Is the Hubble constant a constant?

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based on work with A. Banerjee, H. Cai, L. Heisenberg, C. Krishnan, O. Luongo, R. Mohayaee, M. Muccino, M. M Sheikh-Jabbari, Lu. Yin

Hubble tension is fascinating & confusing.

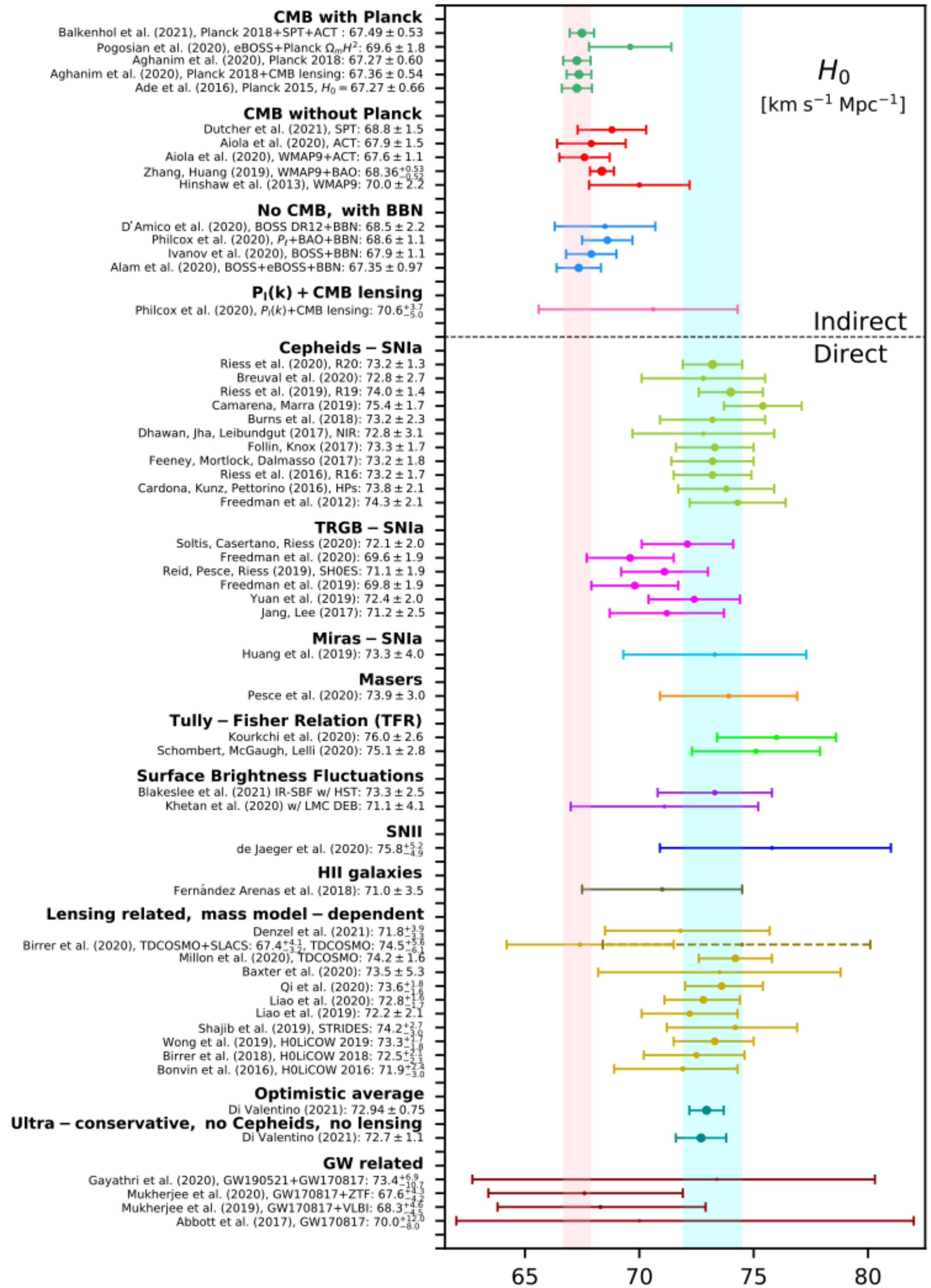
It can be sharply defined as a mismatch between:

1. early Universe model dependent (ΛCDM) inference of H0

2. late Universe model independent H0 determinaton

KEY OBSERVATION:

The only local determination below H0 = 70 km/s/Mpc is TRGB-SN (Freedman et al.).



Almost all local H0 > 70 km/s/Mpc.

This biasing has profound consequences.

Di Valentino et al. (2103.01183)

THEORETICAL PHYSICS

Dark Energy May Be Incompatible With String Theory

A controversial new paper argues that universes with dark energy profiles like ours do not exist in the "landscape" of universes allowed by string theory.

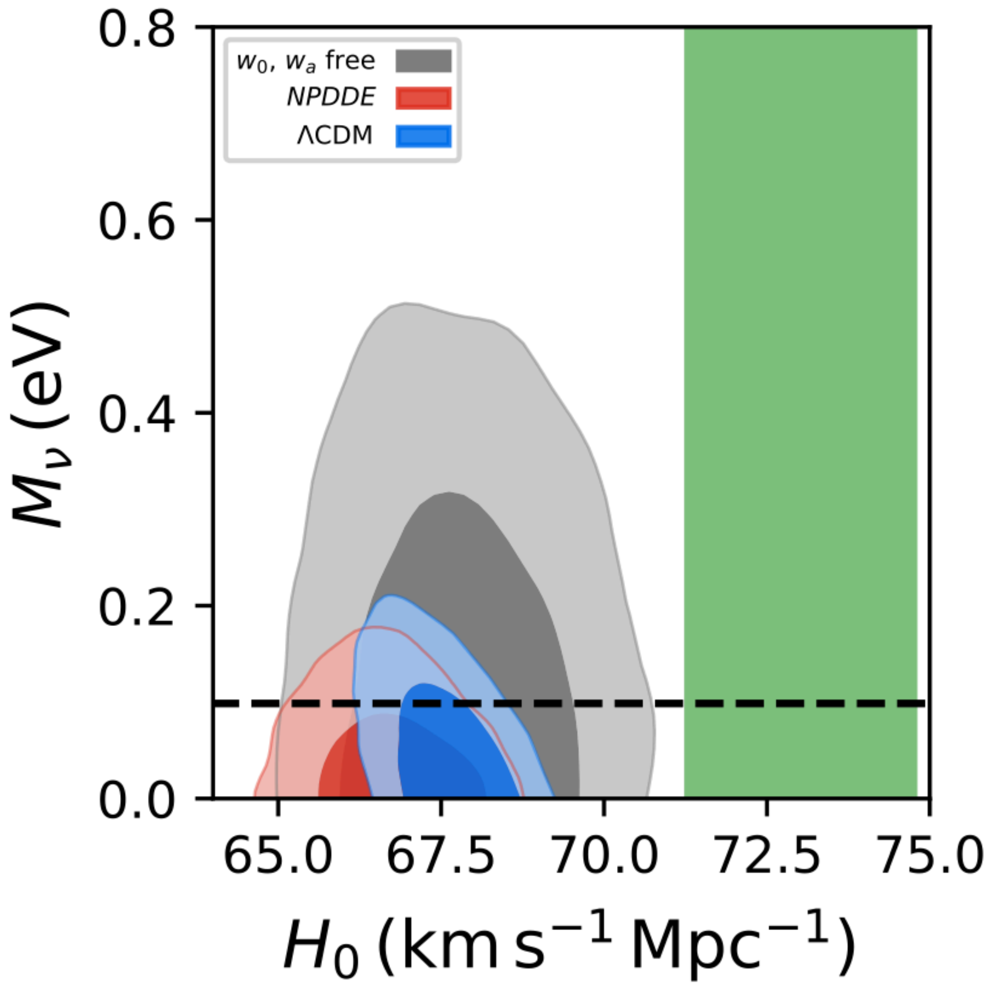
Obied, Ooguri, Spodyneiko, Vafa (1806.08362)

