Alleviating H_0-tension in T-dual Friedmann cosmologies

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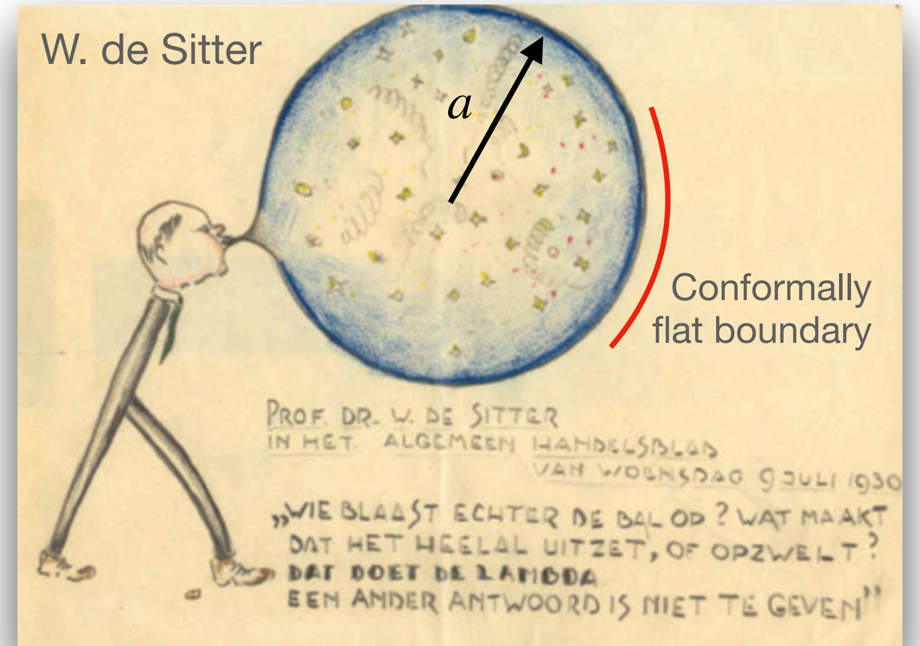
References:

van Putten, **2023**, submitted
van Putten, **2021**, PLB, 823, 136737
Abchouyeh & van Putten, **2021**, Phys. Rev. D, 104, 083511
O'Colgain, van Putten, Yavartanoo, **2019**, PLB, 793, 126;
van Putten, **2020**, MNRAS, 491, L6
van Putten, **2017**, ApJ, 837, 22; 848, L28;
van Putten, **2015** MNRAS 450 L48

The conformally flat Universe



"Who, however, inflates the balloon? What causes the Universe to expand or swell?

Conformally flat FLRW-cosmologies

$$ds^2 = g_{ab}dx^a dx^b = a^2 \eta_{ab} dx^a dx^b.$$

Minkowski metric $\eta_{ab} = -d\tau^2 + dx^2 + y^2 + dz^2.$

Expansion by *global stretching* is *not* a dynamical mode of general relativity.

Tension between FLRW and GR

GR assumes asymptotically flat Minkowski spacetime, i.e., a **frozen** scale $a = a_0$ by some constant a_0. This allows a time-like Killing vector at large distances. In reality, this is not so.

FLRW cosmologies evolve by a ***running*** *conformal scale* a:

- Big Bang breaks global time-translation invariance: $a(t)$ is **unfrozen** at a finite temperature $k_B T \sim H\hbar$.

- GR, and hence Newtonian gravitation, is limited to accelerations **above** $a_{dS} = cH$, i.e., in galaxy rotation curves within the transition radius

$$r_t = \sqrt{R_H R_G} \simeq 4.6\,\text{kpc}\left(\frac{M}{10^{11}M_\odot}\right)^{1/2}$$

for a galaxy of mass M.

Metric contribution J

Equivalently, FLRW in 3+1

$$ds^2 = a^2\eta_{ab}dx^a dx^b = -dt^2 + a^2\left(dx^2 + dy^2 + dz^2\right)$$

J. A. Schouten, 1938–39

Conformally invariant wave equation $\square\varphi - J\varphi = 0$,

$J \equiv \mathrm{tr}P$ in $R_{ab} = 2P_{ab} + Jg_{ab}$ (Schouten).

