The Hubble parameter of the Local Distance Ladder from dynamical dark energy with no free parameters

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Based on

JHEAP 45:194 (2025), JHEAP 45:290 (2025), PRD 104:083511 (2021), MNRAS (2020), PLB 823: 136737 (2019), ApJ 837:22 (2017), ApJ 848:28 (2017), MNRAS 450:L48 (2015)

August 10-16, 2025

ICISE, Quy Nhon, Vietnam

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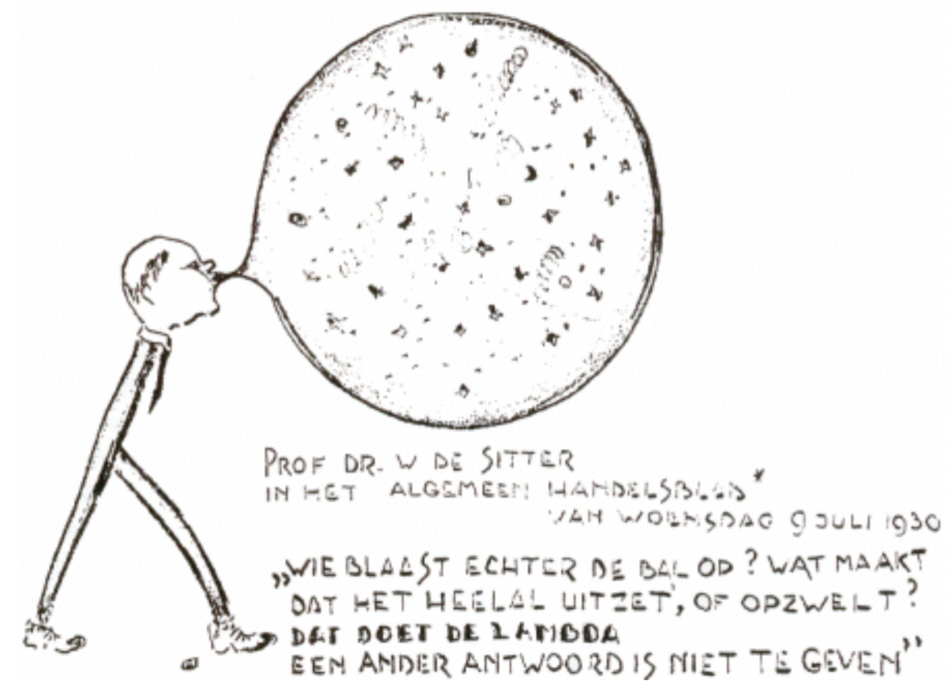
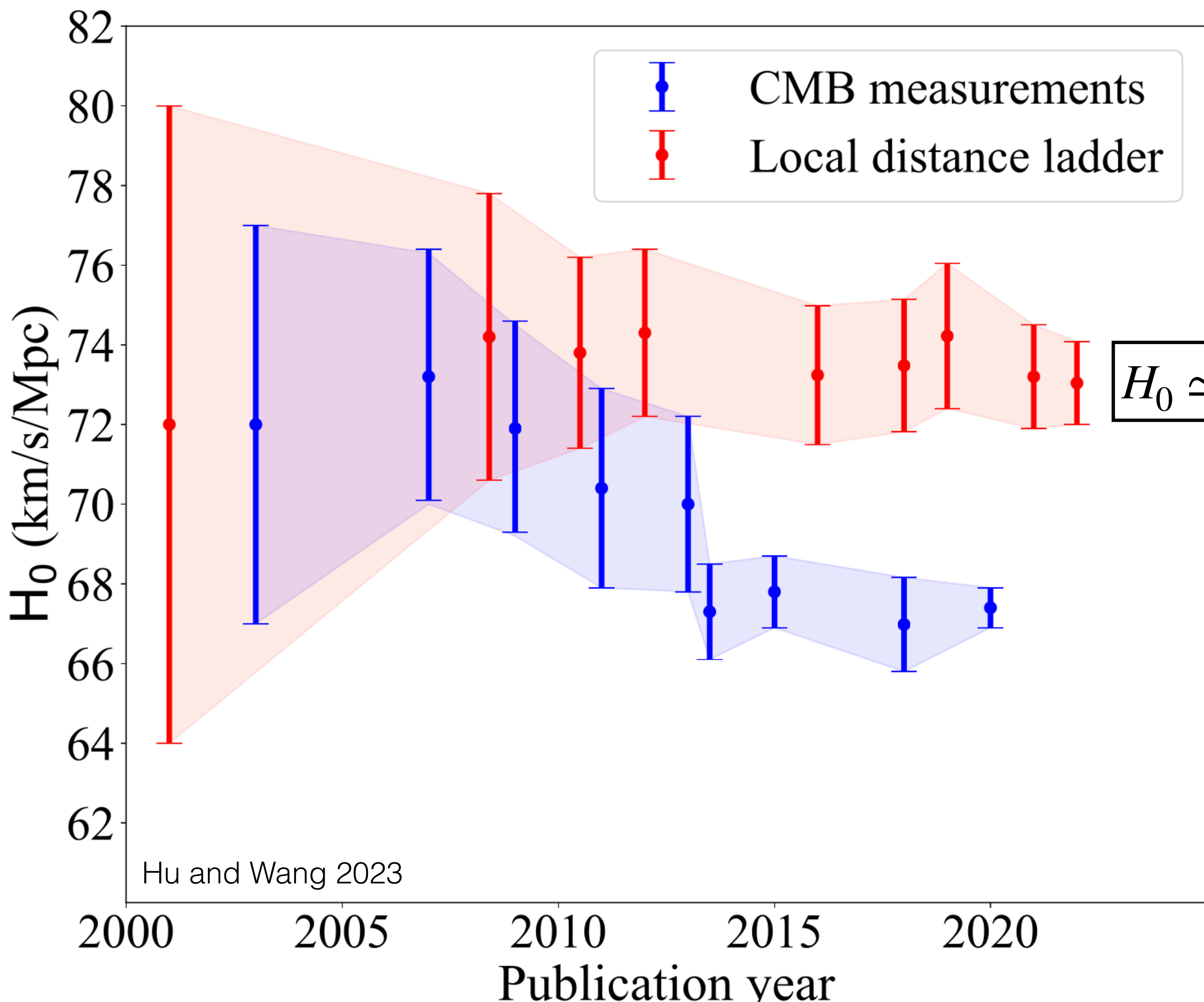


"What inflates the bal?"
W. de Sitter (1930)