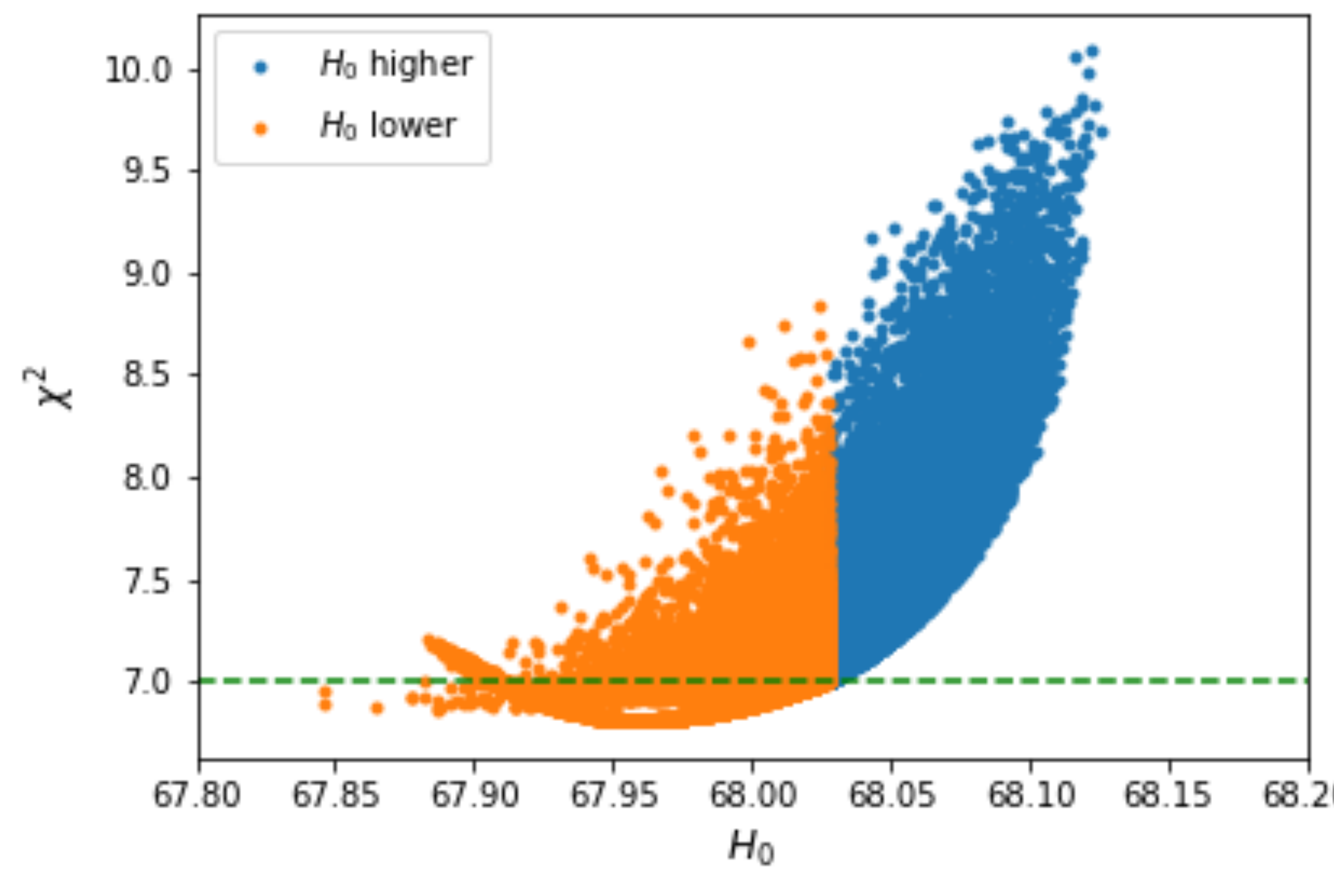
Turns out that embedding de Sitter vacua in string theory is beyond your average HEP theorist, cf. Eva's talk.

Natural to look beyond Λ and Quintessence is as good a first guess as any.

Agrawal, Obied, Steinhardt, Vafa (1806.09718)

But with local H0 being biased high, this idea cannot work.





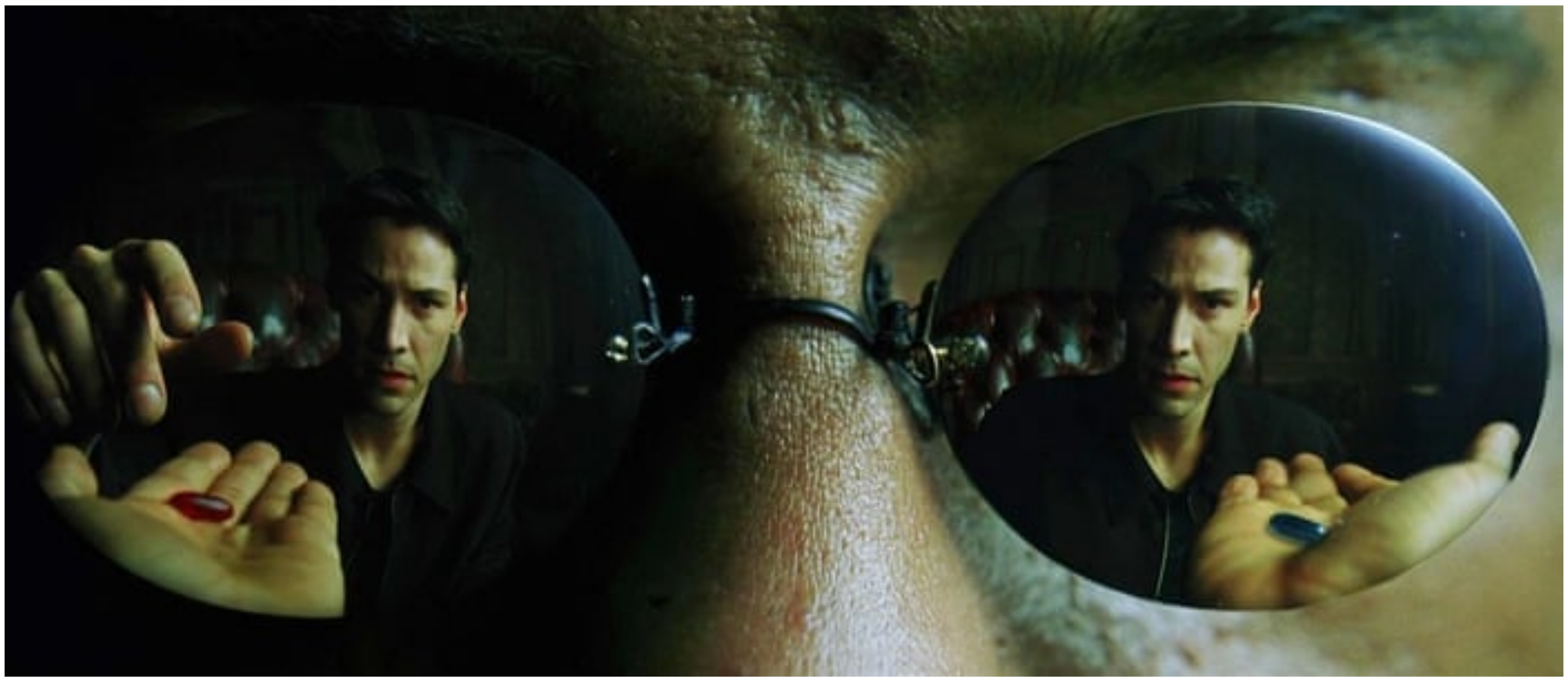
Vagnozzi et al. (1801.08553)

Banerjee et al. (2006.00244)

$$w(z) = w_0 + w_a \frac{z}{1+z}$$

generic V(ϕ) at low z

This apparent conflict between HEP and ΛCDM may have a more drastic resolution.