J in conformal scaling by a:

$$J \equiv \frac{1}{6}R = (1-q)\,H^2 = \frac{1}{2}a^{-2}\frac{d^2}{dt^2}a^2.$$

By common closure density of cosmological and black hole spacetimes based on the Bekenstein bound and the uncertainty principle, anticipate a first-principle origin in J…

Infrared origin of J

Propagator $e^{i\Phi}$ with $\Phi = \hbar^{-1}\int \mathscr{L}\sqrt{-g}d^4x.$

e.g. Wald 1984

Super-Hubble scale variations require a global phase reference $\Phi_0 = \Phi_0\left[\mathscr{H}\right]$ derived dynamically from the Hubble horizon $\mathscr{H}$, given the absence of an asymptotically flat Minkowski spacetime in conformally flat FLRW.

The result is a *normalized propagator*

$$e^{i(\Phi-\Phi_0)} = \frac{e^{i\Phi}}{e^{i\Phi_0}} \text{ with } \Phi_0\left[\mathscr{H}\right] = \int 2\Lambda\sqrt{-g}d^4x.$$

Super-Hubble scale variations $\left(k \sim 0\right)$ hereby assume an equivalent density:

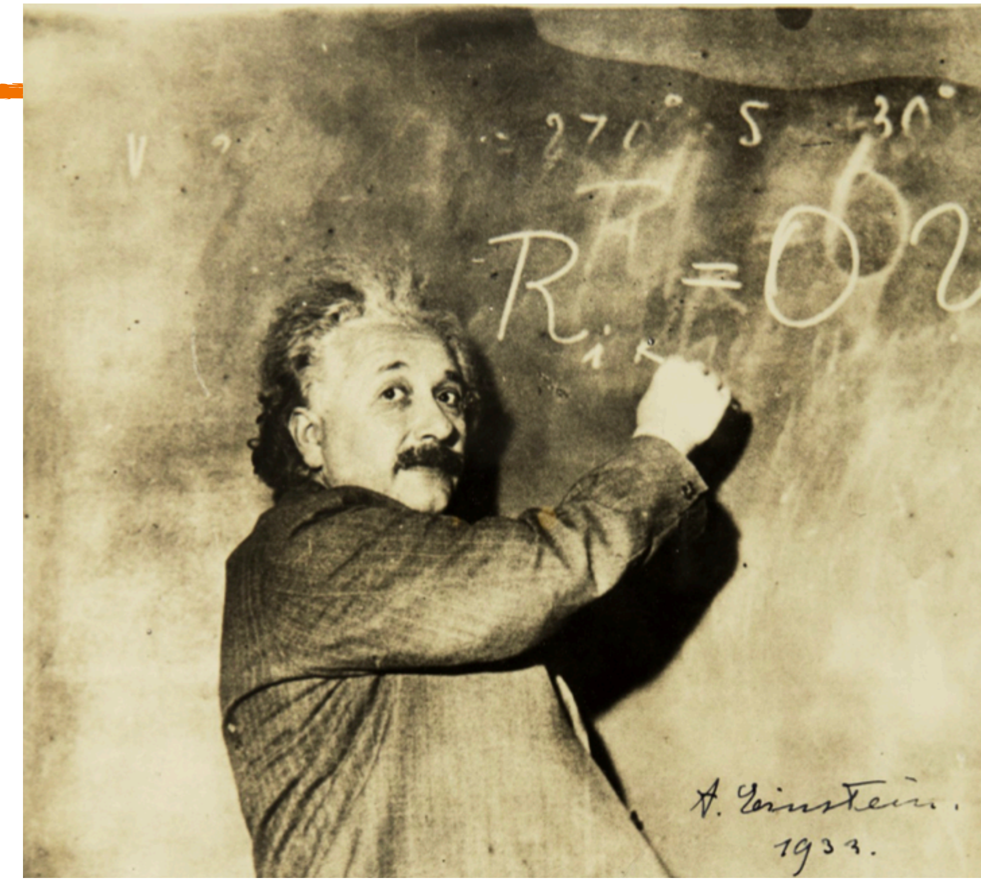
$$\Lambda = \lambda R \equiv gJ.$$

Confrontation with observations (Hubble data $H(z)$, age of the Universe, BAO):

$$g \simeq 0.9964.$$

van Putten, 2020, MNRAS, 491, L6; 2021 PLB 823, 136737
Corfu 2023 "Tensions in Cosmology"

Dark cosmology: $R_{ab} = ?$



Consider a stress-energy tensor of dark matter with unsigned phantom pressure p

$$T_{ab} = \left(\rho + p\right) u_a u_b + p g_{ab},$$
$$\rho = \rho_0 \left(1 + z\right)^3.$$

Couple T_{ab} to the Schouten tensor

$$P_{ab} = 4\pi \left(T_{ab} - \frac{1}{2} g_{ab} T \right).$$

Dynamical equations of motion

$$R_{ab} - \frac{1}{3} g_{ab} R = 8\pi T_{ab}.$$

de Sitter $R = 4\Lambda$ is a special case with $J = \dfrac{2}{3}\Lambda$, i.e., $H = \sqrt{\Lambda/3}$.

