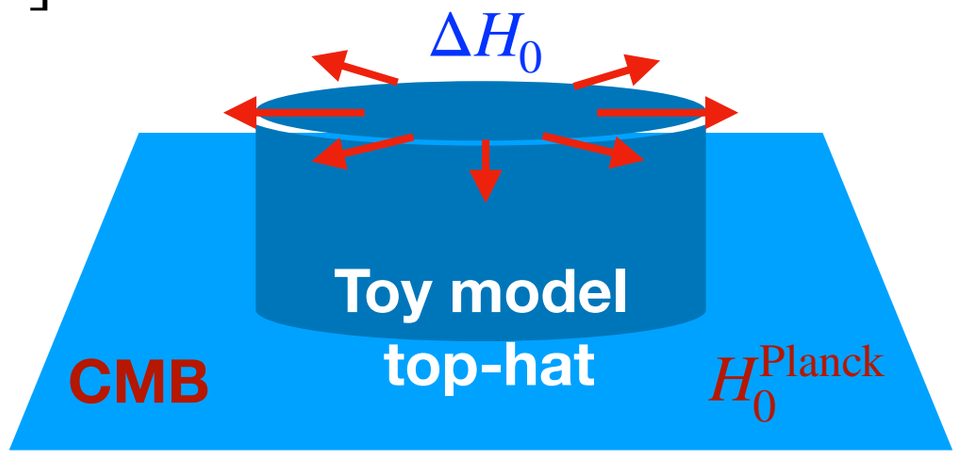
Effective potential — **Peebles-Ratra potential**

$$V_{\rm eff}(\phi)=V(\phi)+\Omega(\phi)\hat{\rho}_{\rm m}$$

$V(\phi)$: **Chameleon**; $\Omega(\phi)$: **Dilaton coupling**; $\hat{\rho}_{\rm m}$: **Matter density**

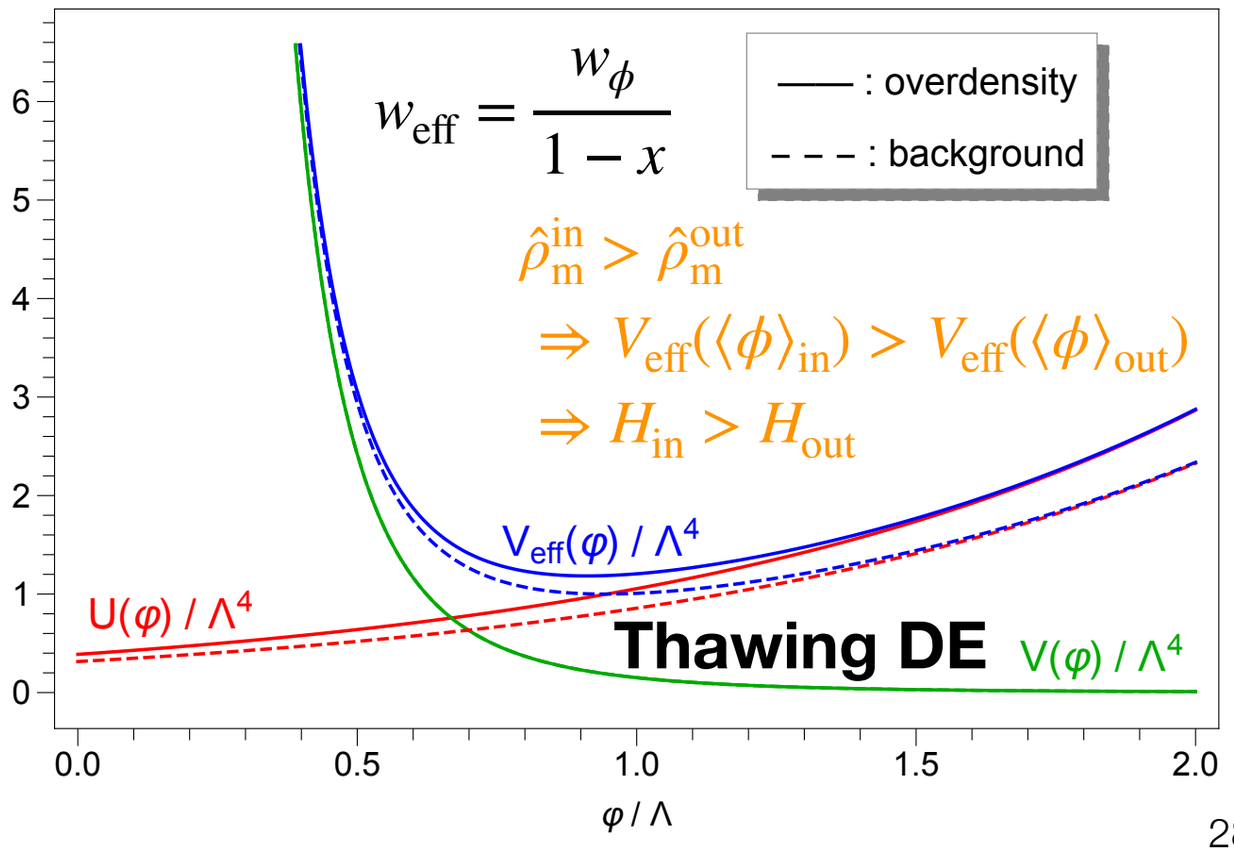
$$V(\phi)=\alpha\Lambda^4\left(\frac{\Lambda}{\phi}\right)^n$$

