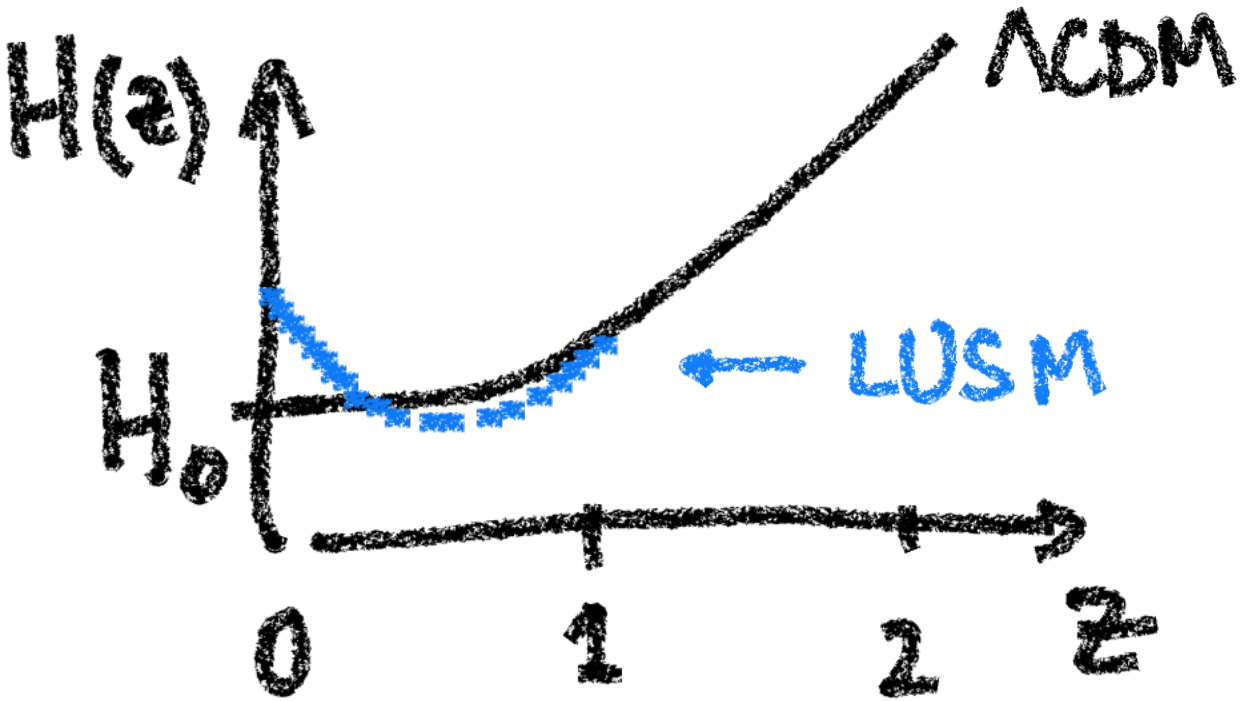
UMD workshop

9/15/2022 M. Schmaltz

H_0 discussion

late universe solutions have a "sound horizon problem"



late universe solutions have a "sound horizon problem"

SOUNDS DISCORDANT: CLASSICAL DISTANCE LADDER & ΛCDM-BASED DETERMINATIONS OF THE COSMOLOGICAL SOUND HORIZON

KEVIN AYLOR,[1] MACKENZIE JOY,[2] LLOYD KNOX,[1] MARIUS MILLEA,[3,4,5] SRINIVASAN RAGHUNATHAN,[6,7] AND W. L. KIMMY WU[8]

Assume that early universe is ΛCDM
extract parameters from CMB (or BBN)

$\Longrightarrow$ calculate sound horizon

$$r_s = \int_0^{\tau_*} c_s(\tau)\, d\tau = \int_{z_*}^{\infty} c_s(z) \left[\frac{8\pi G_N}{3} (\rho_m(z) + \rho_r(z)) \right]^{-1/2} dz$$