Hu and Wang 2023

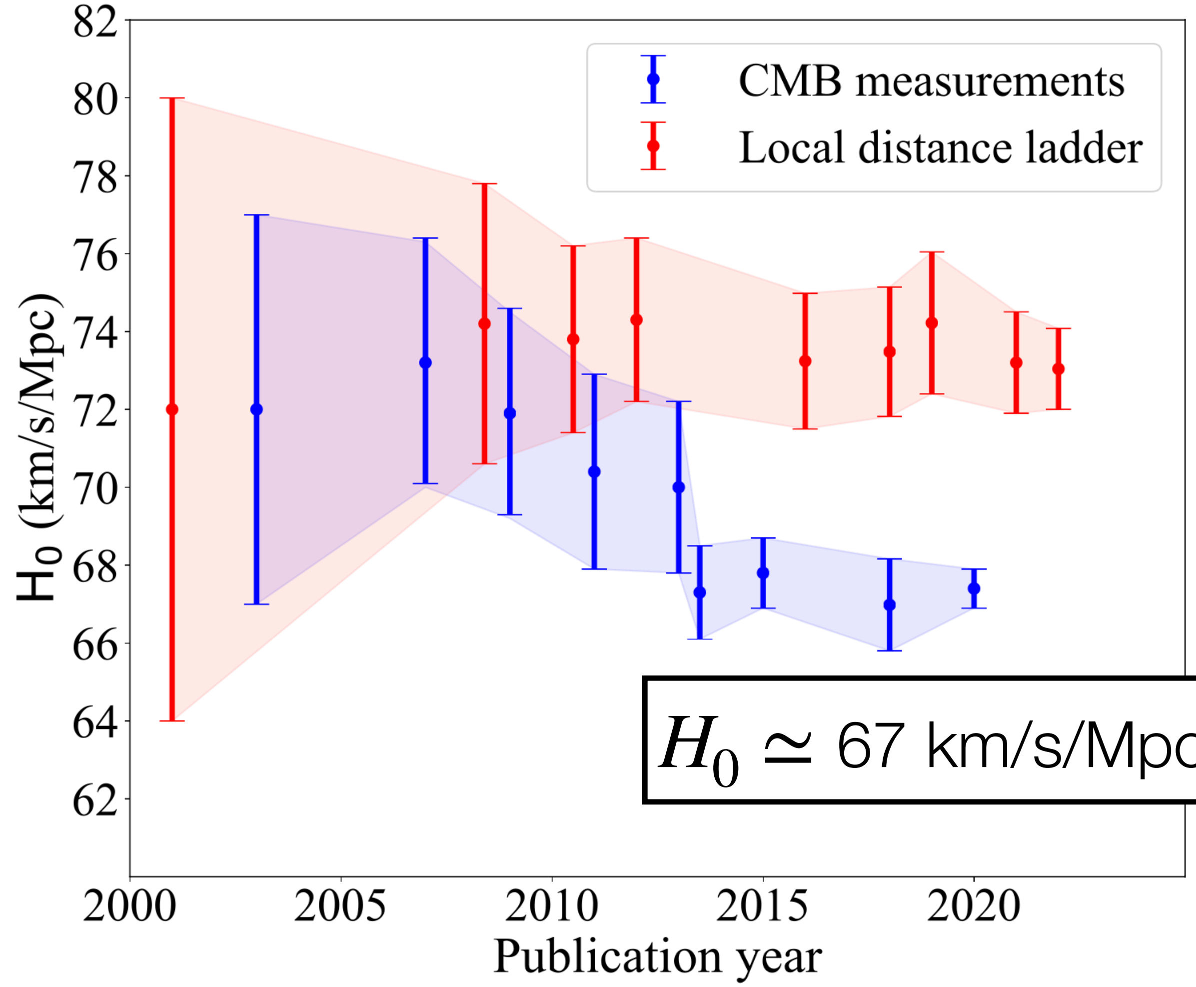
H_0 from the Local Distance Ladder



$H_0 \simeq 73$ km/s/Mpc

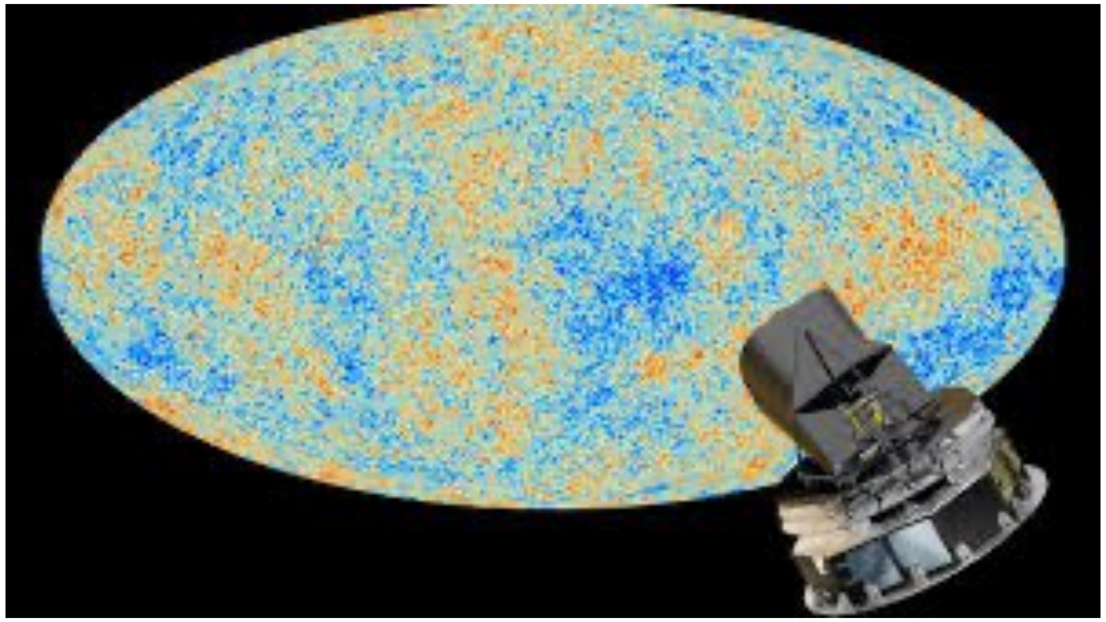
Hu and Wang 2023

H_0 from *Planck* CMB



Hu and Wang 2023

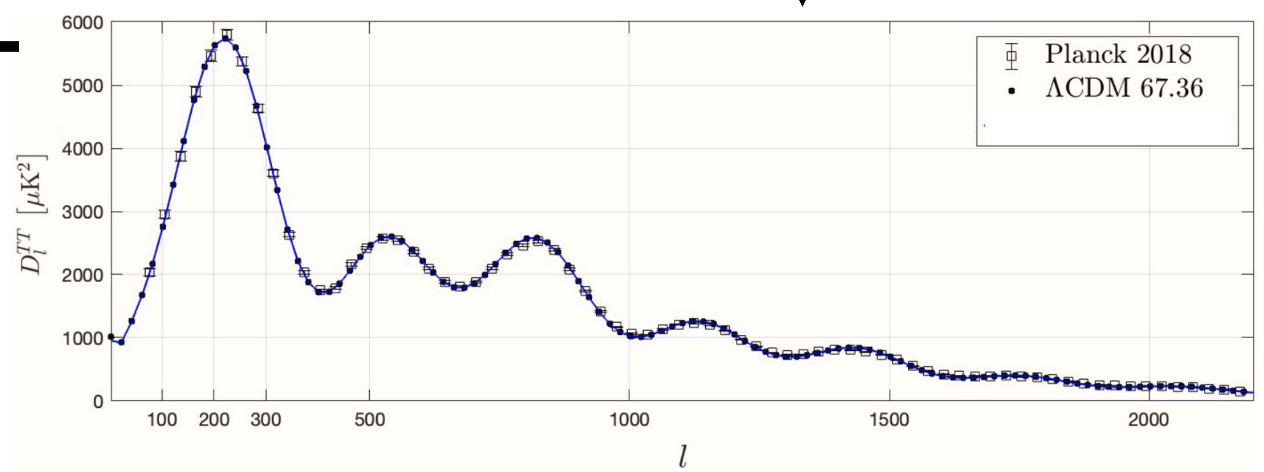
$H_0 \simeq 67$ km/s/Mpc



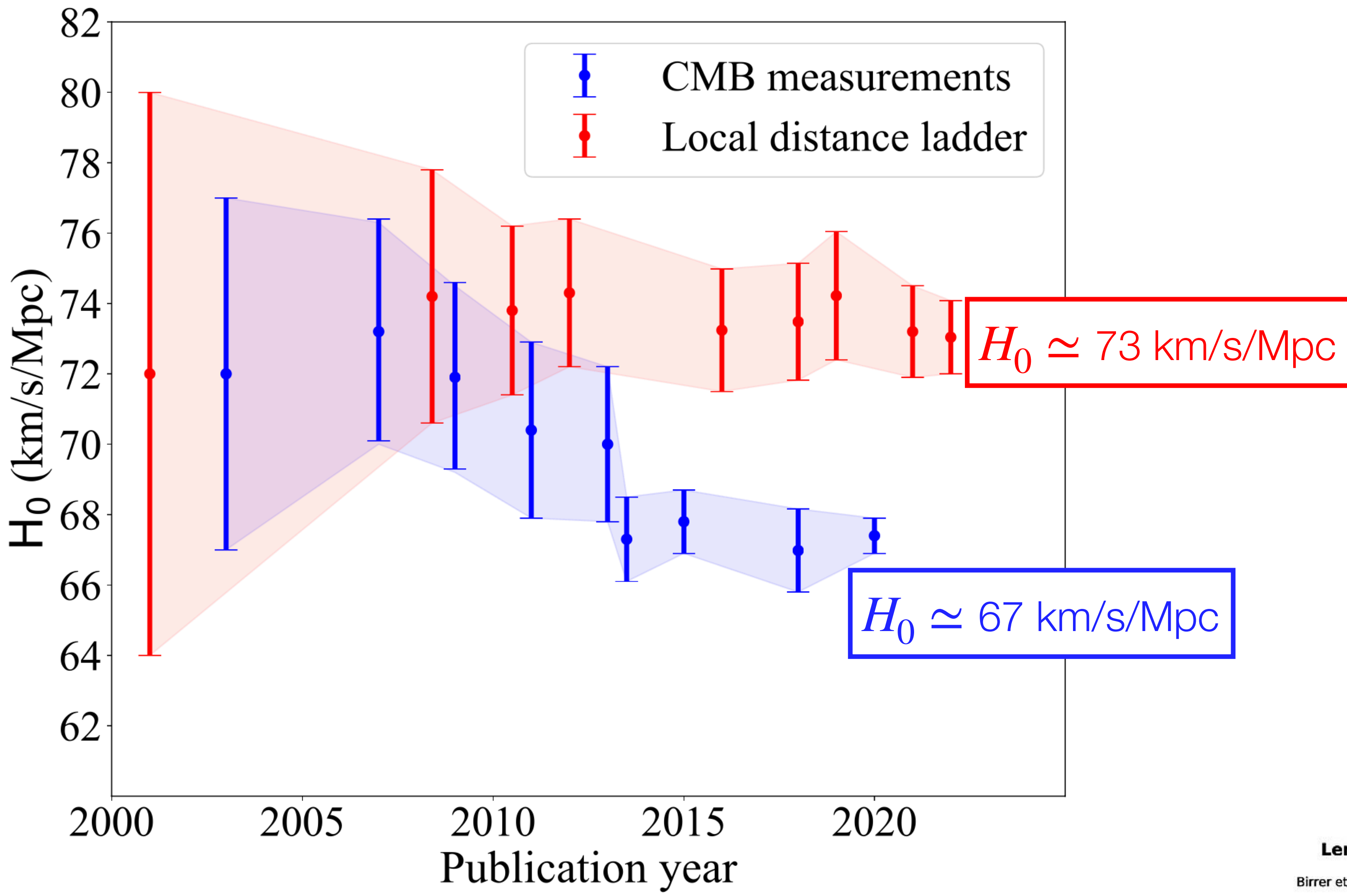
Planck CMB

Planck ΛCDM-analysis

BAO: primordial seeds of galaxy formation and Large Scale Structure (LSS)