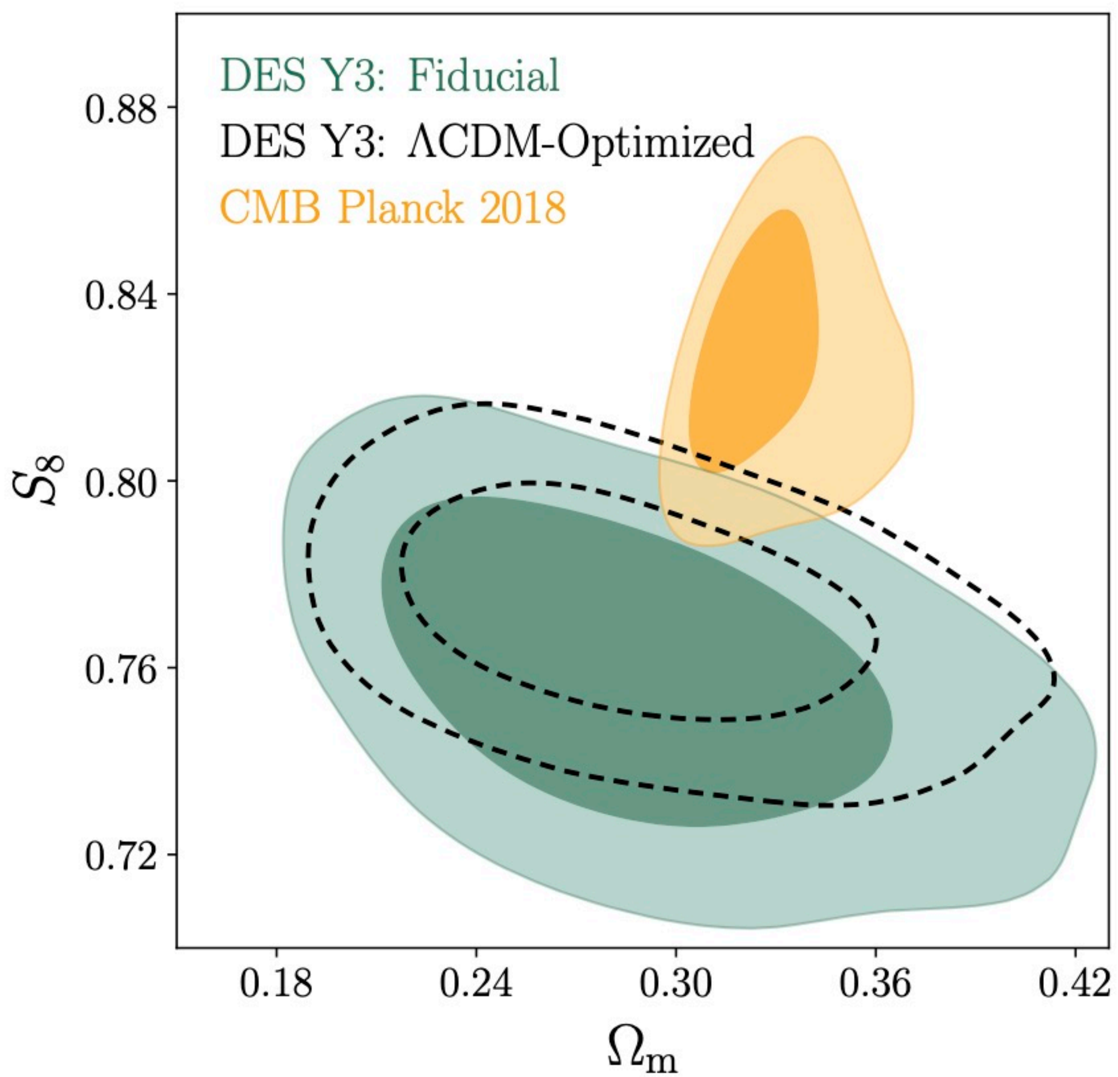


Red pill and the Universe profoundly changes.

Blue pill and one returns to your weekly H0 tension arXiv feed.

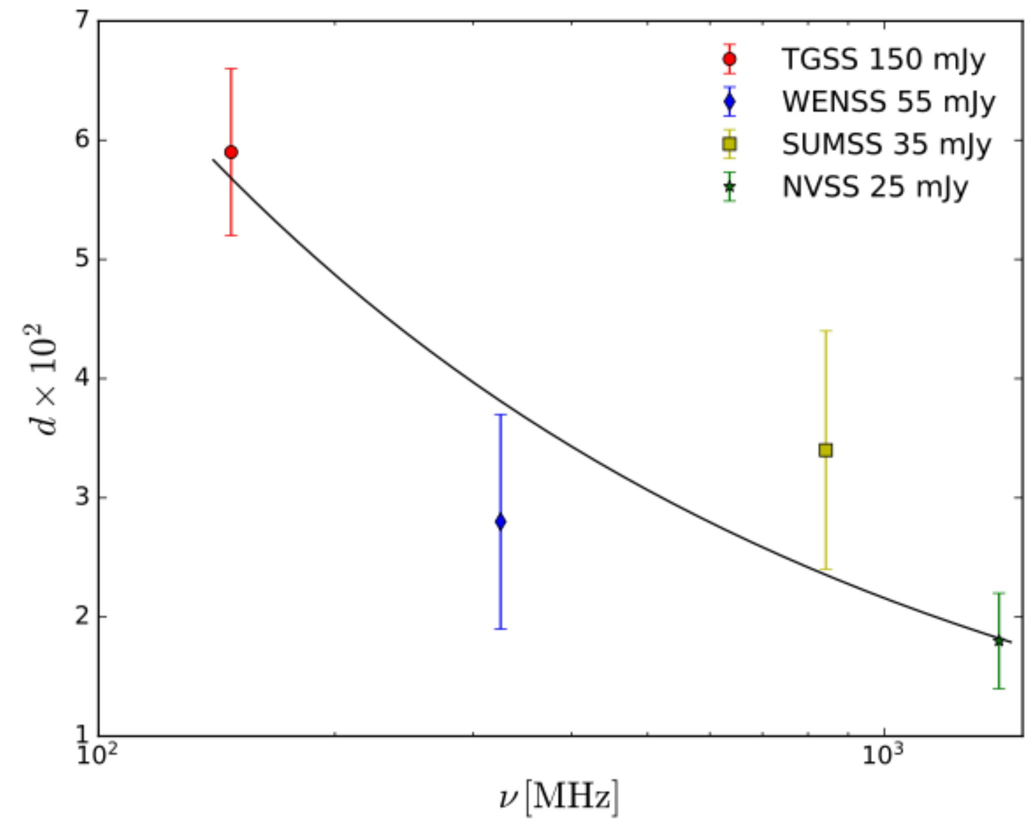
Recall that H0 tension is not the only game in town.

There is a model dependent early-late Universe discrepancy in S_8.



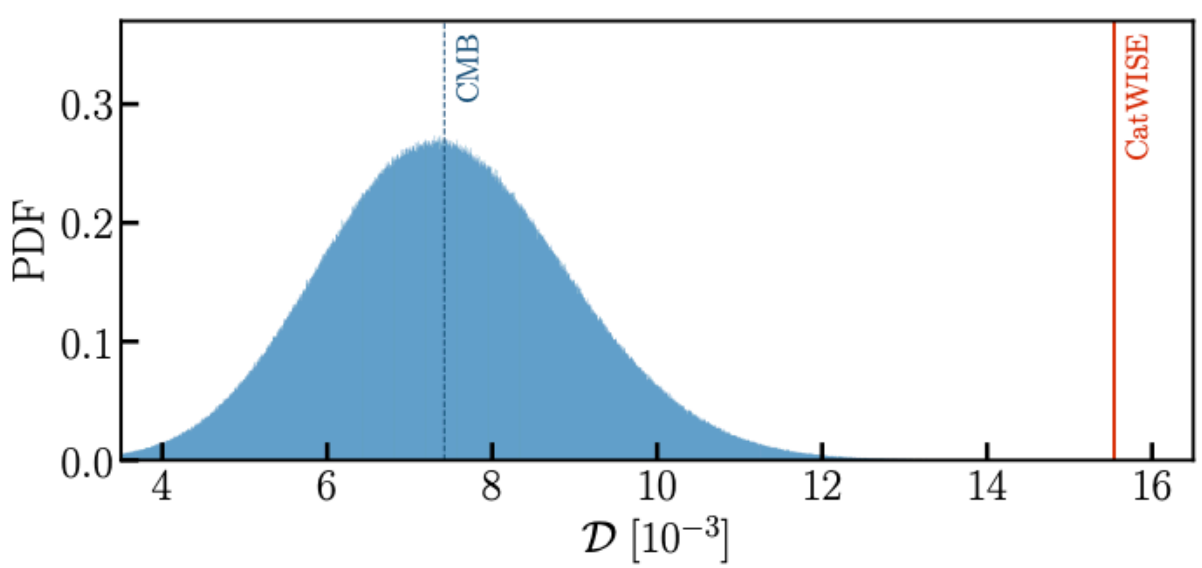
MORE TROUBLING, there appears to be completely cosmological model independent early-late Universe discrepancy in the cosmic dipole.