ω_b ↑ at z_*; z_{eq} ↑ in ρ_m; T_0, N_{eff} ↑ in ρ_r

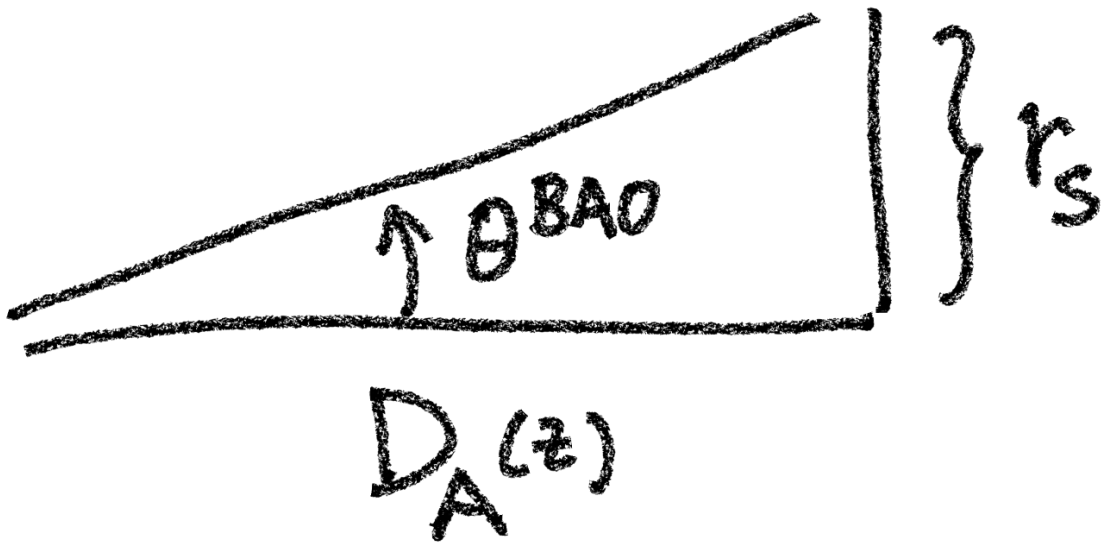
$= 147 \pm 1$ Mpc

Determine a conflicting value for r_s from BAO + distance ladder from Riess et.al. (sepheids + SN1a)

$$r_s^{BAO} = 138 \pm 3.6 \text{ Mpc}$$

$$r_s^{\Lambda CDM} = 147 \pm 1 \text{ Mpc}$$

r_s from BAO:

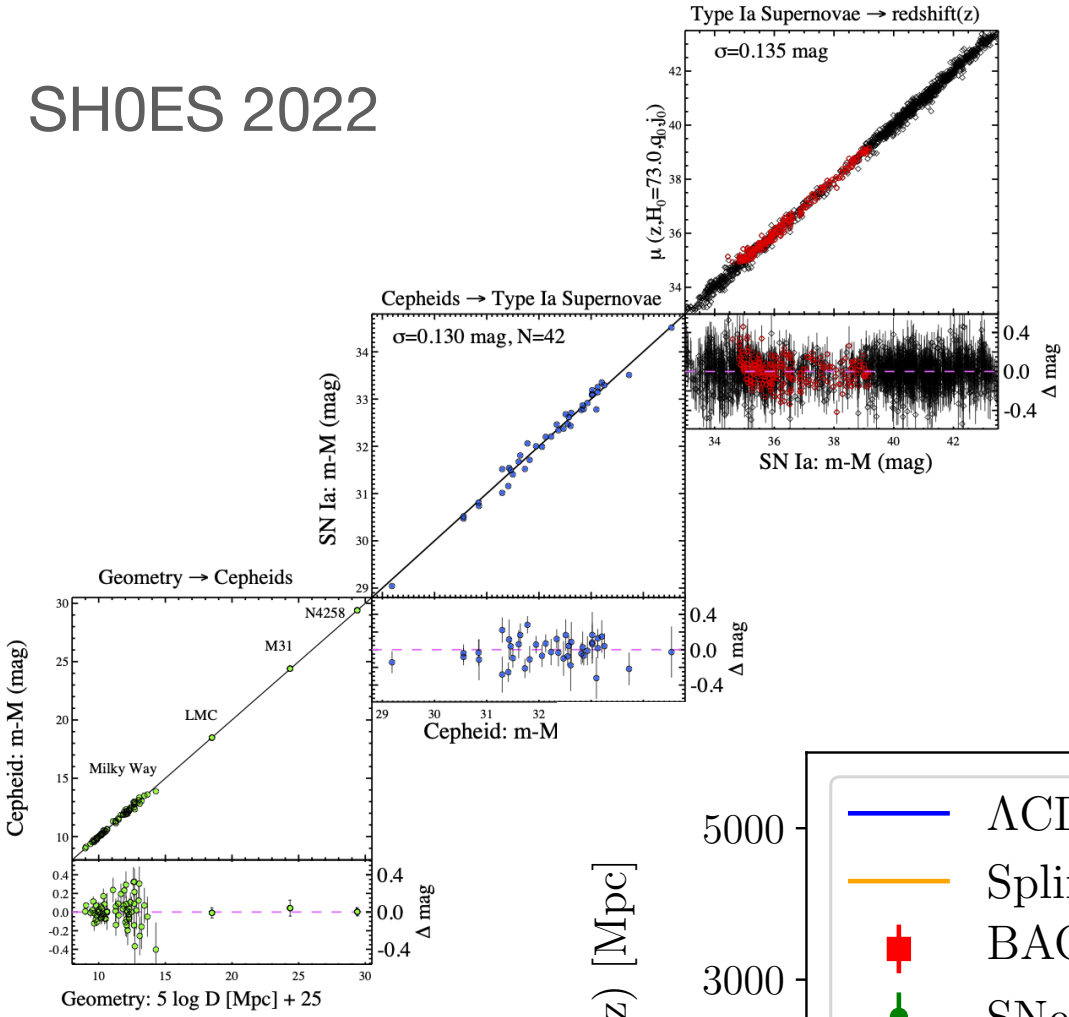


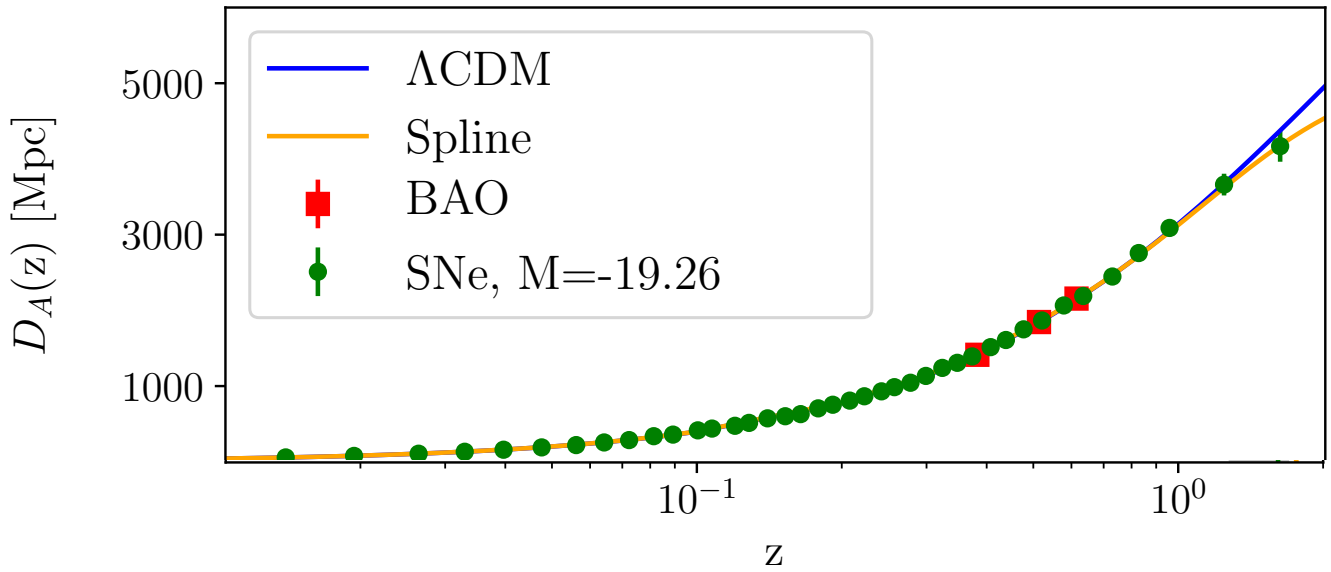
$$r_s = D_A(z) \sin \theta^{BAO}$$

Riess ladder ↗ ↖ measured

Geometry > Cepheids > SN1a luminosity calibration

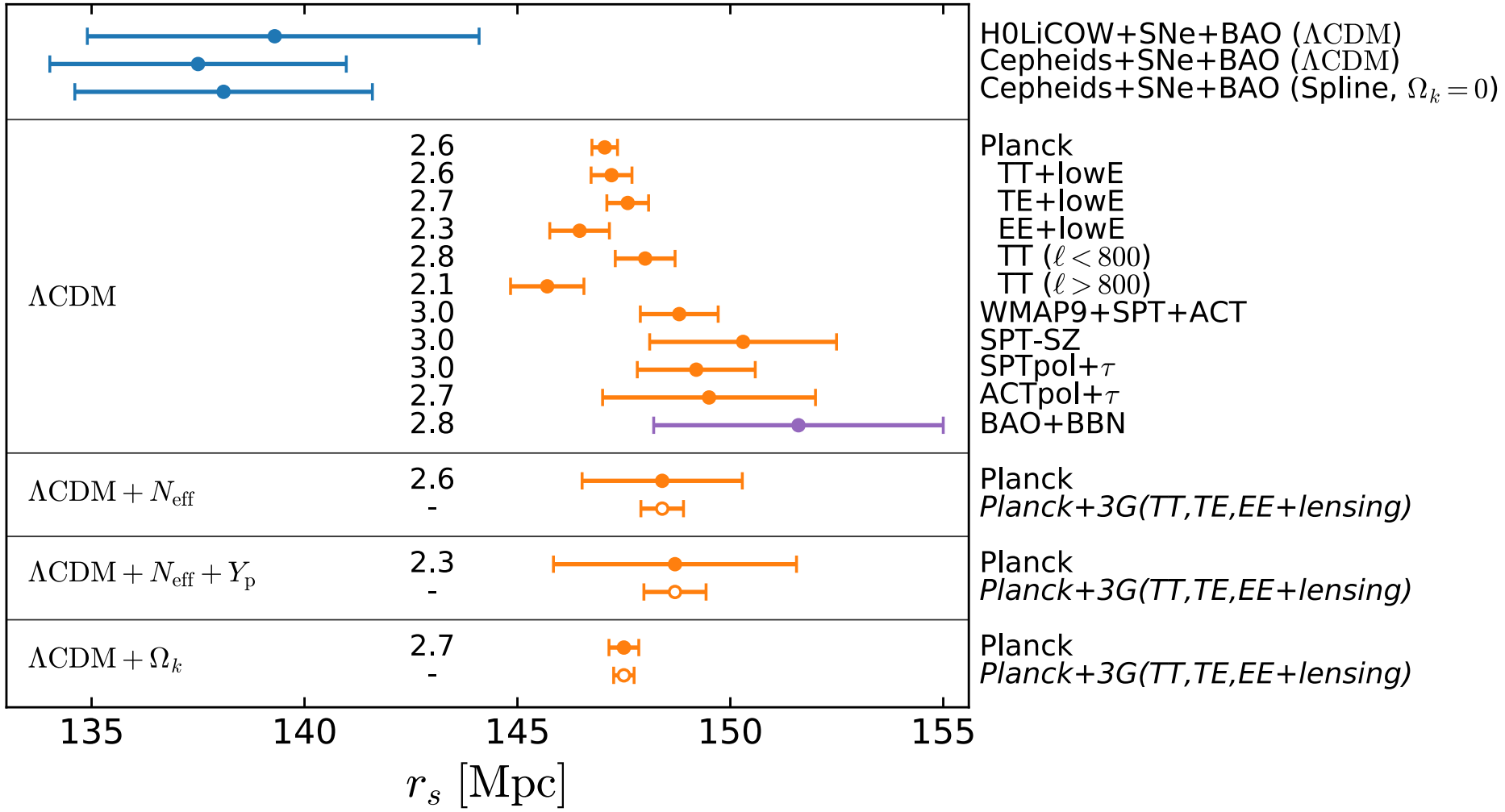
SH0ES 2022