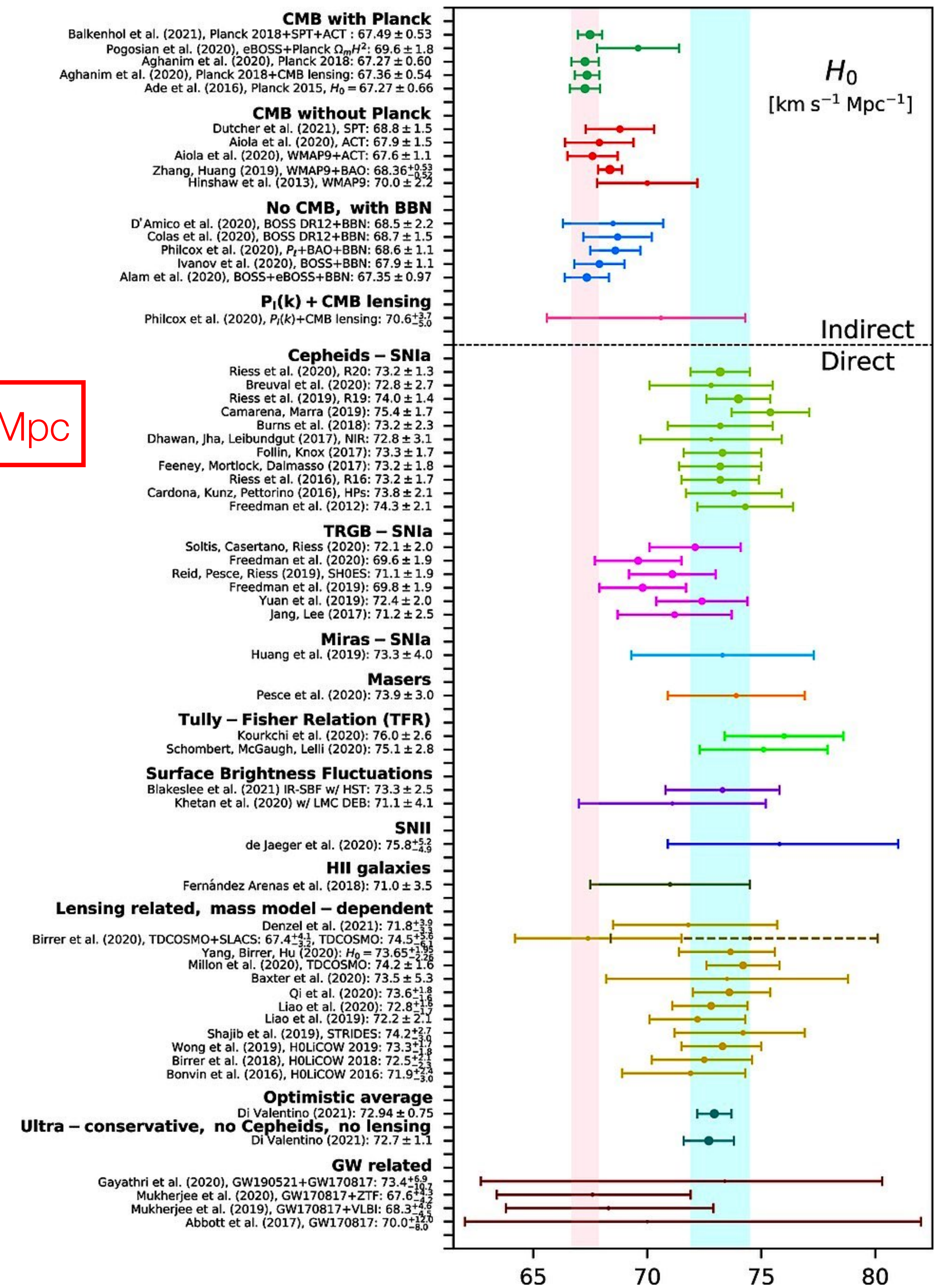


H_0-tension



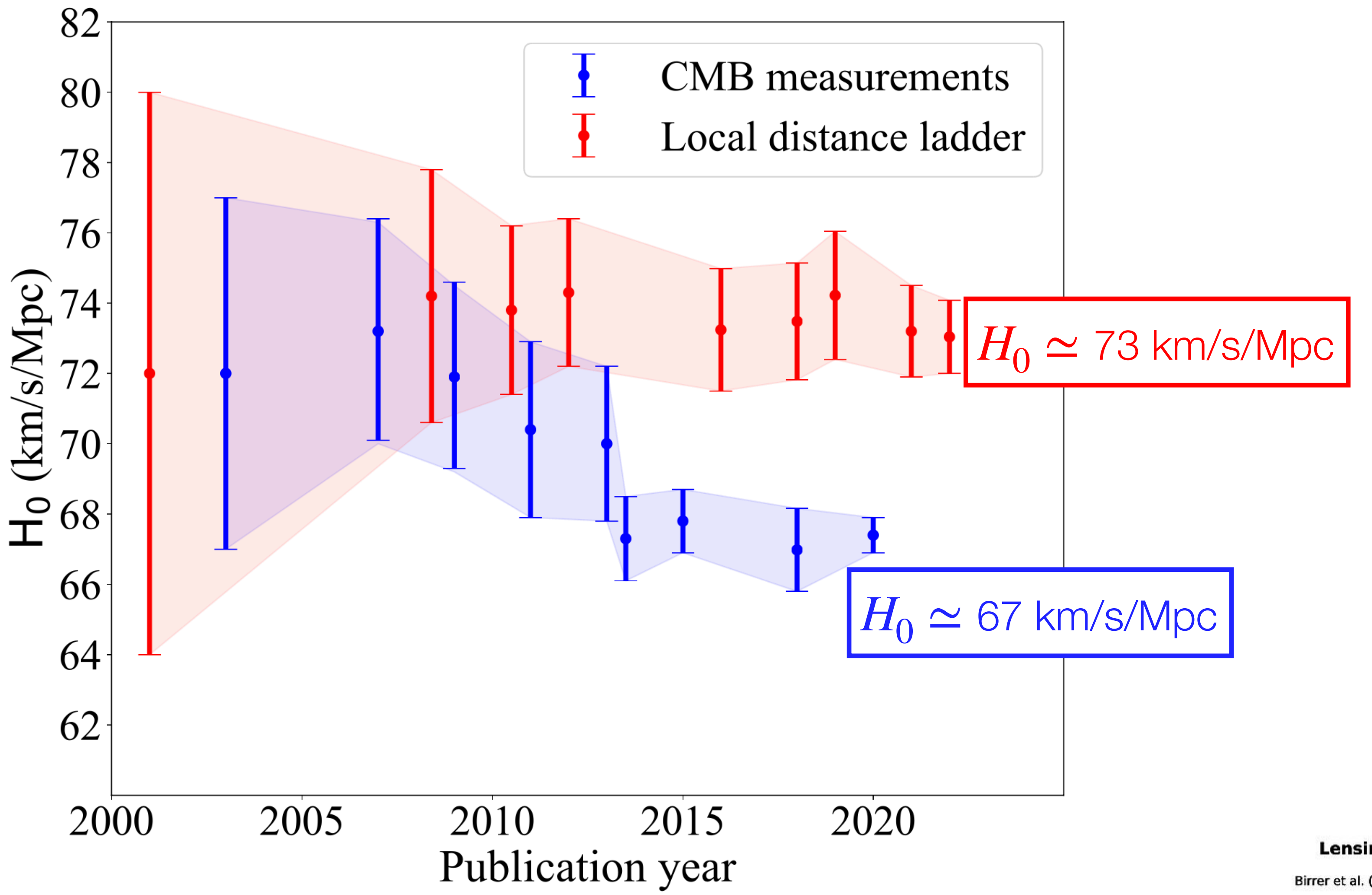
Hu and Wang 2023

$$\frac{H_0^{LDL} - H_0^{Planck}}{H_0^{Planck}} \simeq 9\,\%$$

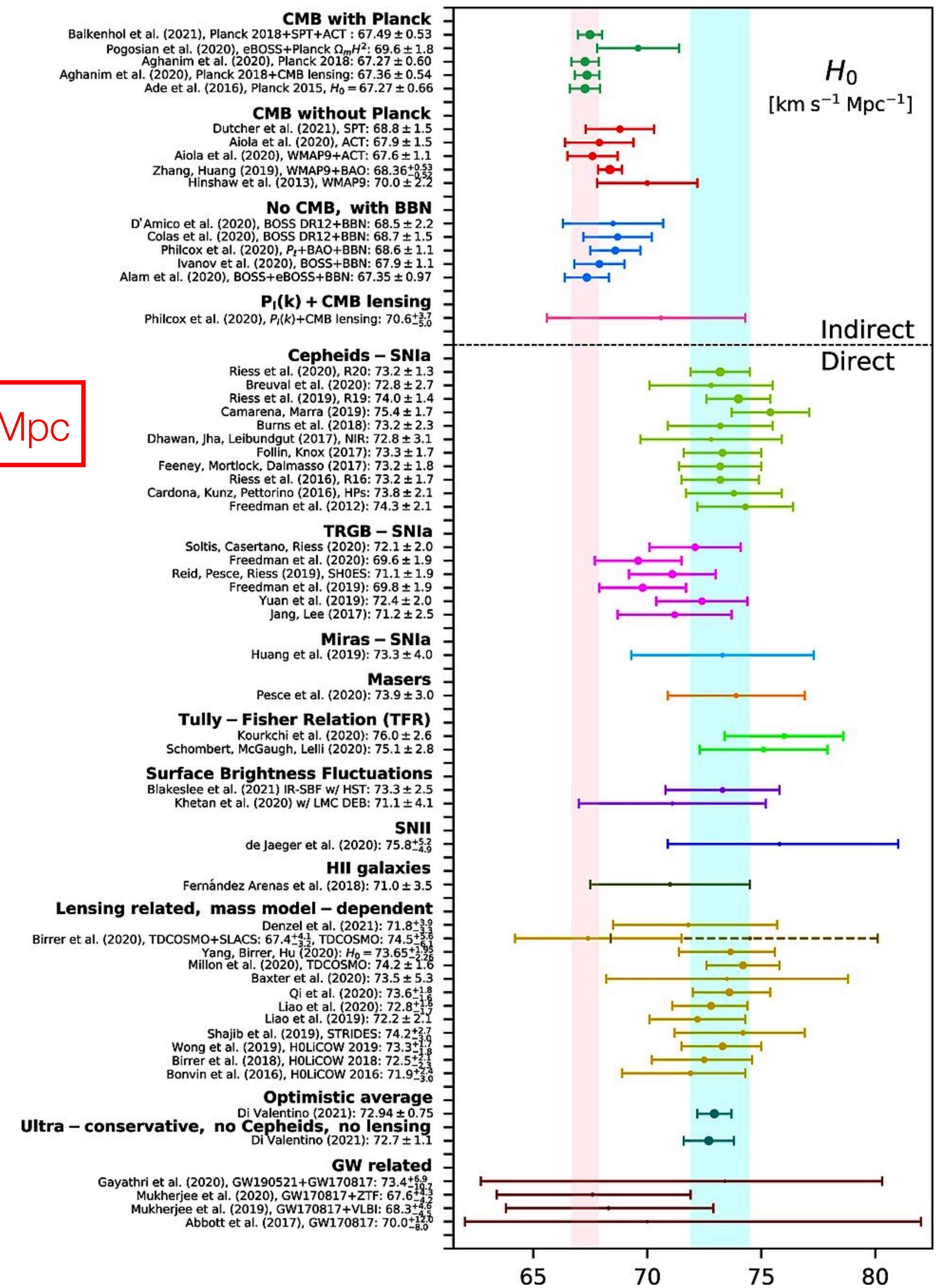


E. Di Valentino 2021

H_0-tension



Hu and Wang 2023



E. Di Valentino 2021

All about Λ*?*

Cosmological Constant Problem (a revisit)

(Zel'dovich 1967, Weinberg 1989)

$$\langle\rho\rangle = \int_0^{\Lambda} \frac{4\pi k^2 dk}{(2\pi)^3} \frac{1}{2}\sqrt{k^2+m^2} \simeq \frac{\Lambda_0^4}{16\pi^2}$$

$$\Lambda_0 \simeq \frac{1}{\sqrt{8\pi G}} \sim G^{-1/2}:$$

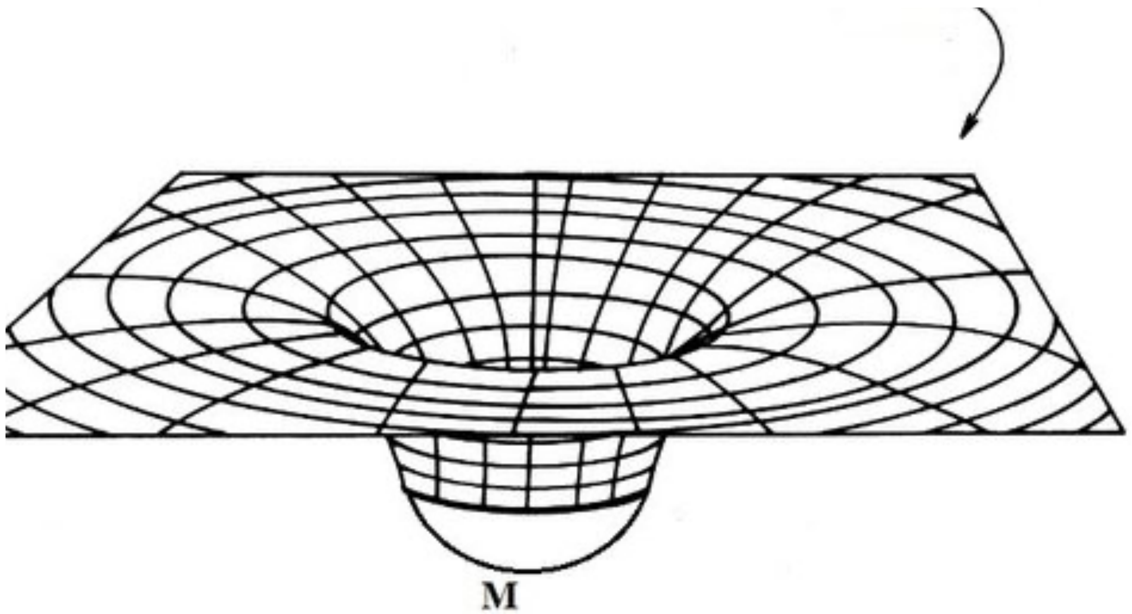
$$\langle\rho\rangle \simeq 2^{-10}\pi^{-4}G^{-2} = 2\times 10^{71}\,\mathrm{GeV}^4 \gg$$

$$\rho_c = \frac{3H^2}{8\pi G} \simeq 10^{-29}\,\mathrm{g\,cm^{-3}} \simeq 10^{-47}\,\mathrm{GeV}^4$$

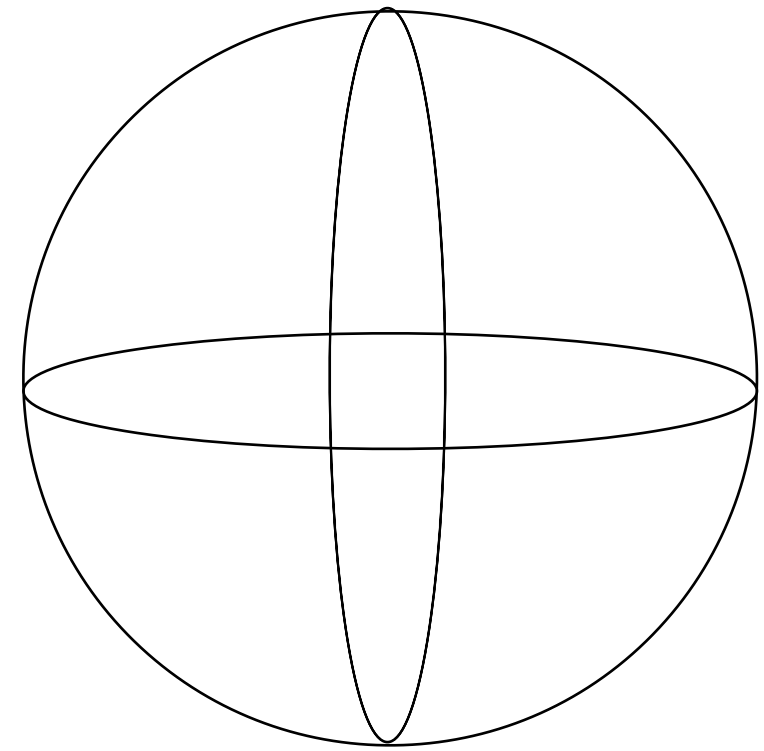
Zel'dovich paradox of QFT on a classical vacuum,
locally, ignoring causality on a Hubble scale