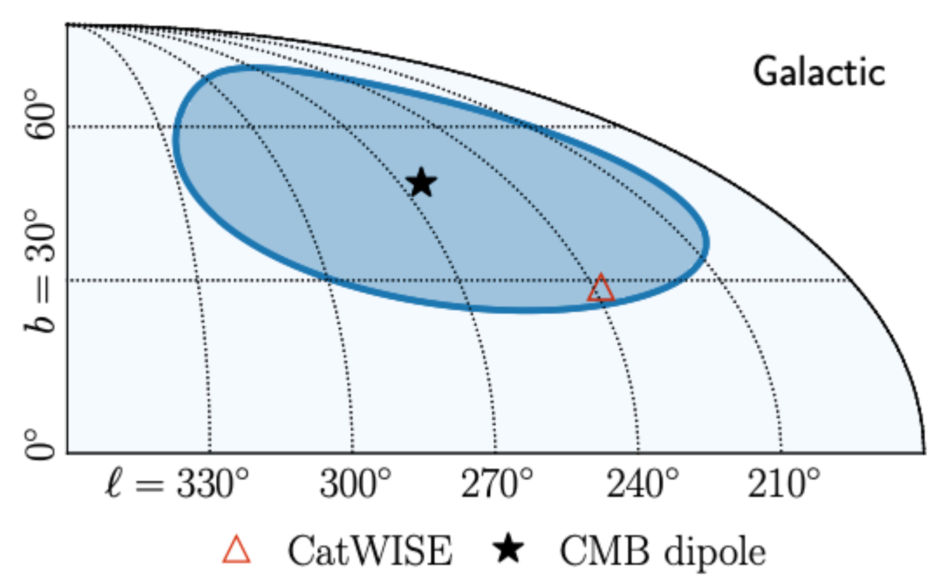
Blake & Wall (2002); Singal (2011); Rubart & Schwarz (2013); Tiwari & Nusser (2016); Bengaly et al. (2018)



Siewert, Schmidt-Rubart, Schwarz (2010.08366)

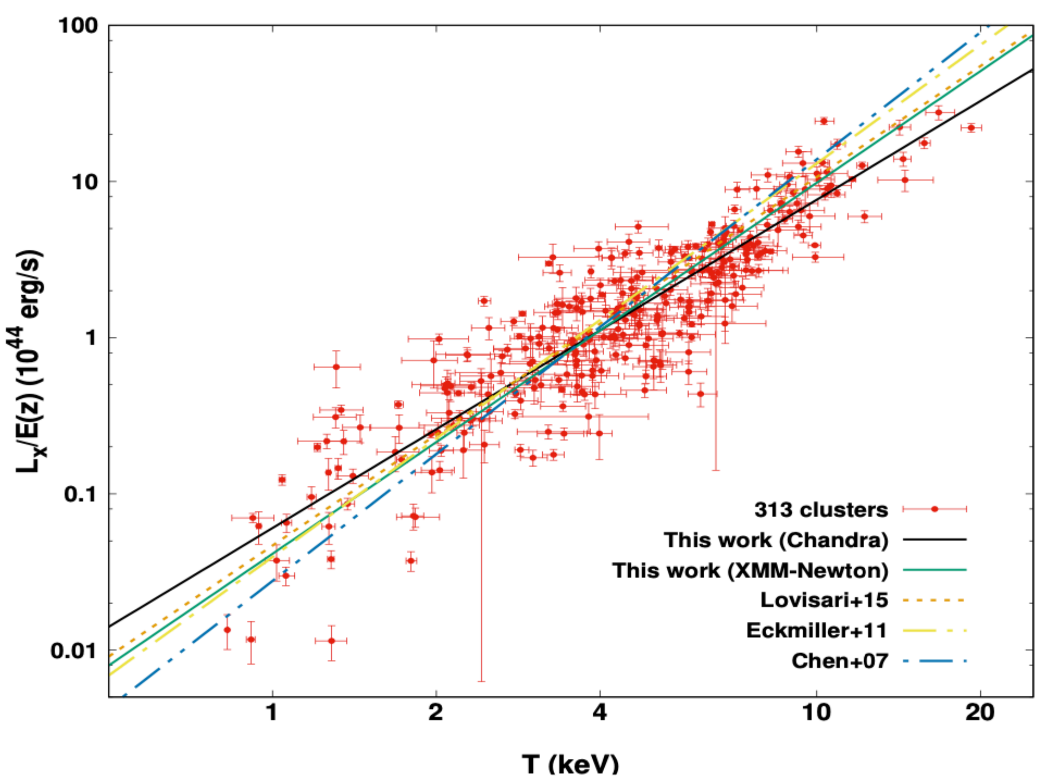
Secrest, Sebastian von Hausegger et al. (2009.14826)





Here I will argue that cosmological H0 is larger in the CMB dipole direction despite being in "CMB frame".

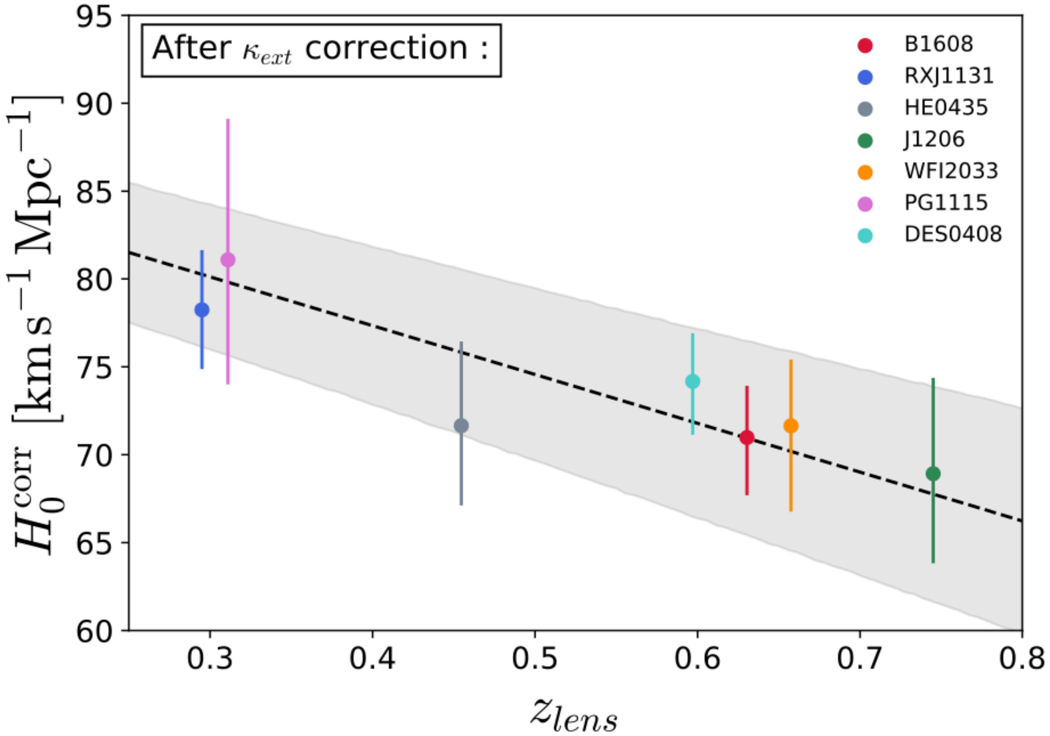
Related work at low redshifts.

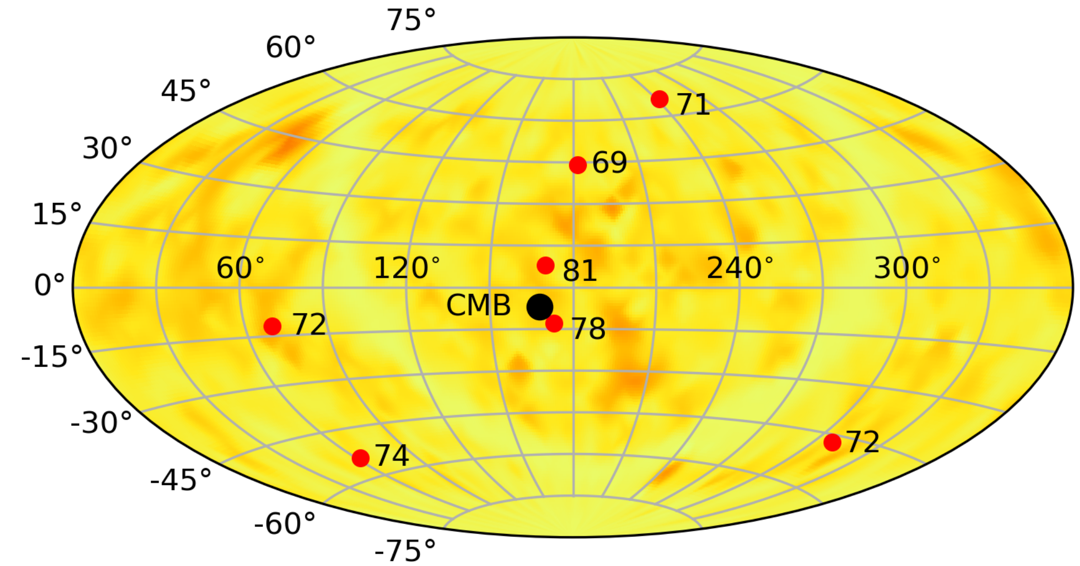


$$\frac{L_X}{10^{44}\ \mathrm{erg/s}} E(z)^{-1} = A \times \left(\frac{T}{4\mathrm{keV}}\right)^B$$