ΛCDM is a special case, fixing $J \equiv \Lambda$.

Evolution with T-duality

Dynamical equations of motion

$$\mathscr{R}_{ab} \equiv R_{ab} - \frac{1}{3} g_{ab} R = 8\pi T_{ab}.$$

Expand in curvature operator $D(u) \equiv \ddot{u}u/\dot{u}^2$ applied to a and $\kappa = c^2/a$:

$$D(\kappa) = 3\Omega_M$$

$$D(a) = -3\Omega_p.$$

$$\boxed{\begin{aligned} \Omega_\Lambda &= \frac{1}{3}\left(1 - q\right) \\ \Omega_M &= \frac{1}{3}\left(2 + q\right) \\ w &= \frac{2q - 1}{1 - q} \end{aligned}}$$

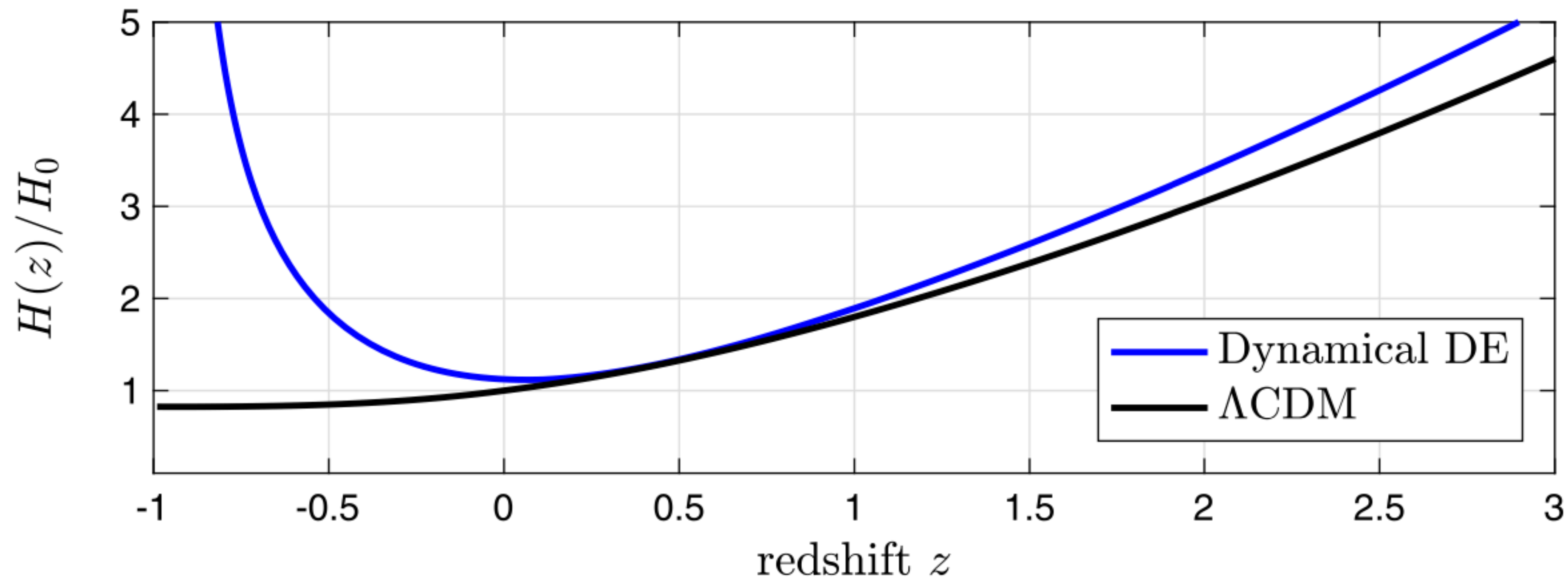
T-duality: $D(a) + D(\kappa) = 2$

van Putten 2021 PLB 823 136737

Hubble expansion

$\mathscr{R}_{00} = 8\pi T_{00}$:

$$H(z) = H_0 \frac{\sqrt{1 + \frac{6}{5}\Omega_{M,0}\left[(1+z)^5 - 1\right]}}{1+z}$$