Inequivalent background vacua

Asymptotic Minkowski
vacuum: ***classical***

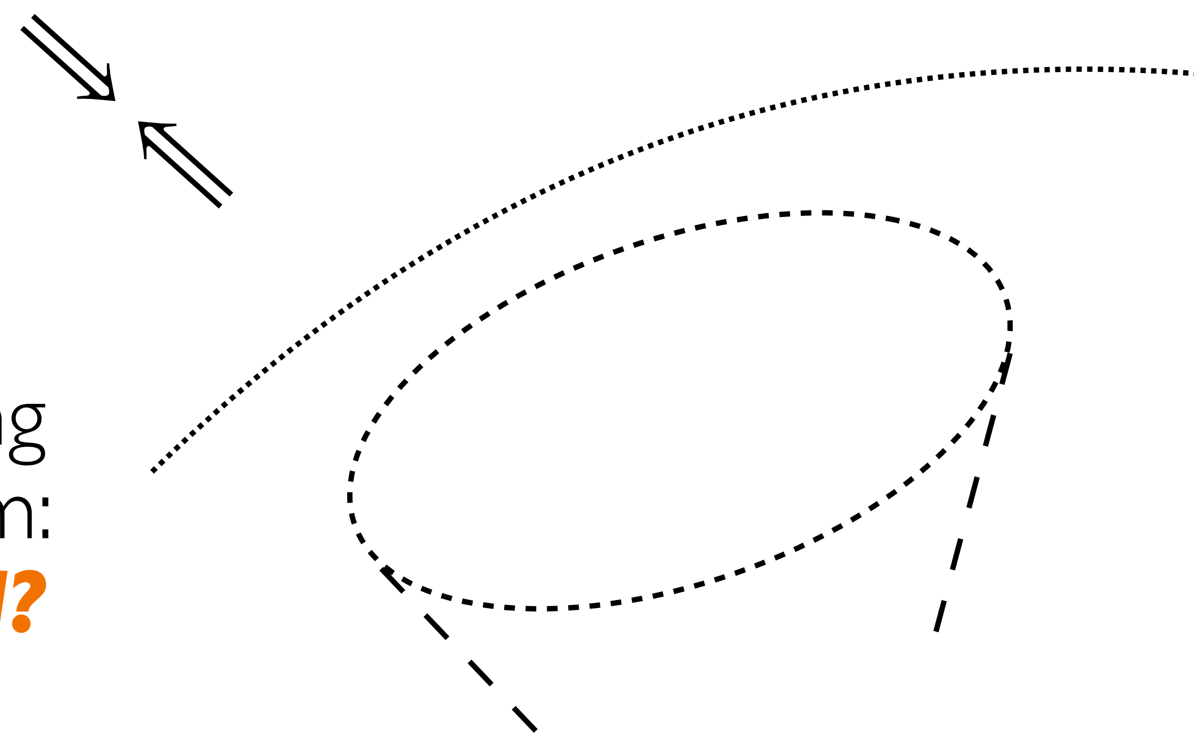


$\Longrightarrow \Longleftarrow$



Expanding
background vacuum:
nonclassical?

(Conformal scaling by $a(\tau)$)

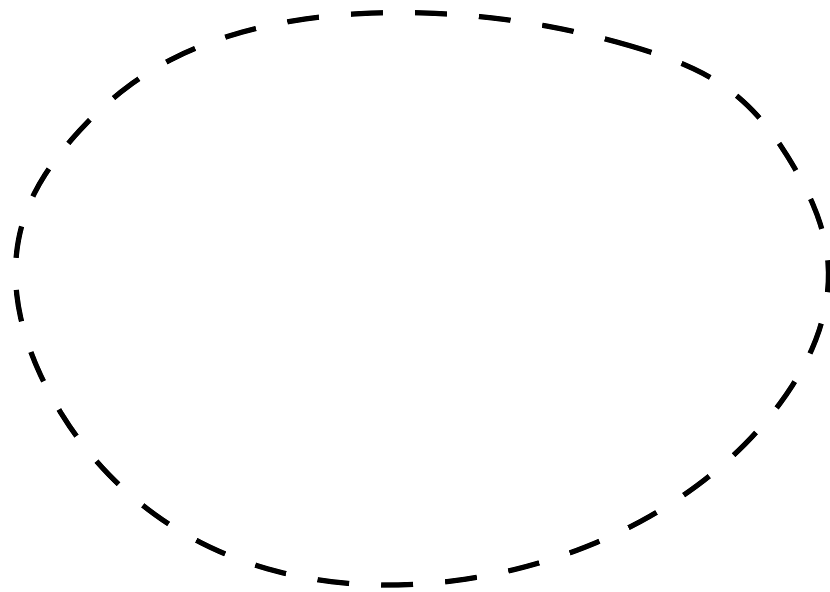


Big Bang cosmologies

Causal boundary conditions on a Hubble scale

van Putten ApJ 837, 22 (2017)

Causal limit of luminosity $L_0 \equiv \frac{c^5}{G}$



Hubble horizon

$$R_H = c/H$$

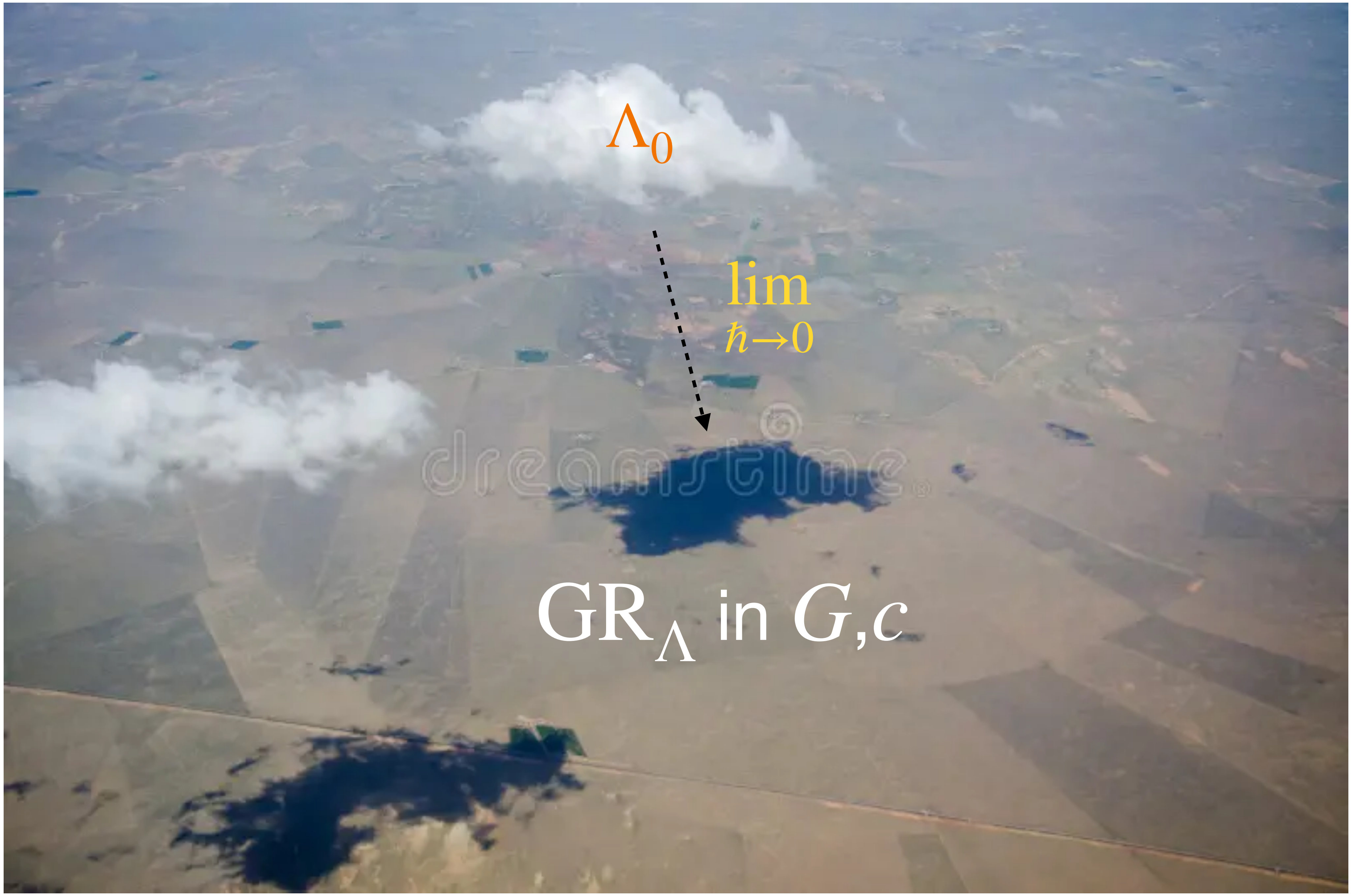
Implied pressure:

$$p = -\frac{L_0/c}{4\pi R_H^2} = -\frac{2}{3}\rho_c: \qquad \Omega_\Lambda = \frac{2}{3}$$

A formal treatment follows the detailed nature of the Hubble horizon

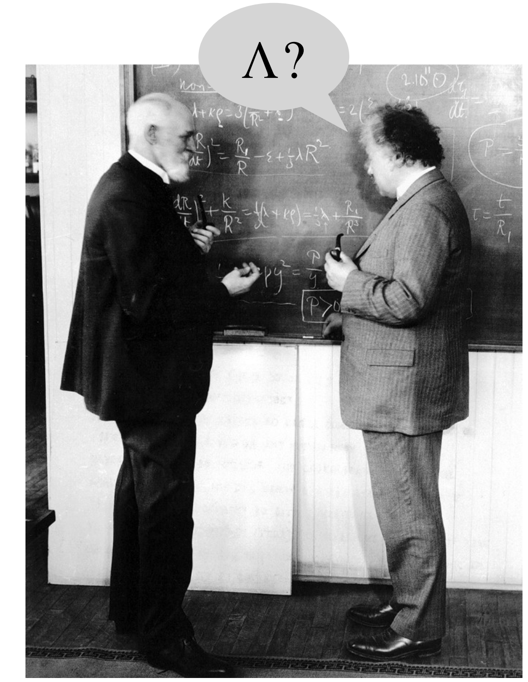
UV-shadows of $\hbar$

Primitives: UV-divergent in $\hbar$



IR consistent completion outside the Swampland

Dark side of $\hbar$: scaling dimension



QFT predicts a a bare energy density $\rho_0 = \hbar c / l_p^4$:

$$\Lambda_0 = 8\pi G c^{-4} \rho_0 \sim \frac{1}{\hbar}.$$

Λ_0 is a primitive by UV-divergence in $\hbar \sim l_p^2$.

IR-consistency with classical spacetime (G, c) requires a coupling $\alpha_p \propto \hbar$.

Scaling dimension of the phase space is 2, not 3: van Putten CJPh, 91, 377 (2024)

$A_p = 4\pi R_H^2 / l_p^2$ to the Hubble scale $R_H = c/H$,

$$\Lambda \equiv \alpha_p \Lambda_0 = 2H^2/c^2.$$

Dynamical Λ consistent with the swampland conjectures

… in the shadow of $\hbar$

Sub-Hubble scale variations: Einstein equations.