Migkas et al. (2004.03305, 2103.13904)

Anisotropy in the slope A, but can be translated into H0 variations across the sky once one assumes Ω_m.





p = 0.12

Millon et al. (1912.08027)

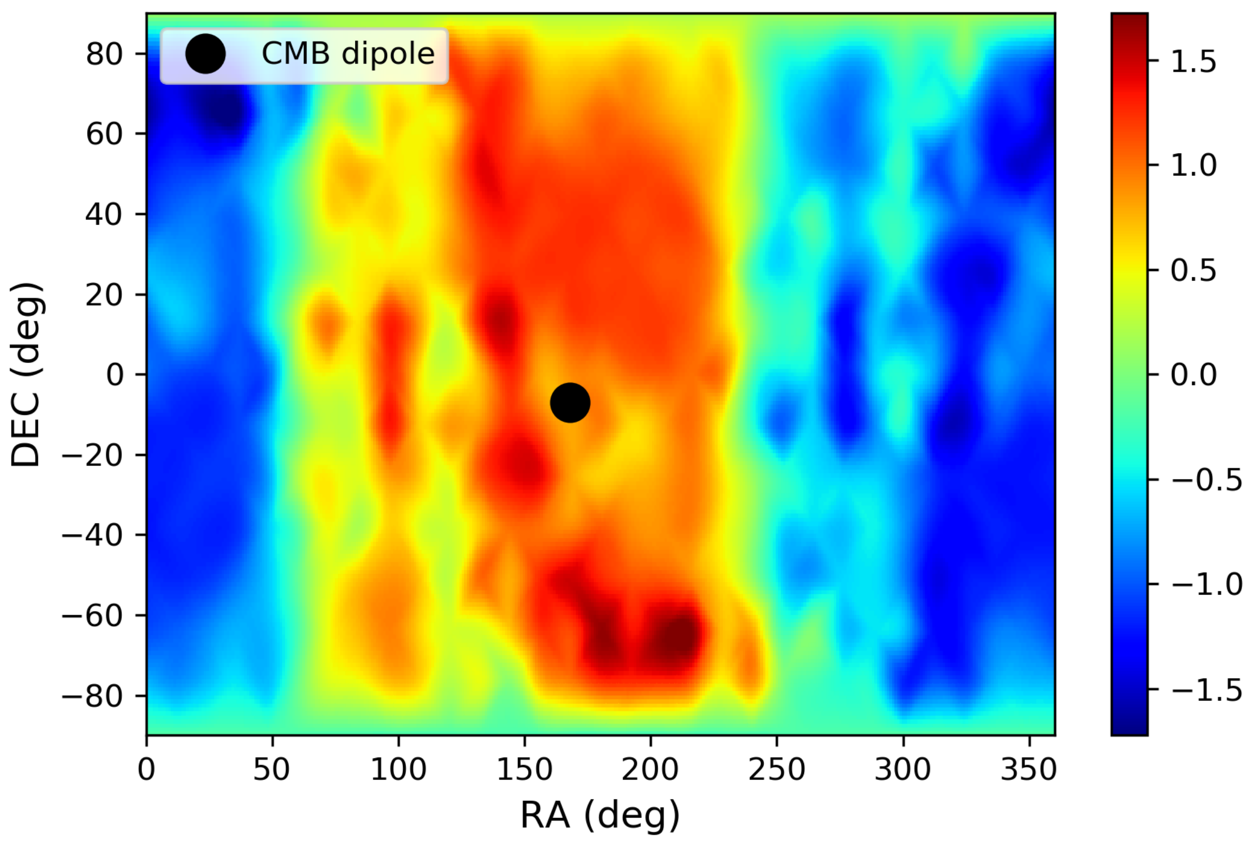
Krishnan, EÓC et al. (2105.09790)

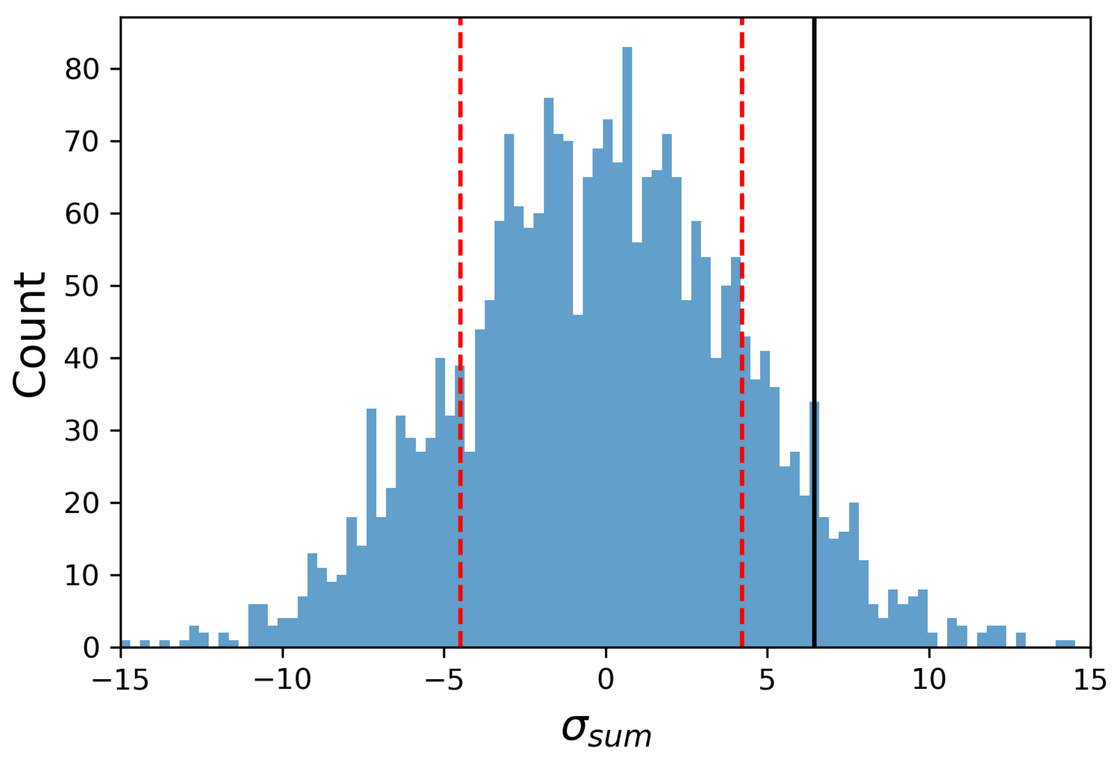
Strongly lensed QSOs return higher H0 values aligned with CMB dipole.

Same paper gives upper bound of H0 ~ 71 km/s/Mpc for any FLRW cosmology.

Same trend in Pantheon Type Ia SN, which are in "CMB frame" by construction.