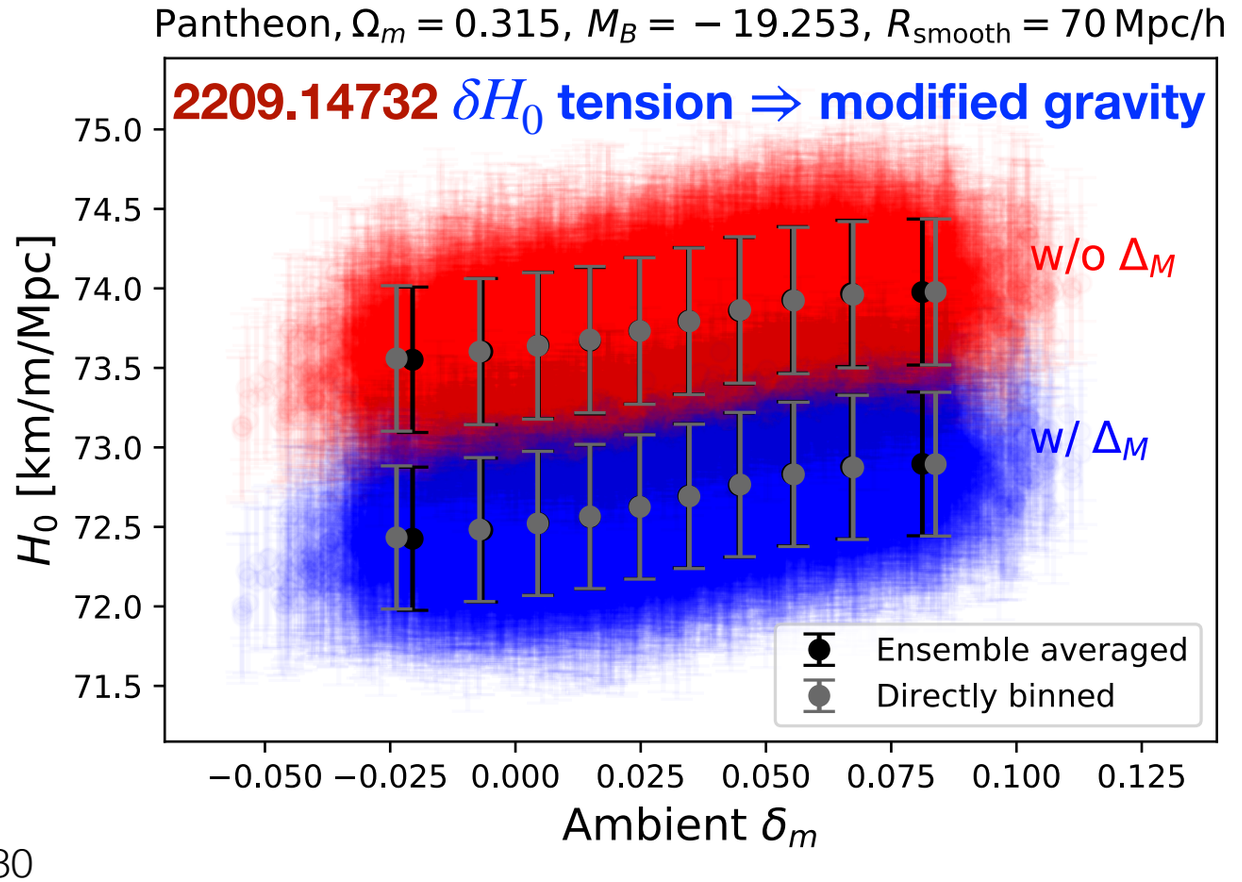
$$\Omega(\phi)=\exp\left(\frac{\phi}{\Lambda}\right)$$



Cai, Guo, Li, SJW, Yu (PRD Letter 2021)

Effective cosmological constant $V_{\rm eff}(\langle\phi\rangle)$





Conclusions and discussions

It is indeed the critical time from ΛCDM to something different { **MG/DDE: crossing?** / **MG&DDE: thawing?**

What DESI BAO really want to tell us is the disagreement with Planck-CMB on Ω_m if ΛCDM is assumed

Whatever left can be interpreted diversely, e.g. MG /& DDE, but the crossing crucially depends on low-z SNe **Phenomenological?**

DESI DDE is not only in tension with H_0 tension (in tension with both early/late solutions to H_0 tension)
but also the way out of it has already ruled out its preferred phantom crossing from $w_{\rm DE} < -1$ to $w_{\rm DE} > -1$

DESI DDE is not only in tension with H_0 tension but also in tension with S_8 tension, γ tension, and δH_0 tension

The beyond-ΛCDM new physics might be thawing dark energy from modified gravity with coupling to matter

Such a non-minimal coupling of scalar field to gravity might be naturally motivated from UV completed theory, e.g. modular field from string compactifications and 2007.04396

Thank you

中国科学院理论物理研究所 & 宁波大学基础物理与量子科技研究院

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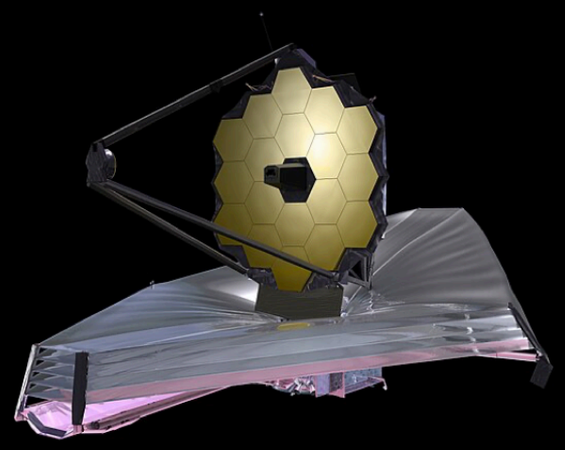
2025年06月27-30日 · 宁波



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