Super-Hubble scale variations $(k \sim 0)$: a global gauge $\Phi_0 = \Phi_0\left[\mathscr{H}\right]$, i.e., a normalized propagator:

$$e^{i\left(\Phi - \Phi_0\right)} = \frac{e^{i\Phi}}{e^{i\Phi_0}}.$$

No asymptotically flat Minkowski spacetime in FLRW:

$$\Phi_0\left[\mathscr{H}\right] = \int 2\Lambda\sqrt{-g}\,d^4x,$$

where $\Lambda = \lambda R$ - nonlocal by the Friedmann scale factor a.

van Putten, 2020, MNRAS, 491, L6

… the trace of the Schouten tensor

Jan A. Schouten
(1883-1971)

$\Lambda = \lambda R$ with $\lambda \simeq 1/6$:

$$\Lambda = \frac{1}{6}R \equiv J.$$

Supported by

- Confrontation with data (H_0, BAO, age): $\lambda \simeq 1/6$ within 1%
- Entropic forcing with $a_H = \frac{1-q}{2}a_{dS}$, $a_{dS} = cH$: $\lambda = 1/6$

It follows that

$$\Lambda = (1-q)H^2,$$

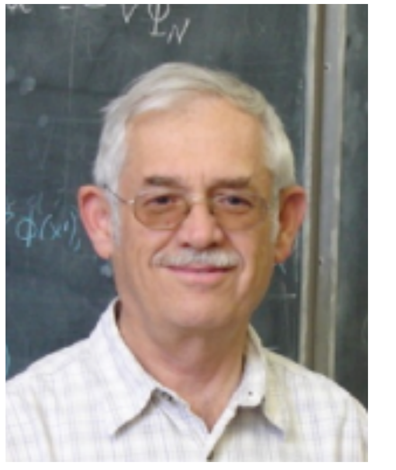
where q is the deceleration parameter.

van Putten, 2015, MNRAS, 450, L48;
2020, MNRAS 491, L6;
2021, PLB, 823, 136737

… heat from broken time-translation symmetry

Scaling dim 2 of phase space by horizon area A_H

(Bekenstein 1981, 't Hooft 1991)



J. Bekenstein
(1947-2015)

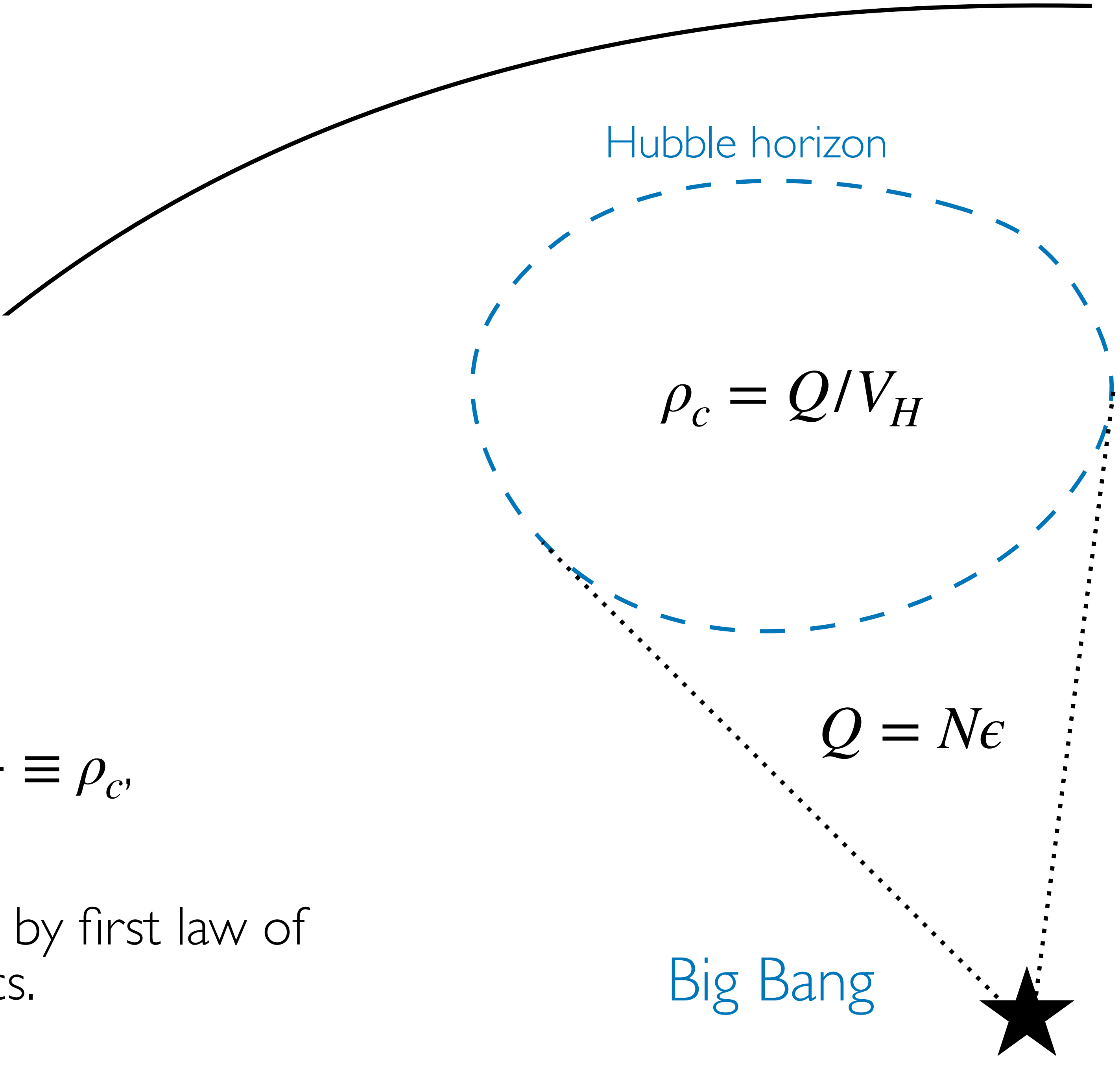
Heisenberg:

$$\epsilon = \lambda H \hbar,$$

whereby

$$\frac{Q}{V_H} = \frac{3c^3}{2A_H} \equiv \rho_c,$$

$\lambda = 1/2\pi$ fixed by first law of thermodynamics.



$N = A_H/4l_p^2$ by Hubble area A_H in Planck units

van Putten MNRAS, 491, L6 (2020); JHEAP, 45, 194 (2025); arXiv:2408.13121

Analytic solution to Hubble expansion

$\Lambda = (1-q)H^2$:

$$\Omega_\Lambda = \frac{1}{3}\left(1-q\right).$$

This enters the first Friedmann equation:

$$\Omega_M + \Omega_r + \Omega_K + \Omega_\Lambda = 1$$

— The Hamiltonian energy constraint is now second order in time…

Analytic solution to Hubble expansion

$\Lambda = (1-q)H^2$:

$\gamma = \frac{6}{g} - 1$: $$H(z) = \frac{\sqrt{1+A(z)}}{(1+z)^{\frac{\gamma+1}{2}}}$$

$$A(z) = A_0(z) + A_r(z) + A_M(z) + A_K(z),\ Z_n = (1+z)^n - 1,\ A_0 = \frac{3\Omega_{\Lambda,0}}{3-2g} Z_{1+\gamma}(z)$$

$$A_r(z) = \Omega_{r,0} Z_{5+\gamma}(z),\ A_M(z) = \frac{6}{6-g} Z_{4+\gamma}(z),\ A_K(z) = \frac{3}{3-g} Z_{3+\gamma}(z).$$

$g = 1$: $$H(z) = H_0 \frac{\sqrt{1 + \frac{6}{5}\Omega_{M,0} Z_5(z) + \Omega_{r,0} Z_6(z) + \frac{3}{2}\Omega_{K,0} Z_4(z)}}{1+z}.$$

Hubble constant H_0

$$H(z) = H_0 \frac{\sqrt{1 + \frac{6}{5}\Omega_{M,0} Z_5(z) + \Omega_{r,0} Z_6(z)}}{1+z}.$$

van Putten 2021 PLB 823 136737

O'Colgain, van Putten & Yavartanoo 2019 PLB 793 121

Subject to Planck BAO data:

$$H_0 \simeq \sqrt{\frac{6}{5}} H_0^{\rm Planck} \simeq 73\,{\rm km\,s^{-1}Mpc^{-1}}.$$

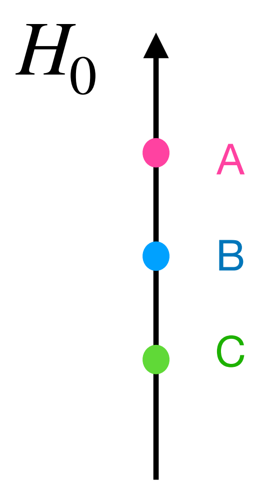
van Putten 2024 arXiv:2403.10865;

2024, PoS 463 arXiv:2408.13121

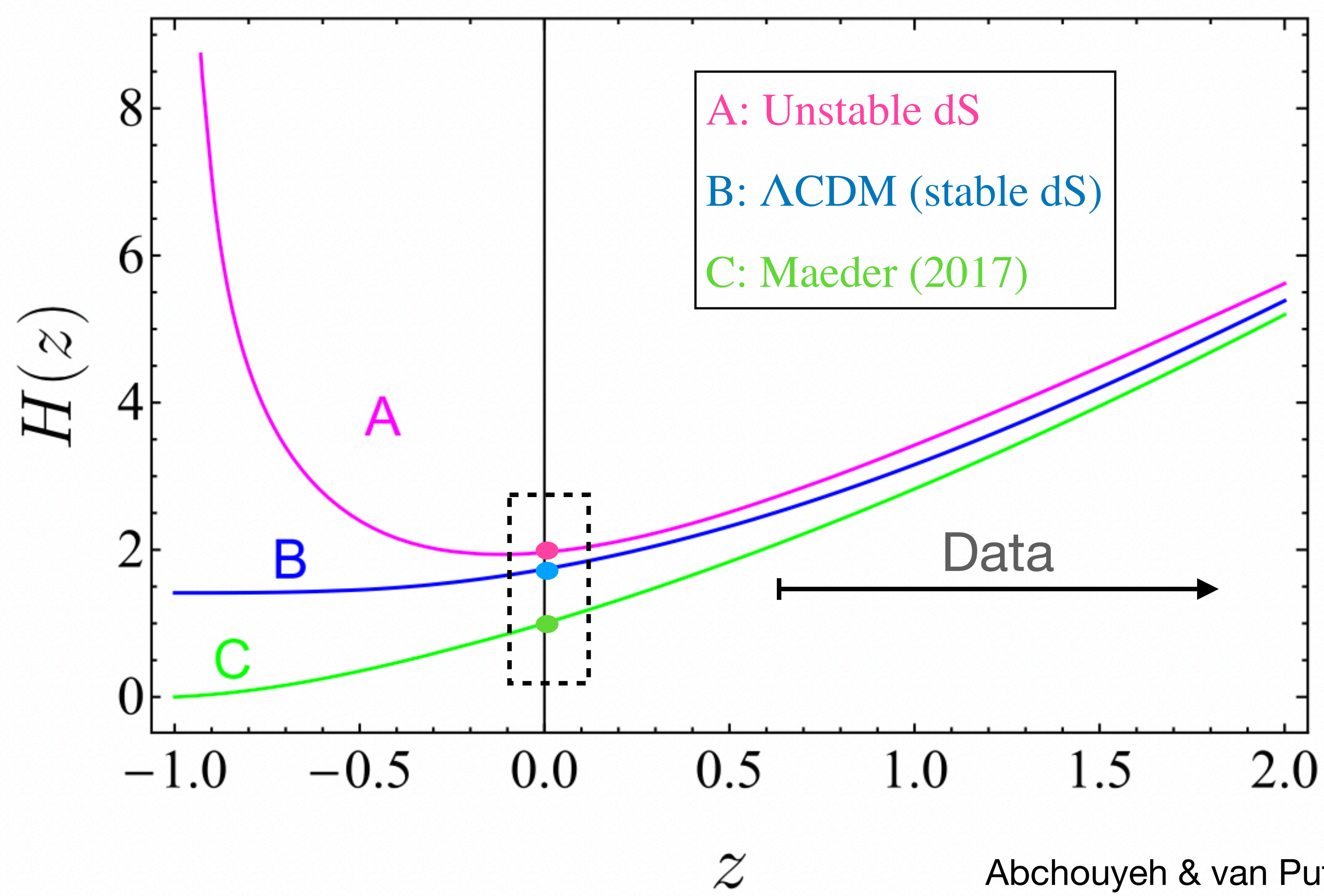
Larger H_0 from dynamical DE

ΛCDM assumes stable dS,
unstable dS favors higher H_0

van Putten (2017)
O'Colgain, van Putten & Yavartano (2019)