Caveat: intense discussion on redshift corrections. We take Scolnic's redshifts at face vale.





$$\sigma_{\text{sum}} = \sum_{i=1}^{25} (\vec{v}_i \cdot \vec{v}_{\text{dipole}}) \sigma_i$$

p = 0.065

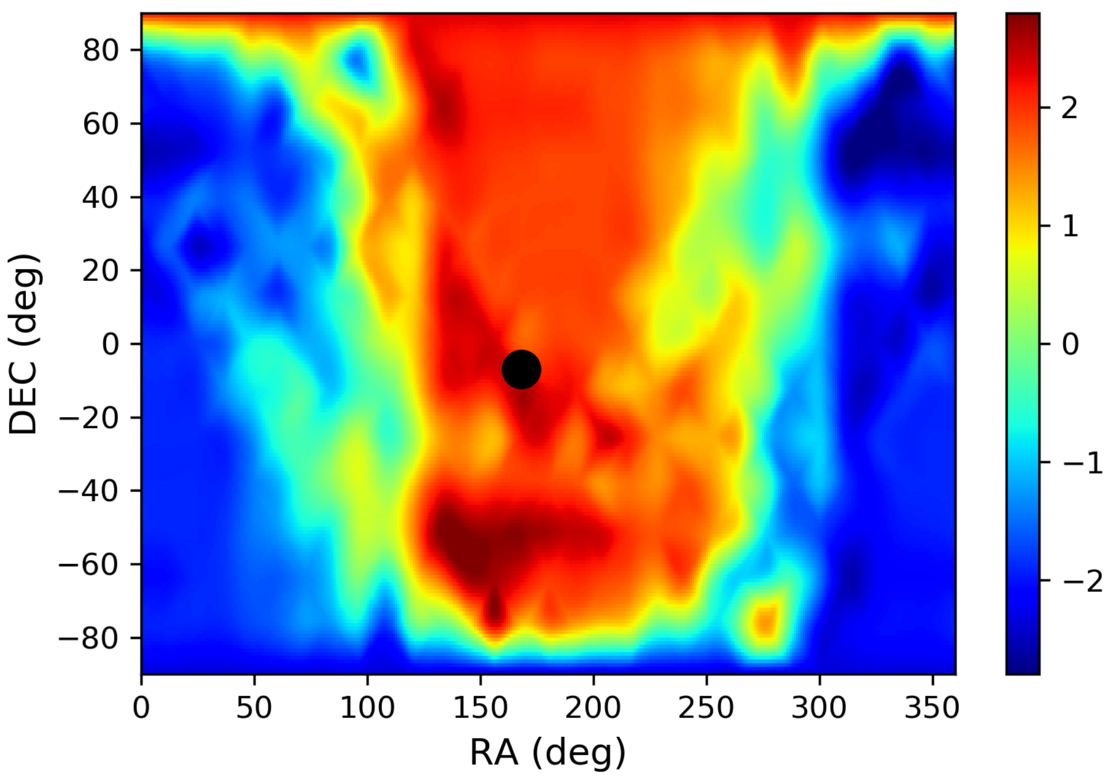
Krishnan, EÓC et al. (2106.02532)

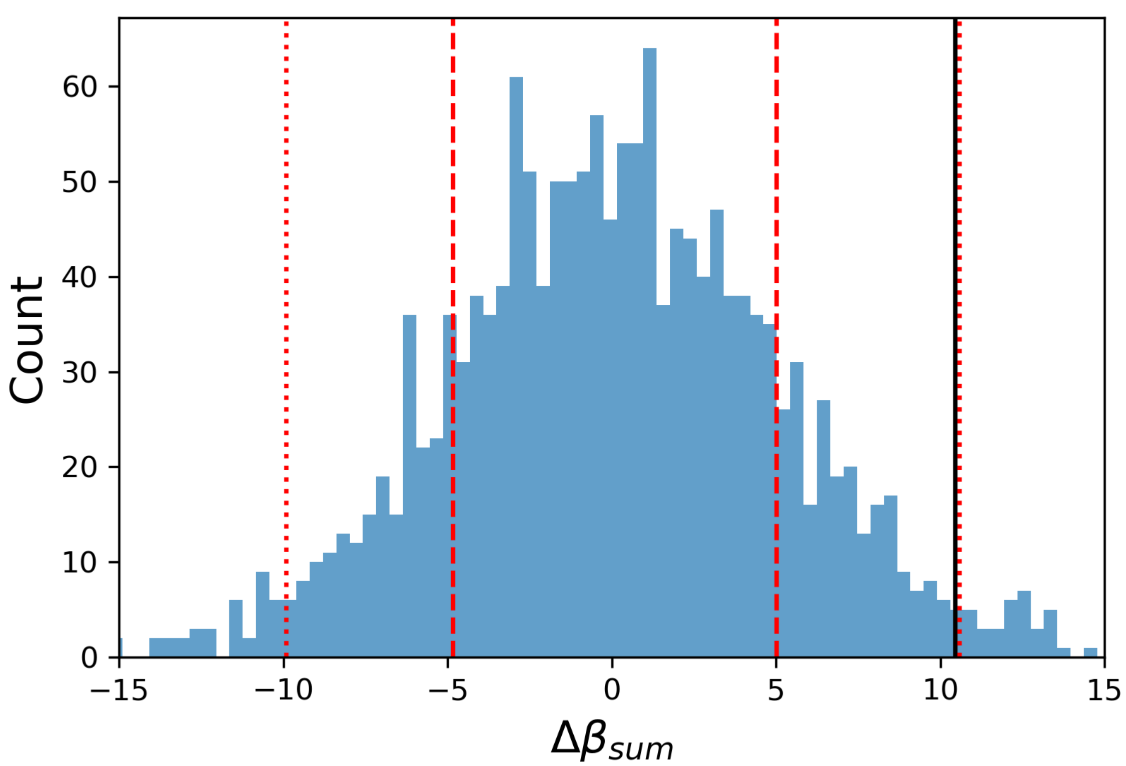
One can see the same thing in Risaliti & Lusso QSOs.

Risaliti, Lusso (1505.07118, 2008.08586)

$$\log_{10}(L_X) = \beta + \gamma \log_{10}(L_{UV}),$$
$$\log_{10}(F_X) = \beta + (\gamma - 1)\log_{10}(4\pi) + \gamma \log_{10}(F_{UV}) + 2(\gamma - 1)\log_{10}(D_L)$$

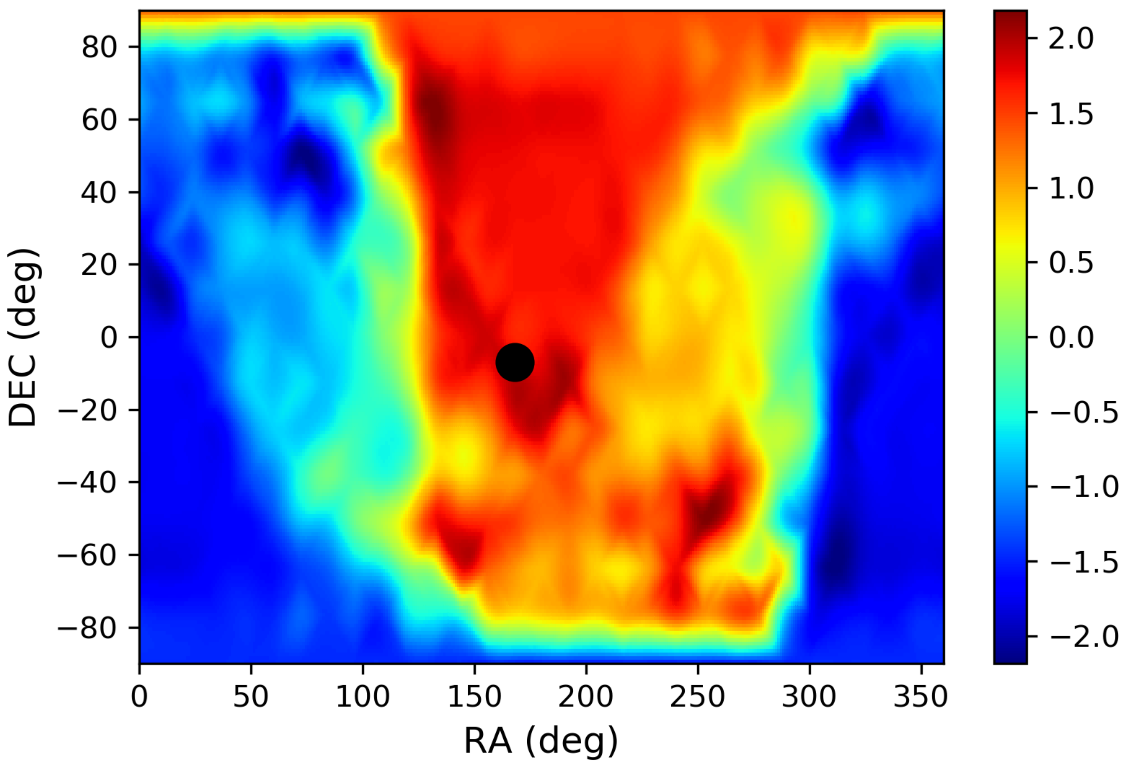
Luongo, EÓC et al. (2108.13228)