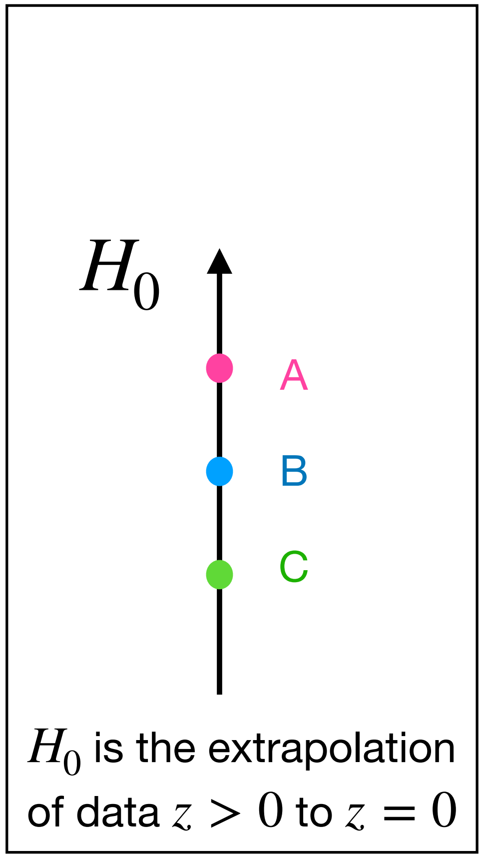


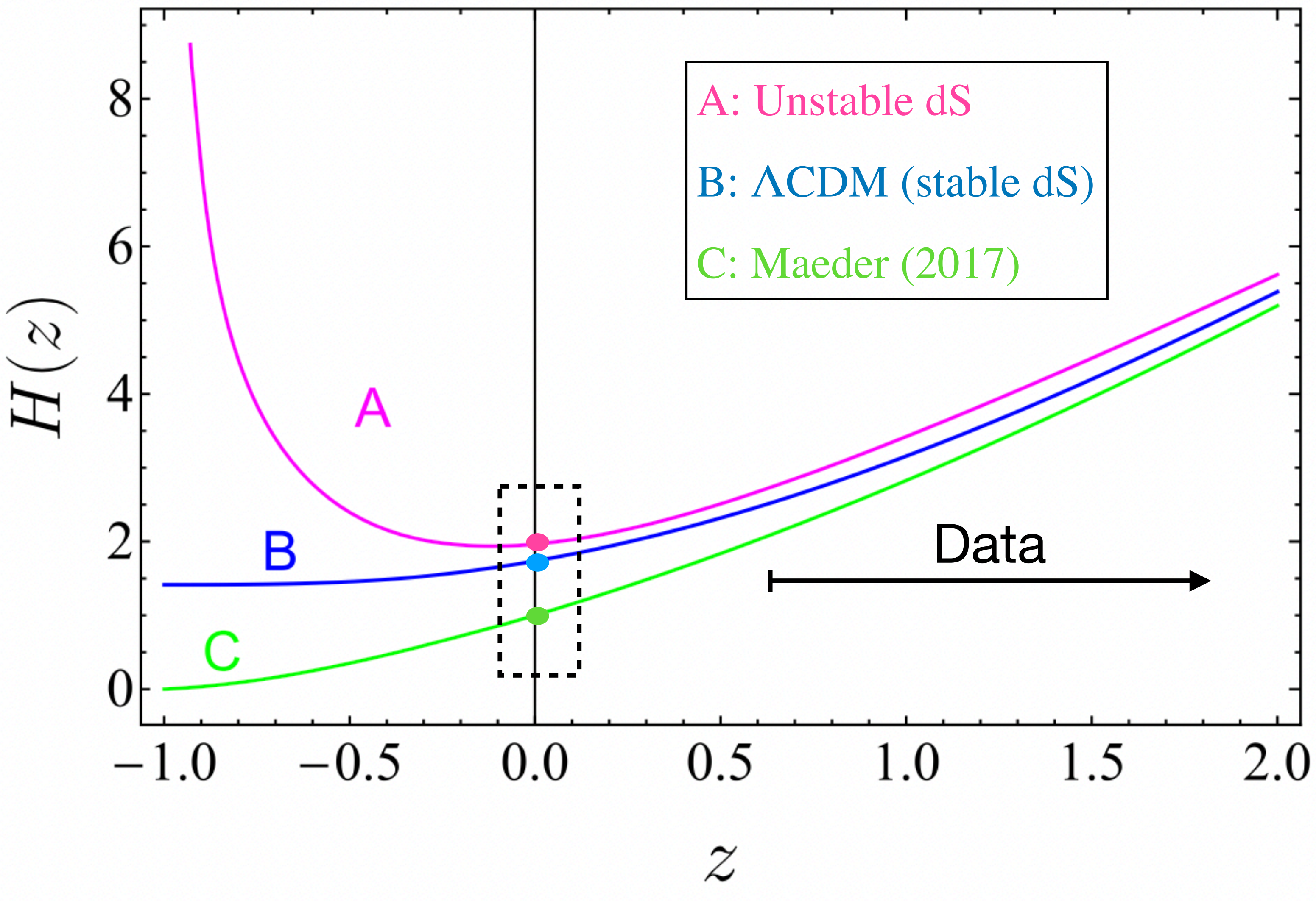
Future is unstable dS with turning point z_* in $H(z)$ about zero