SOUNDS DISCORDANT:
CLASSICAL DISTANCE LADDER & ΛCDM-BASED DETERMINATIONS OF THE COSMOLOGICAL SOUND HORIZON

KEVIN AYLOR,[1] MACKENZIE JOY,[2] LLOYD KNOX,[1] MARIUS MILLEA,[3,4,5] SRINIVASAN RAGHUNATHAN,[6,7] AND W. L. KIMMY WU[8]



Early universe models with extra dark radiation to change the sound horizon

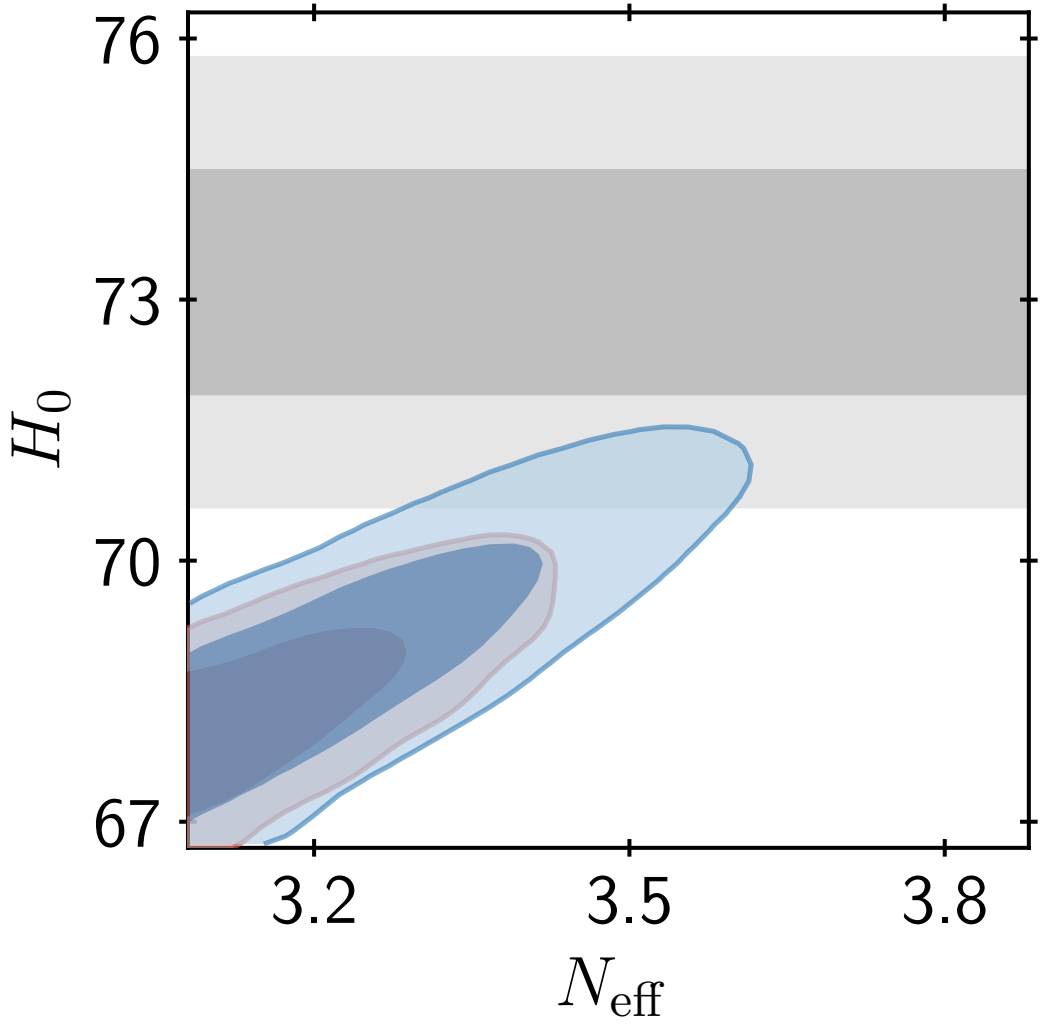
$$r_s = \int_0^{\tau_*} c_s(\tau)\, d\tau = \int_{z_*}^{\infty} c_s(z) \left[\frac{8\pi G_N}{3} \left(\rho_m(z) + \rho_r(z) \right) \right]^{-1/2} dz$$