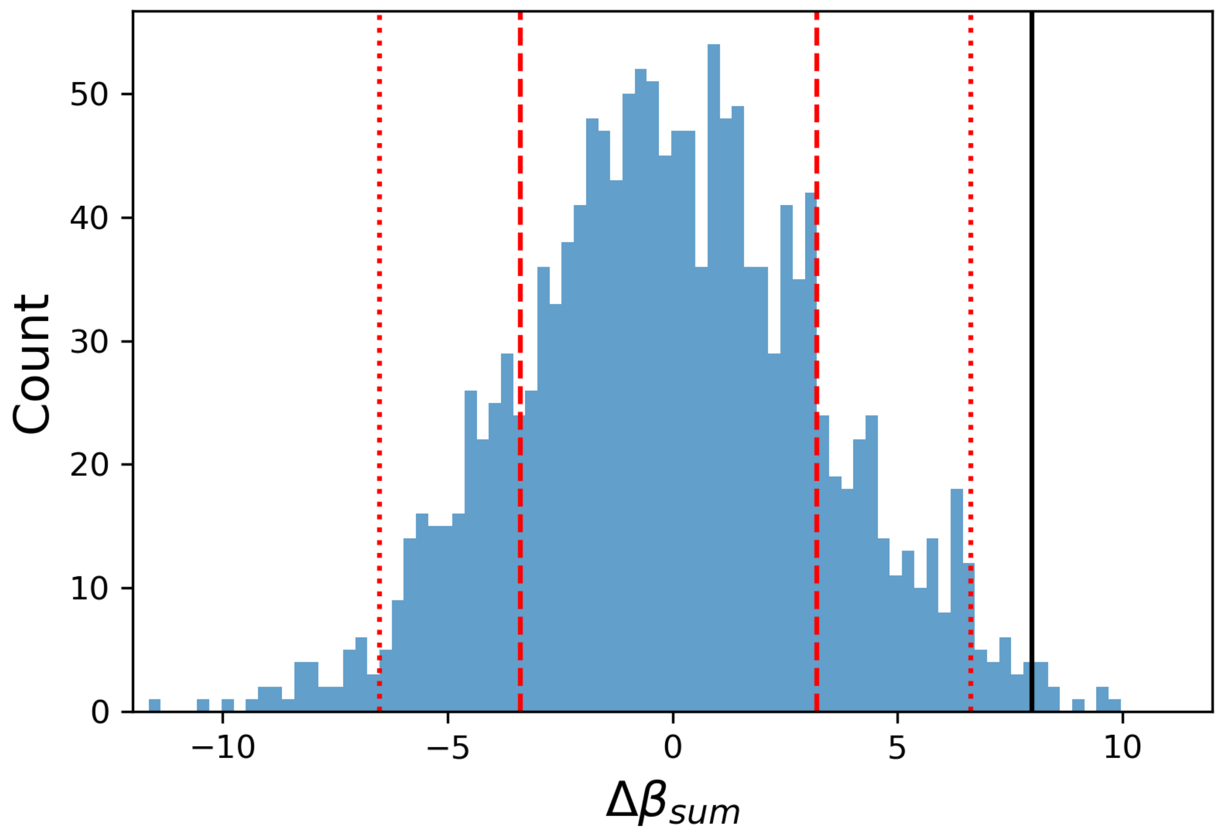




QSOs in range $0.7 \lessapprox z \lessapprox 1.7$

$p = 0.027$



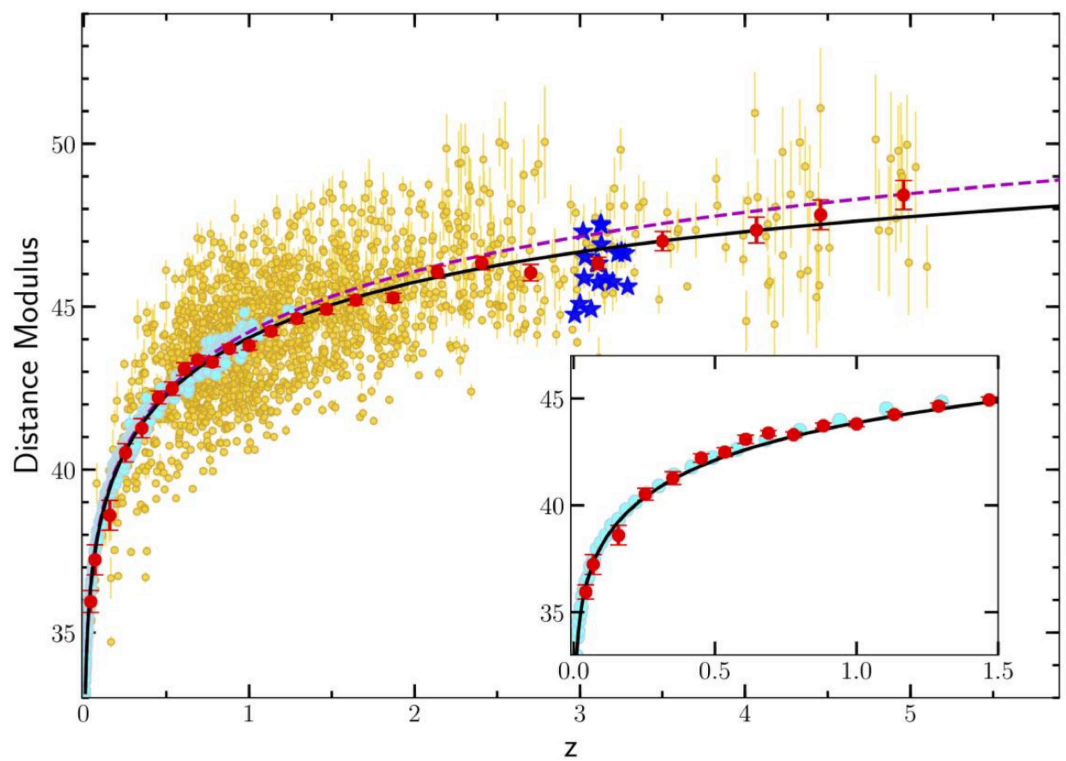


p = 0.004

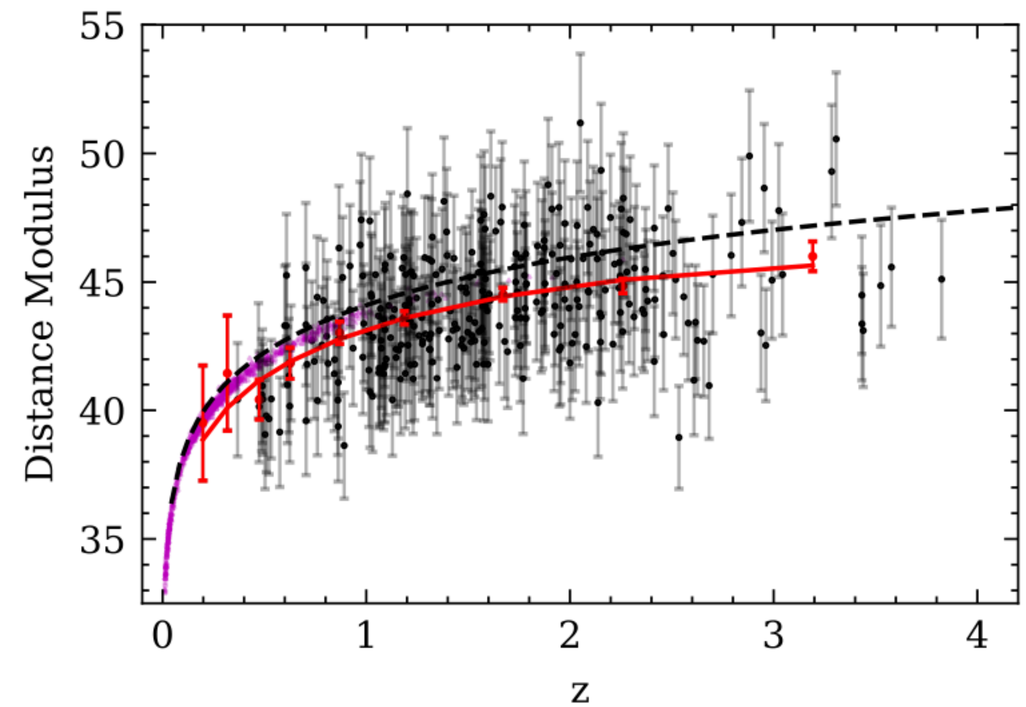
QSOs in range 0.7 ≲ z ≲ 7.5413

Luongo, EÓC et al. (2108.13228)

Are QSOs standardisable? Obviously discrepant with ΛCDM.