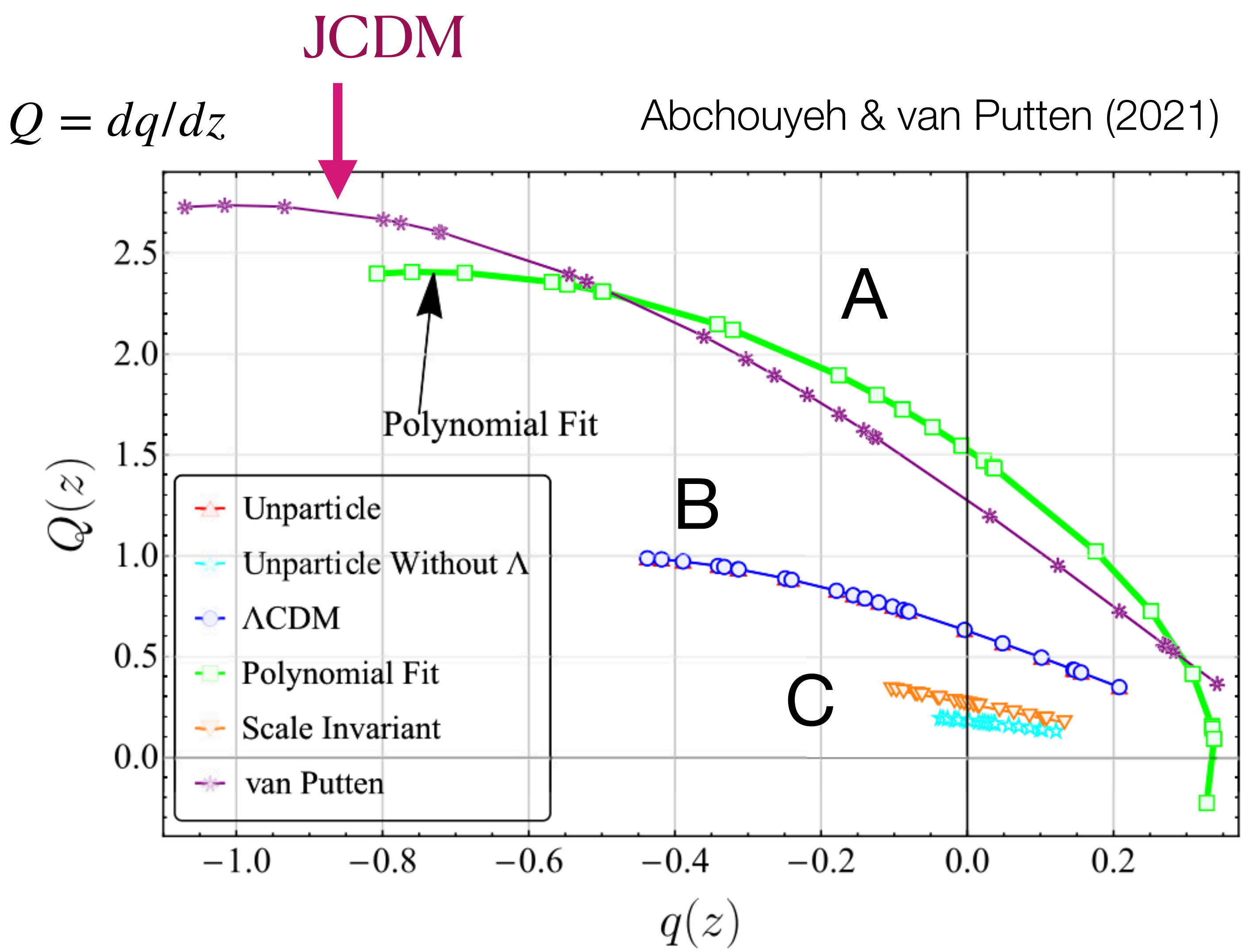
H_0 is the extrapolation of data $z > 0$ to $z = 0$

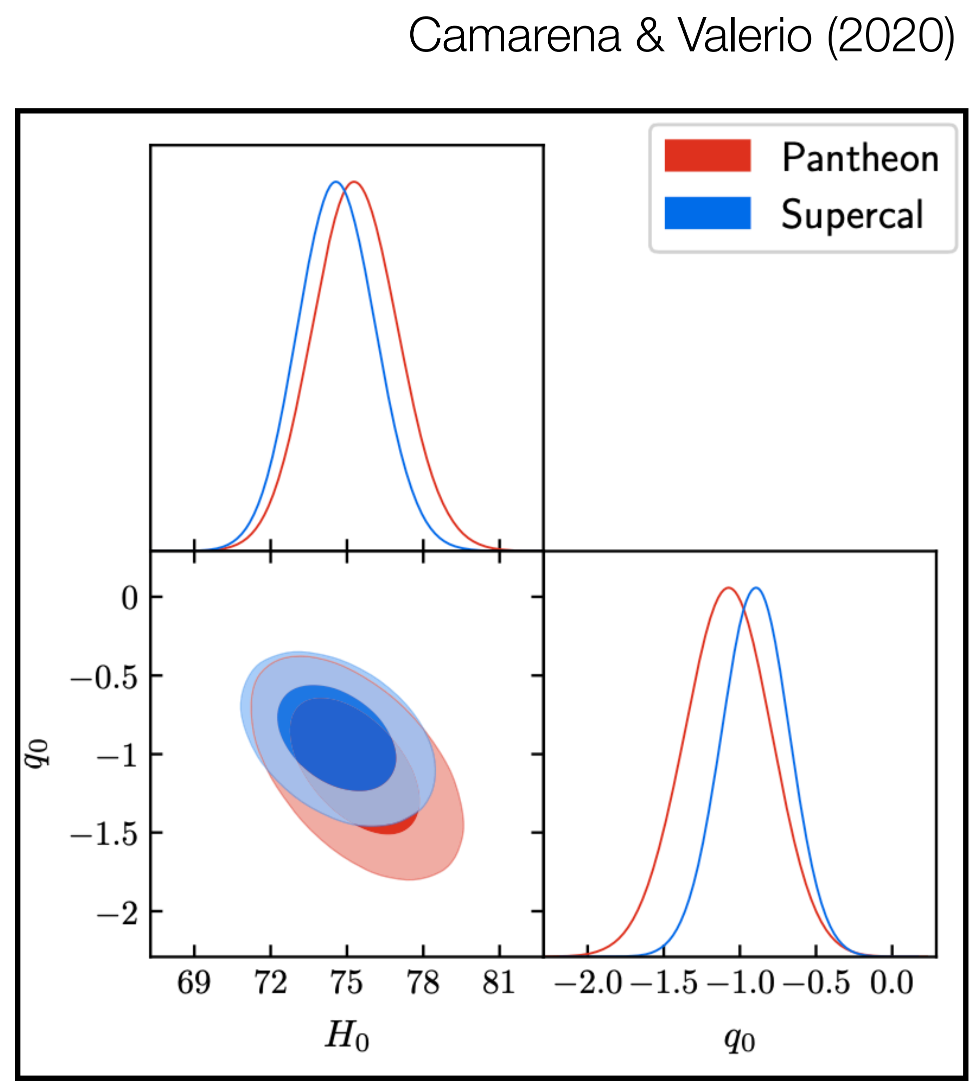


Abchouyeh & van Putten (2021)

H_0 estimates are sensitive to future (in)stability of de Sitter space

… confrontation with data





$$q_0 = 2q_{0,\Lambda\mathrm{CDM}} \simeq -1$$

$$q_0 = -1.08 \pm 0.29$$

Tension free solution consistent with *Planck* BAO

Bootstrapping *Planck*

Consistency with model-independent results

	Planck/CMB[a]	J/Λ−scaling/BAO[b]	JCDM/LDL[c]	Cubic/LDL[d]	SH0ES/LDL[e]
H_0	67.36 ± 0.54	73.79 ± 0.59	74.9 ± 2.60	74.44 ± 4.9	73.04 ± 1.04
q_0	-0.5273 ± 0.011	-1.21 ± 0.014	-1.18 ± 0.084	-1.17 ± 0.34	-1.08 ± 0.29
$\Omega_{M,0}$	0.3153 ± 0.0073	0.2628 ± 0.0061	0.2719 ± 0.028	–	–
S_8	0.832 ± 0.013	0.756 ± 0.012			
T_U	13.797 ± 0.023	13.44 ± 0.022			

Table 1
Estimates of (H_0, q_0, Q_0, ω_m) with 1σ Uncertainties by Nonlinear Model Regression Applied to the Coefficients of the Truncated Taylor Series (16) of Cubic and Quartic Order, and to (H_0, ω_m) in (13) from $\Lambda = \omega_0^2$ and ΛCDM

model	H_0	q_0	Q_0	ω_m	$h'(0)$
Cubic	74.4 ± 4.9	-1.17 ± 0.34	2.49 ± 0.55	$\cdots$	-0.17
Quartic	74.5 ± 7.3	-1.18 ± 0.67	2.54 ± 1.99		-0.18
$\Lambda = \omega_0^2$	74.9 ± 2.6	-1.18 ± 0.084	2.37 ± 0.073	0.2719 ± 0.028	-0.18
ΛCDM	66.8 ± 1.9	-0.50 ± 0.060	1.00 ± 0.030	0.3330 ± 0.040	0.5

Note. H_0 is expressed in units of km s^{-1} Mpc^{-1}.

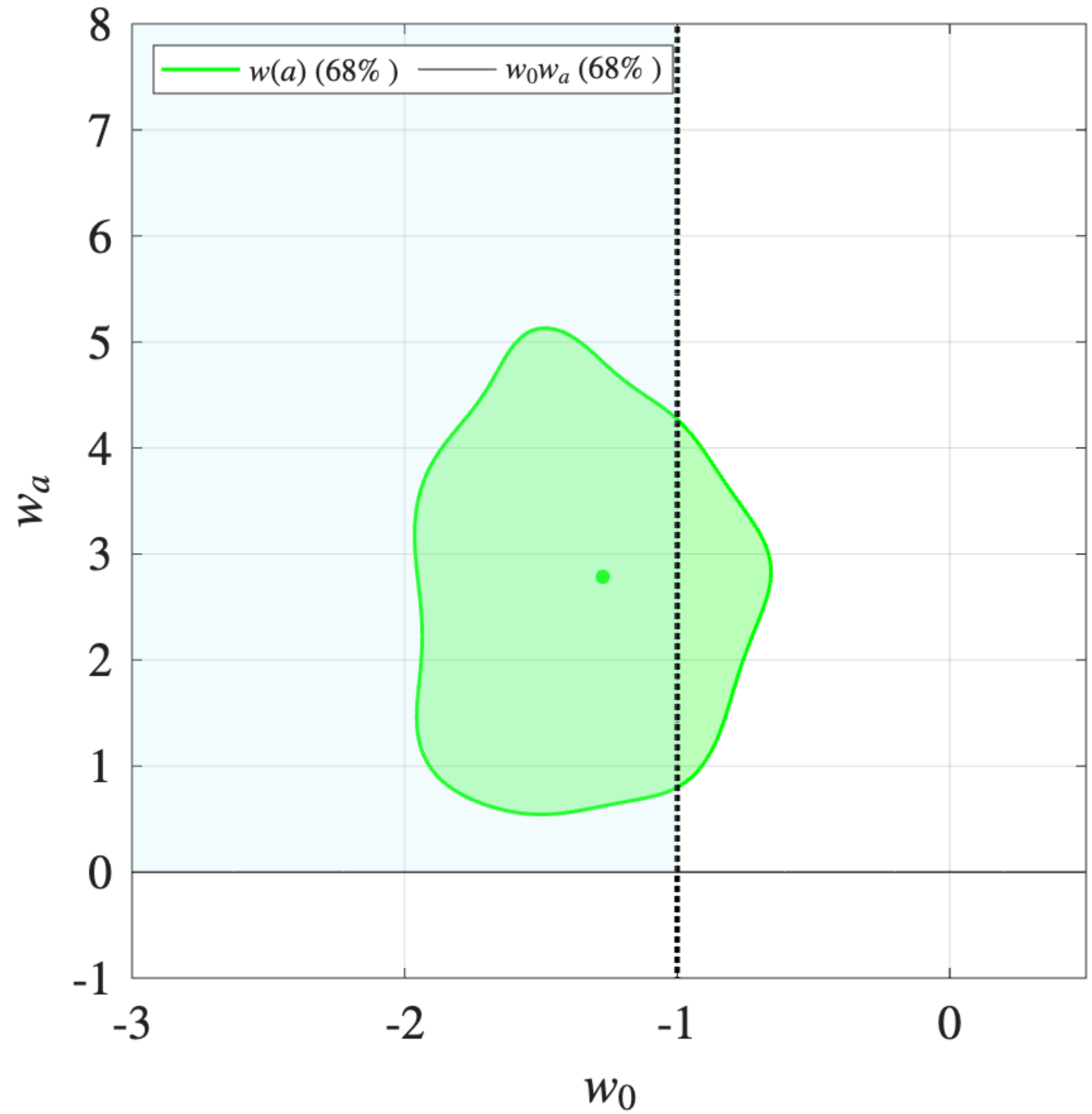
van Putten, 2025, JHEAP 45 194

$q_0 < q_0^{\Lambda\mathrm{CDM}}$: *increasing DE*

LDL in the $w_0 w_a$-plane

($H(z)$-data of Farooq et al. 2017)