T_0, N_{eff}

$H_0 \sim \frac{1}{r_s}$ need $\Delta r_s \sim 7\%$

extra (dark) radiation

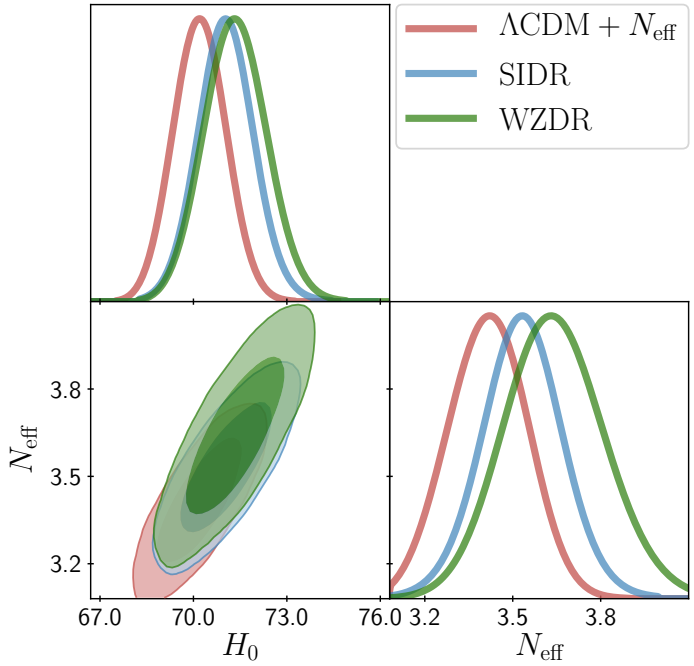
- Free-steaming: Good idea, doesn't work.
- Self-interacting: Better idea, doesn't quite work (Blinov, Marques-Tavares 2003.08387).
- But… looks like the right way to go…



"A step in understanding the Hubble tension"

astro-ph 2111.00014

dark radiation is self-interacting with massive + massless particle



ACT CMB disagrees with Planck

THE ATACAMA COSMOLOGY TELESCOPE: DR4 MAPS AND COSMOLOGICAL PARAMETERS

BEYOND ΛCDM PARAMETERS WITH 68% CONFIDENCE LEVEL

Parameter	ACT	**ACT+WMAP**	ACT+Planck	Planck[a]
Ω_k	$-0.003^{+0.022}_{-0.014}$	$\mathbf{-0.001^{+0.014}_{-0.010}}$	$-0.018^{+0.013}_{-0.010}$	$-0.037^{+0.020}_{-0.014}$
Σm_ν[eV]	< 3.1	$\mathbf{< 1.2}$	< 0.54	< 0.37
$N_{\rm eff}$	2.42 ± 0.41	$\mathbf{2.46 \pm 0.26}$	2.74 ± 0.17	2.97 ± 0.19
$dn_s/dlnk$	0.069 ± 0.029	$\mathbf{0.0128 \pm 0.0081}$	0.0023 ± 0.0063	-0.0067 ± 0.0067
$Y_{\rm HE}$	0.211 ± 0.031	$\mathbf{0.220 \pm 0.018}$	0.232 ± 0.011	0.243 ± 0.013

arXiv:2007.07288v2 [astro-ph.CO] 3 Dec 2020

S_8?

Can we solve both H_0 & S_8 ?

see talk by Melissa Joseph

What data will settle this?

- NS mergers ? 10 years ?
- More CMB precision ?
- an even better model ?
- TRGB vs cepheids ?