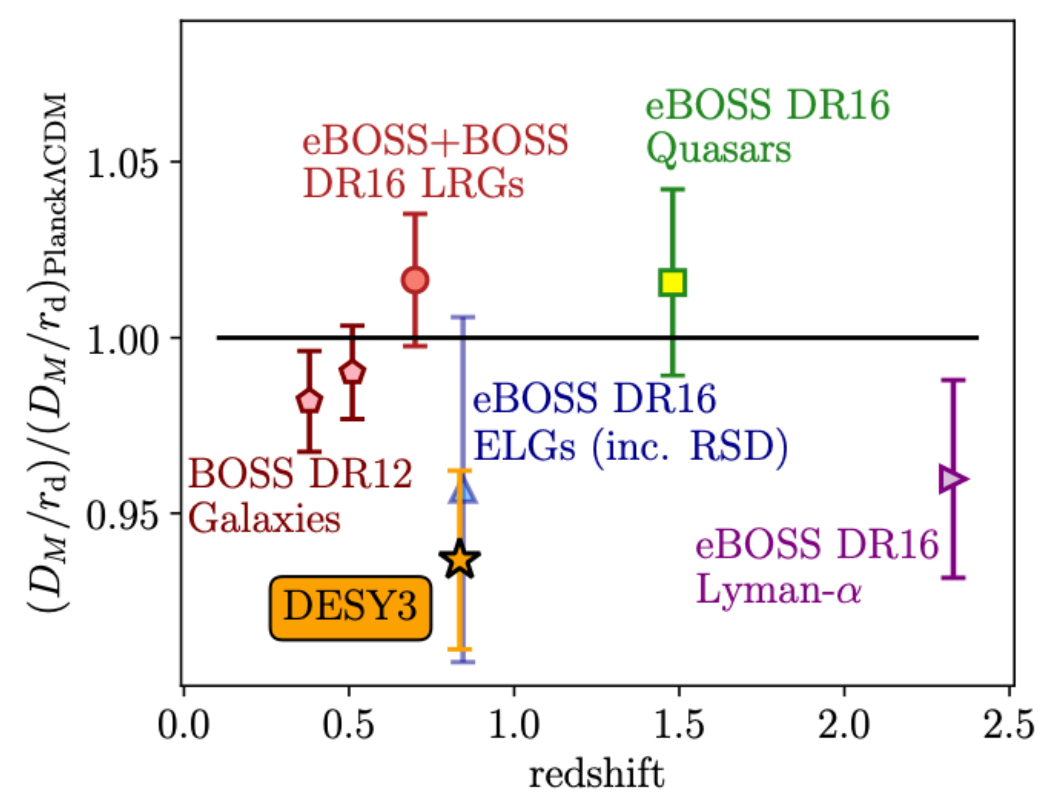


Risaliti & Lusso, 1811.02590



Solomon & Stojkovic, 2110.03671

DES Collaboration, 2107.04646

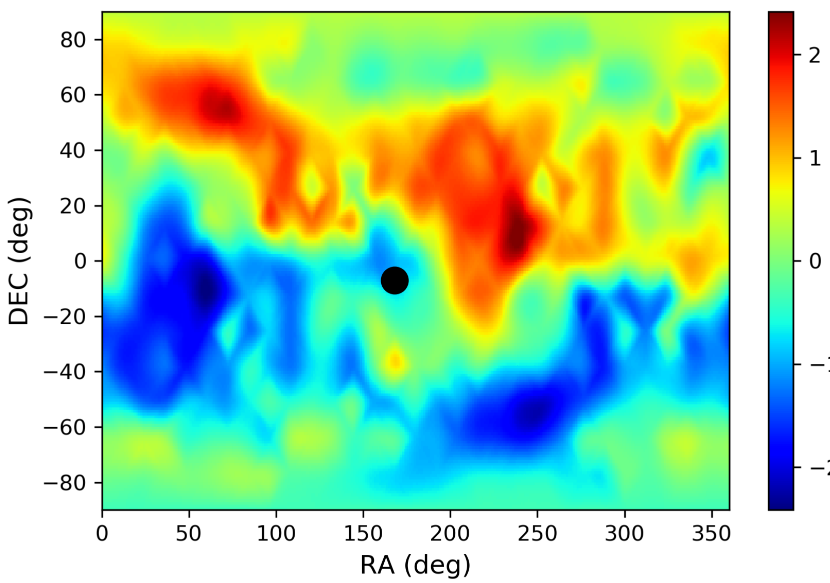


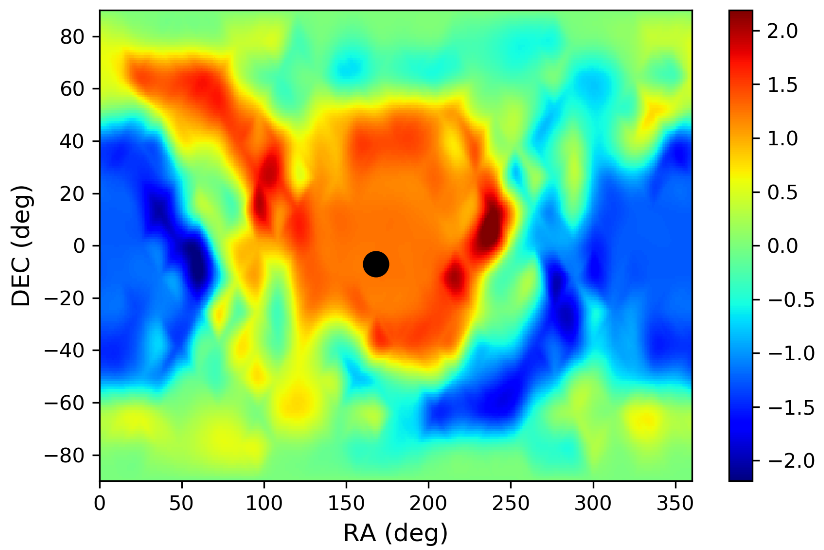
Hints in HST SN?

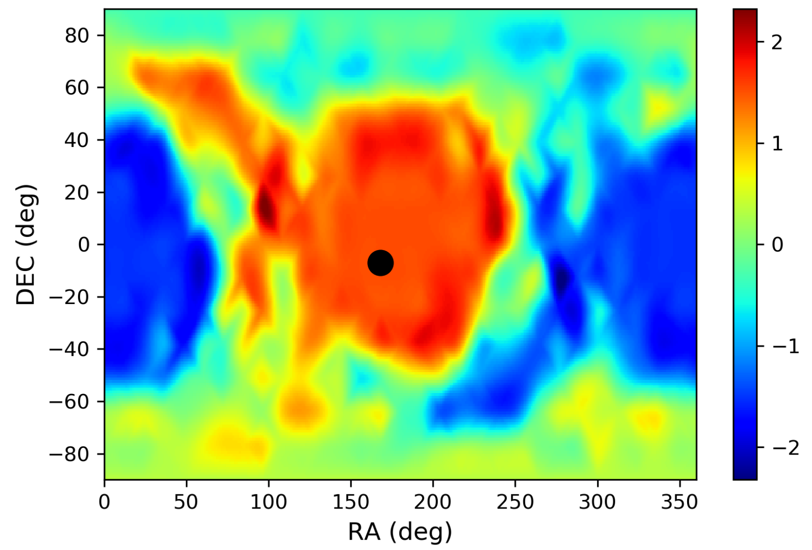
Dainotti et al. (2103.02117)

GRBs are currently the most mysterious. Different samples give different results.

Demianski et al. (1610.00854)







inconclusive

p = 0.091

p = 0.047

Luongo, EÓC et al. (2108.13228)

Can now do some simply exercises.

SN + strong lensing - 2.4 **σ**

SN+strong lensing+QSOs ($z < 1.7$) (conservative) - 3.5 **σ**

SN+strong lensing+QSOs - 4 **σ**

SN+strong lensing+QSOs+GRBs (optimistic) - 4.6 **σ**

Punchlines

The most serious cosmological tension concerns the cosmic dipole as this is cosmological model independent.

H0 within ΛCDM may be higher in the CMB dipole direction.

Easy to check our claim with any “standardisable candle”.

Obvious implications for Hubble hunters.

As this is an interdisciplinary meeting: Cumrun Vafa and collaborators bet against Λ may work out ok in the end.