LDL in 2nd quadrant of the $w_0 w_a$-plane



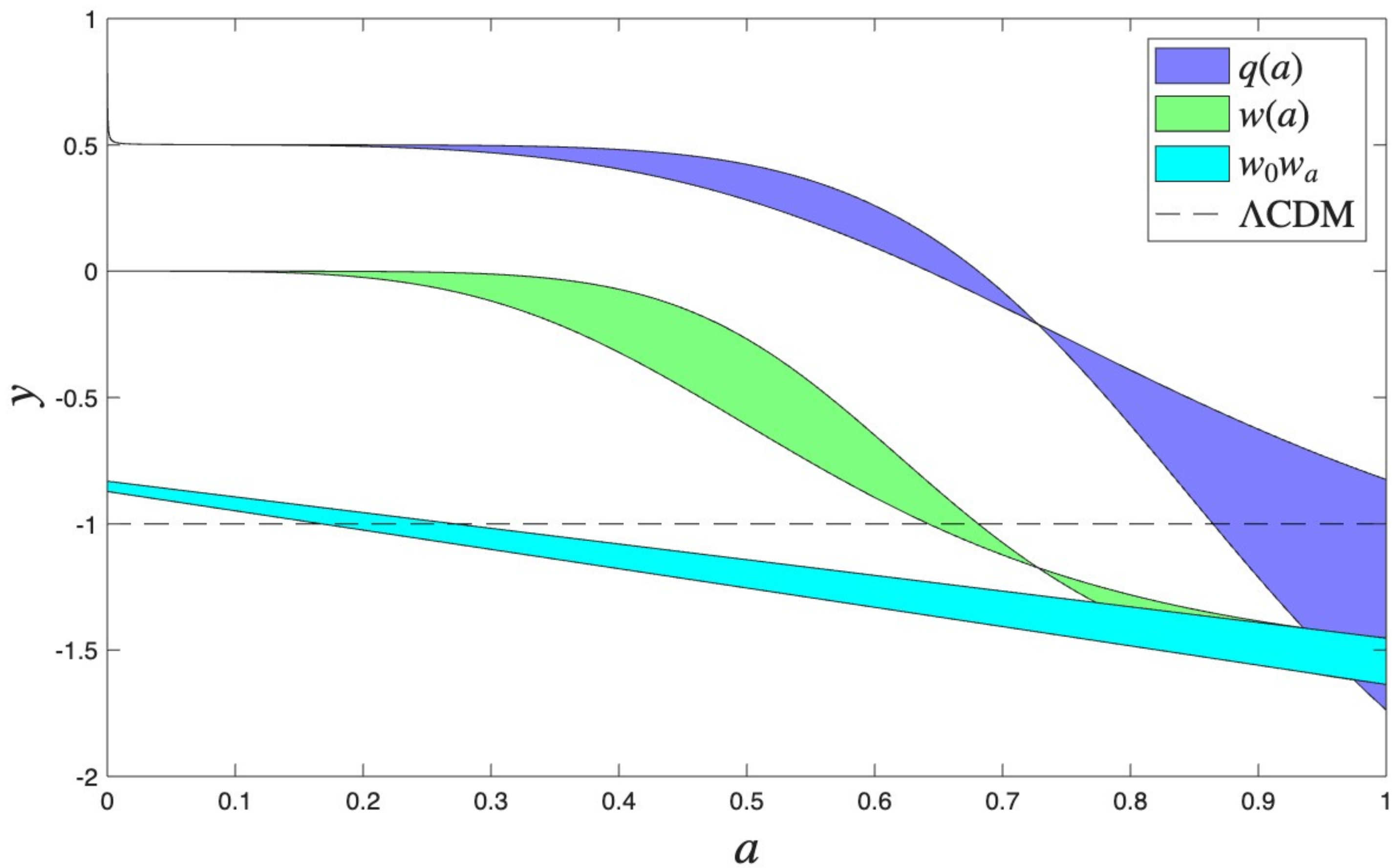
$$w_0 = \frac{2q_0 - 1}{3\Omega_{DE}}$$

$$w_0 < -1 \Leftrightarrow q_0 < q_0^\Lambda \simeq -0.5$$

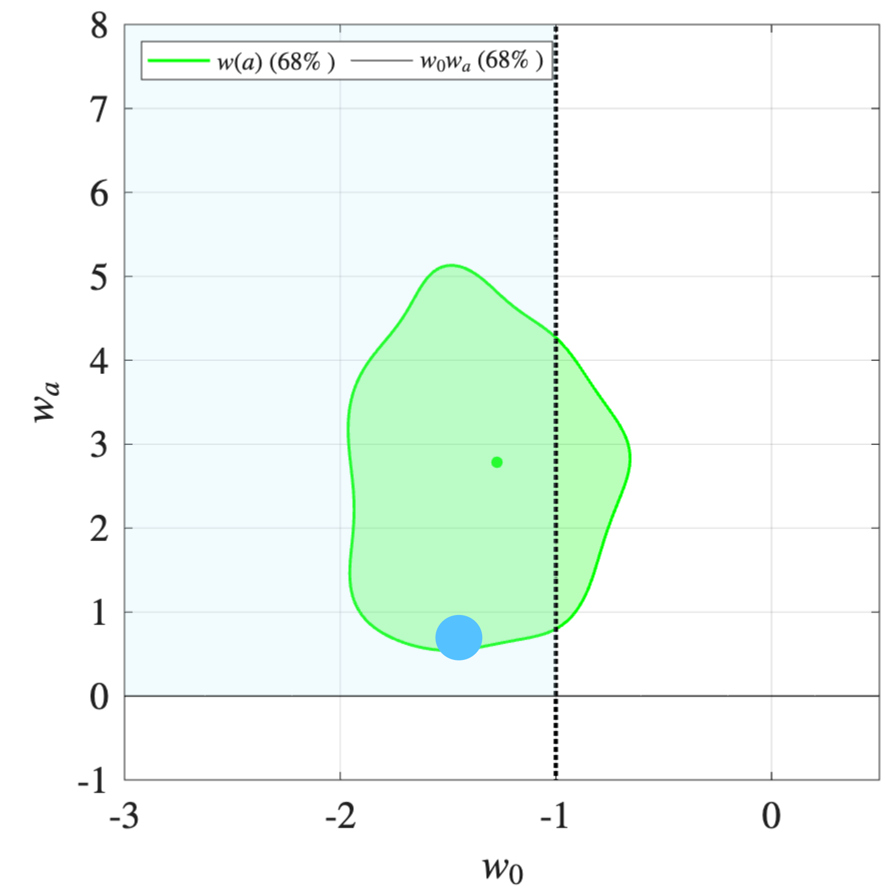
Abchouyeh & van Putten
(under review)