$$z_* = \left(\frac{5 - 6\Omega_{M,0}}{9\Omega_{M,0}}\right)^{\frac{1}{5}} - 1 \gtrsim 0 \quad \left(\Omega_{M,0} \lesssim 1/3\right)$$

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

H_0-tension alleviated by unstable de Sitter

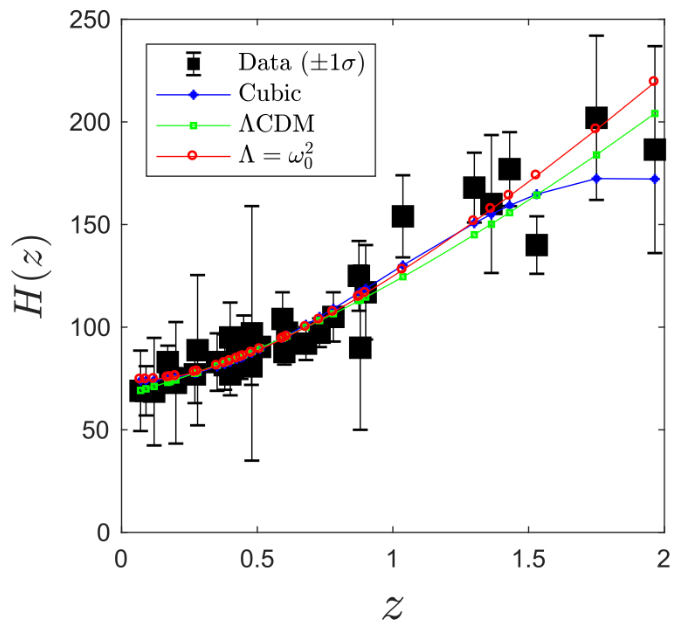


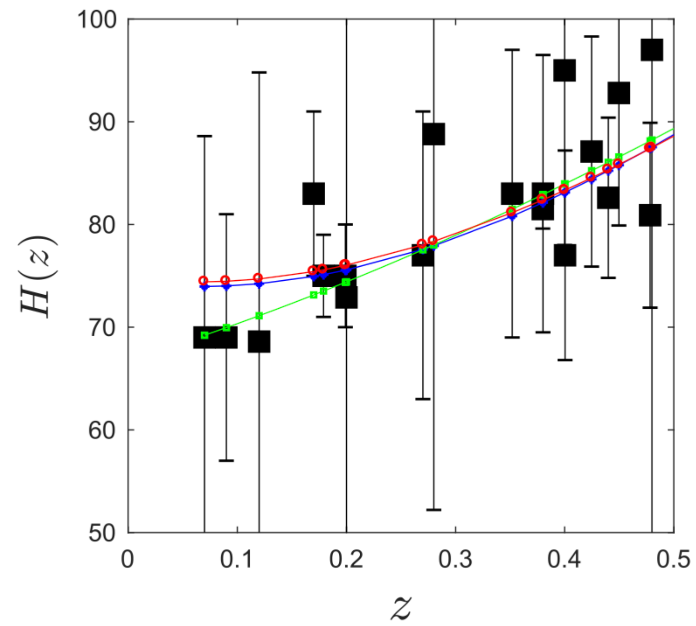


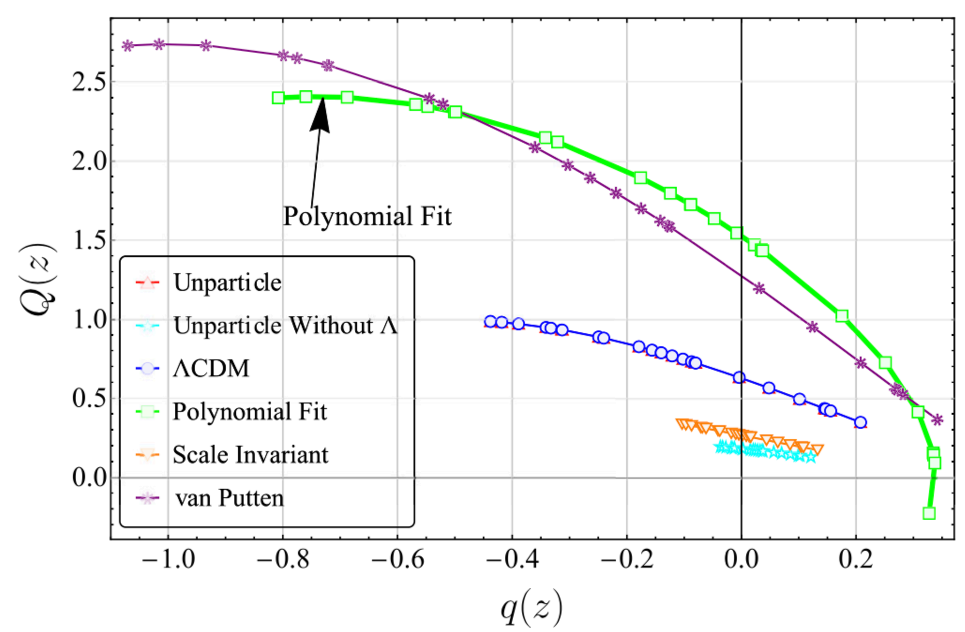
Abchouyeh & van Putten, **2021**, Phys. Rev. D, 104, 083511
O'Colgain, van Putten, Yavartanoo, **2019**, PLB, 793, 126

Confrontation with data

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







van Putten 2017 ApJ 848 L28
Abchouyeh & van Putten 2021 PRD 104, 083511

Model fit:

$$H_0 = 74.9 \pm 2.6 \,\text{km s}^{-1}\,\text{Mpc}^{-1}$$

$$q_0 = -1.18 \pm 0.084$$

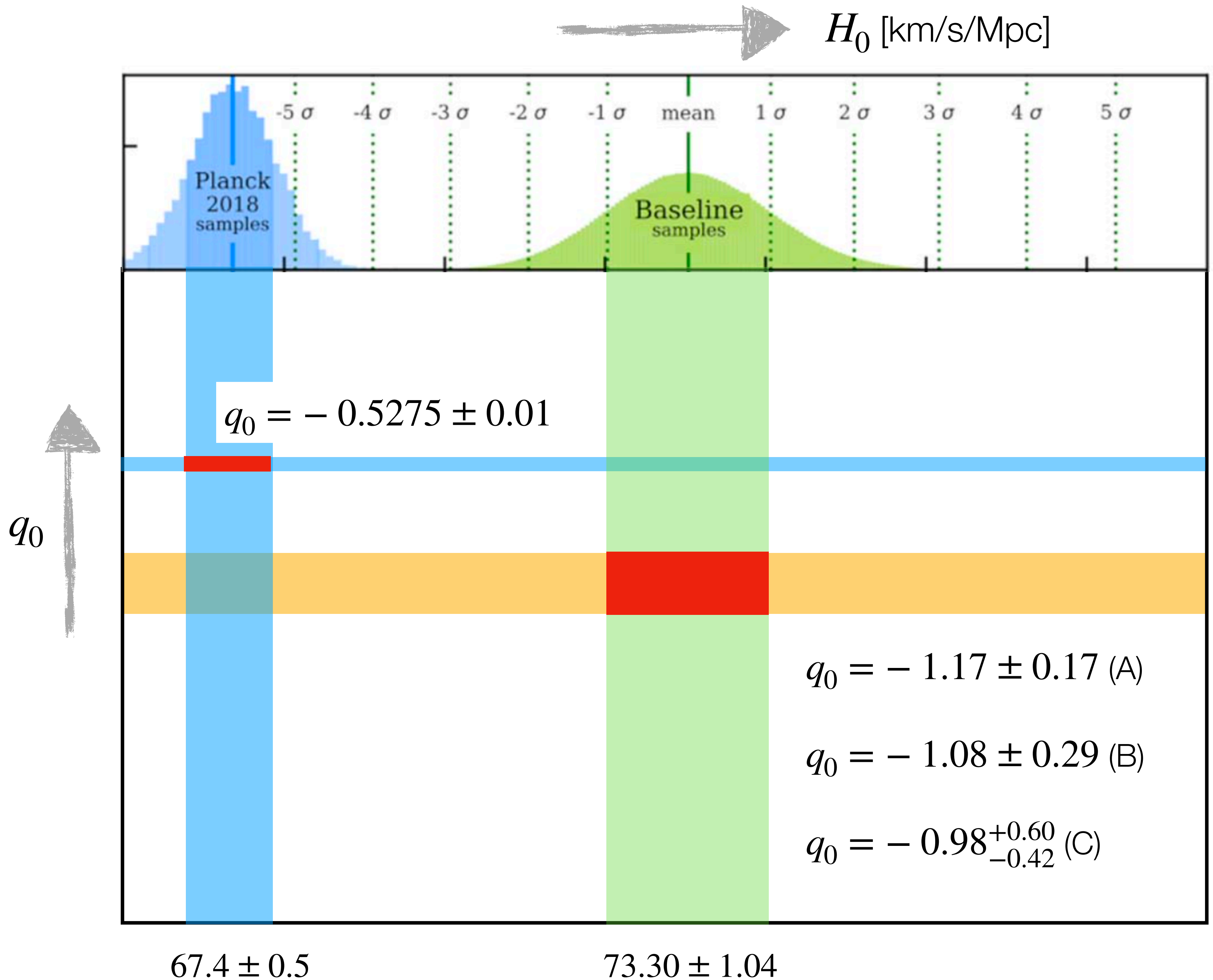
$$\Omega_{M,0} = 0.2719 \pm 0.028$$

Cubic fit

$$H_0 = 74.4 \pm 4.9 \,\text{km s}^{-1}\,\text{Mpc}^{-1}$$
$$q_0 = -1.17 \pm 0.17$$

- Satisfies $\Omega_{M,0} h^2 = 0.139 \pm 0.017$ (Dinda, B.R., 2023, arXiv:2311.13498v1)
- Below *Planck*, reducing $S_8 = \sigma_8 \sqrt{\Omega_{M,0}/0.3}$.

$H_0 q_0$-tension



Riess et al. 2022

Planck 2018

Fits to data

A. Cubic fit to $H(z)$ of Farooq et al. 2017 (van Putten 2017)
B. Local Distance Ladder (Camarena & Valerio 2020)
C. Baryonic Tully-Fisher relation-Milgrom (van Putten, 2023, subm.)

Total tension 5.8σ

Conclusions and outlook

Conformally flat FLRW-cosmologies carry a **dark sector** in $R_{ab} = 2P_{ab} + Jg_{ab}$:

- J *is* a **dark energy** background of infrared metric fluctuations due to the Big Bang.
- J equivalent to **de Sitter heat** similar to black hole spacetimes.
- P_{ab} couples to non-Newtonian **dark matter** with unsigned phantom pressure.

Gravitation with **T-duality** in a:

$$\mathscr{R}_{ab} = R_{ab} - \frac{1}{3}g_{ab}R = 8\pi T_{ab}.$$

Existing general relativity:

- $\mathscr{R} = 0$ preserves conventional BH solutions, orbital precession…
- Newton's law for baryonic matter by trace correction $T^b_{ab} \to T^b_{ab} - (1/6)g_{ab}T^b$:

$$\mathscr{R}_{ab} = R_{ab} - \frac{1}{3}g_{ab}R = 8\pi T^b_{ab} + 8\pi T_{ab}$$

Cosmological implications:

- de Sitter is unstable.
- H_0q_0-tension is alleviated between the LDL and ΛCDM.
- S_8-tension is reduced by a reduced matter density.