LDL favors a dynamic DE - ***increasing*** *with time*

Extrapolating late-time *J*CDM

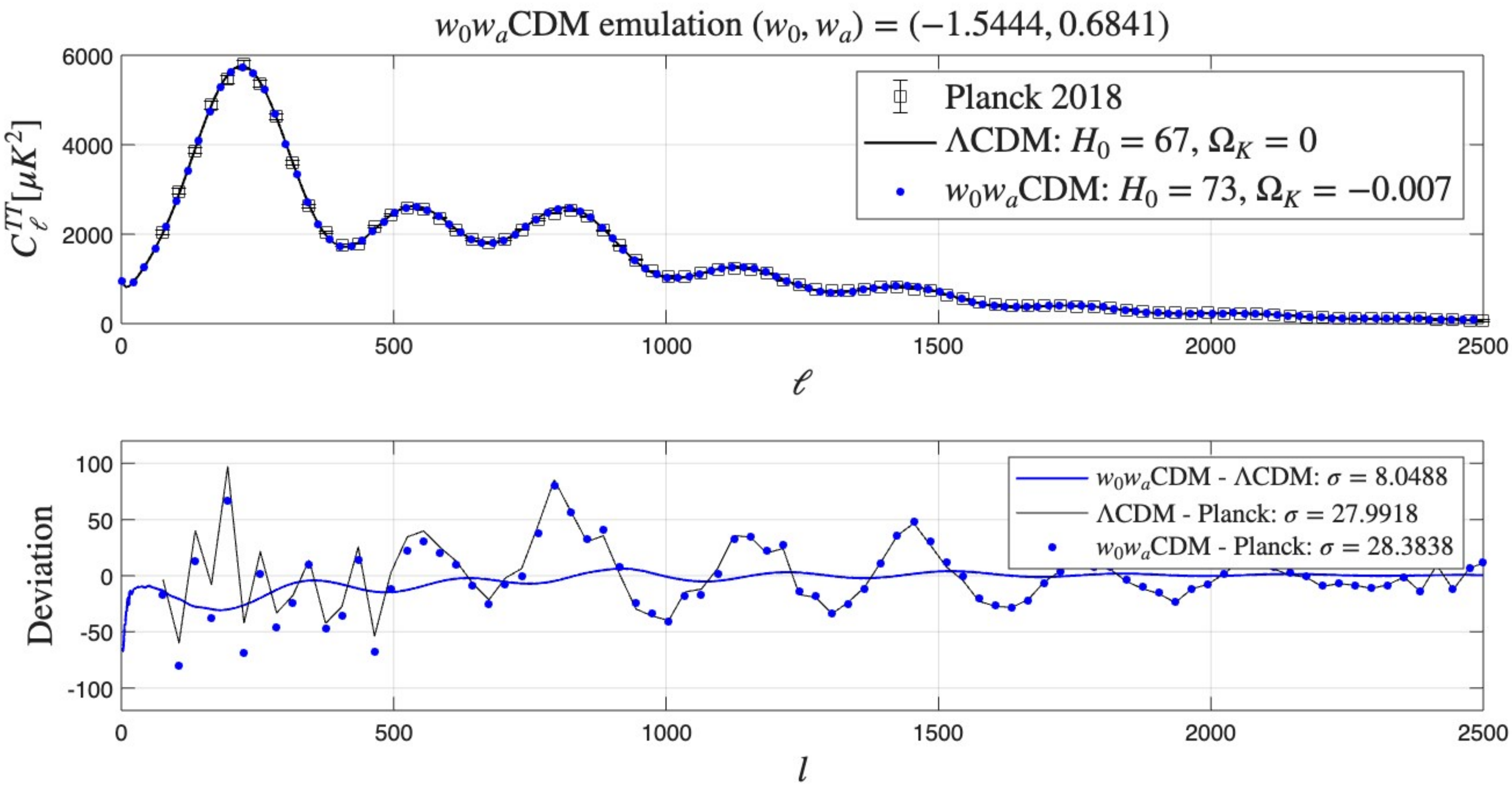


LDL in 2[nd] quadrant of the $w_0 w_a$-plane



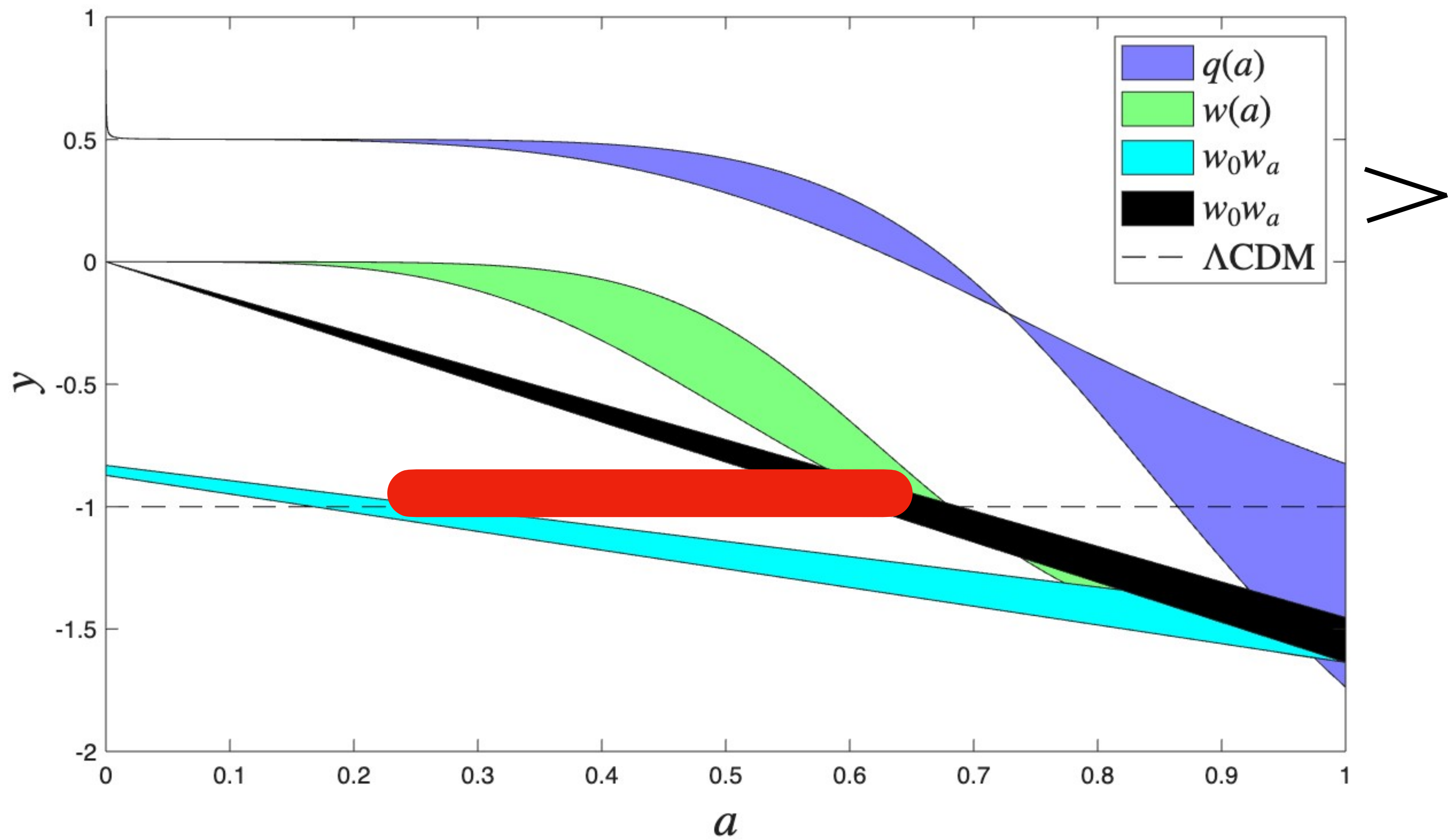
Second quadrant of the $w_0 w_a$-plane: increasing DE

$w_0 w_a$CDM fit by CAMB



Key is w_0 (substantial degeneracy with respect to w_a)

Phantom crossing?

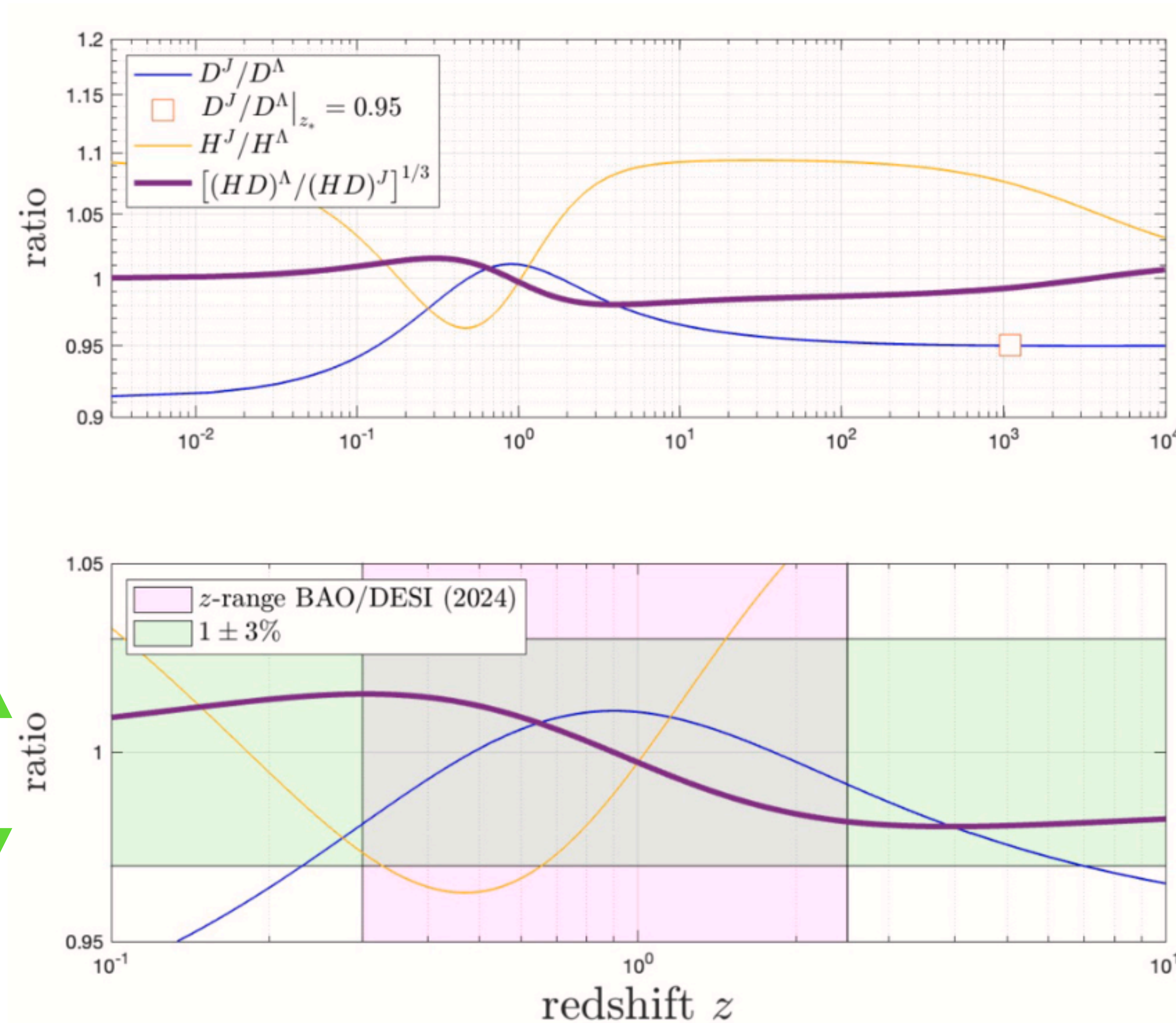


CAMB fits to Planck 2018
(nearly indistinguishable)

Expected phantom crossing $z \in [0.25, 0.65]$

DESI DR1 $(0.3 \lesssim z \lesssim 2.3)$

DESI

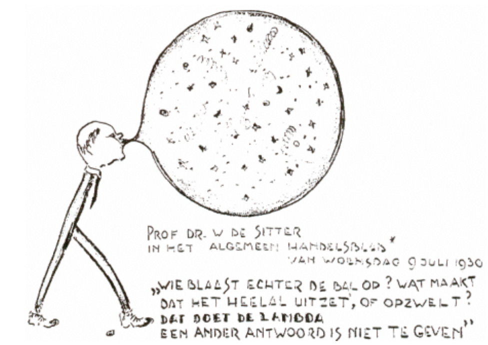


*J*CDM

R: distance ratio of angle-averaged distance to the sound horizon at the baryon drag epoch.

van Putten, 2025, JHEAP 45 194

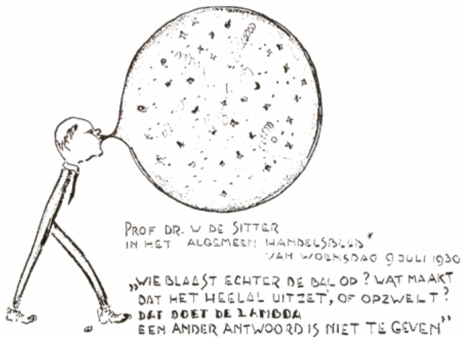
Conclusions



In the shadows of $\hbar$, causality in IR-consistency gives DDE $\Lambda \sim H^2$ from scaling dim 2 of cosmological spacetime.

$\Lambda \sim H^2$ resolves Zel'dovich' paradox of a UV-divergent Λ_0.

Conclusions



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$J = (1-q)H^2$ derived from global gauge by Hubble horizon.

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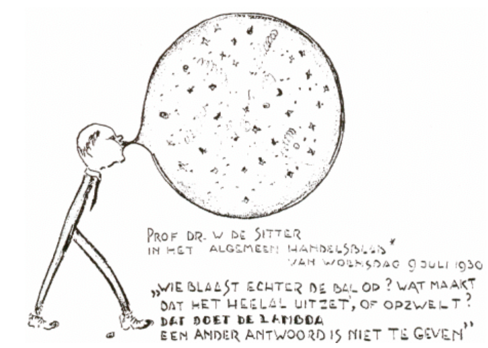

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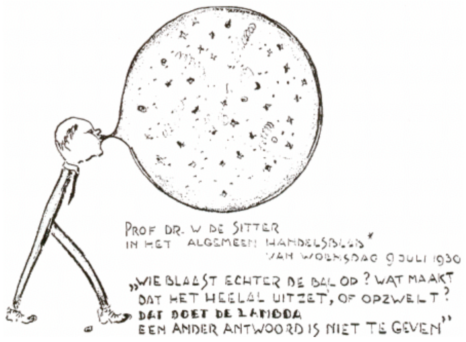
$J = (1-q)H^2$ derived from global gauge by Hubble horizon:

- Tension-free fit with LDL satisfying $H_0 = \sqrt{\frac{6}{5}} H_0^\Lambda, \Omega_{M,0} = \frac{5}{6}\Omega_{M,0}^\Lambda$
- Consistent with the Planck BAO constraint on $\Omega_{M,0}h^2$
- Likely phantom crossing $z \in [0.25, 0.65]$
- Consistent with DESI constraints on R.

Conclusions



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- Consistent with DESI constraints on R.

Outlook:

Λ appears to be of *geometric origin*, potentially involving additional cosmographic terms j, s, etc. when considered over the full expansion history of the Universe.