Stress test for models willing to solve the Hubble tension

A. Blanchard, J.-Y. Héloret, B.Lamine, S. Illić, I.Tutusaus

Marseille, November 18th, 2022

Tensions for ΛCDM.

Successes of ΛCDM :

$\longrightarrow$ predictive

Tensions for ΛCDM.

Successes of ΛCDM :

$\rightarrow$ predictive

$\rightarrow$ accurate parameters determination $\sim$ % precision.

Tensions for ΛCDM.

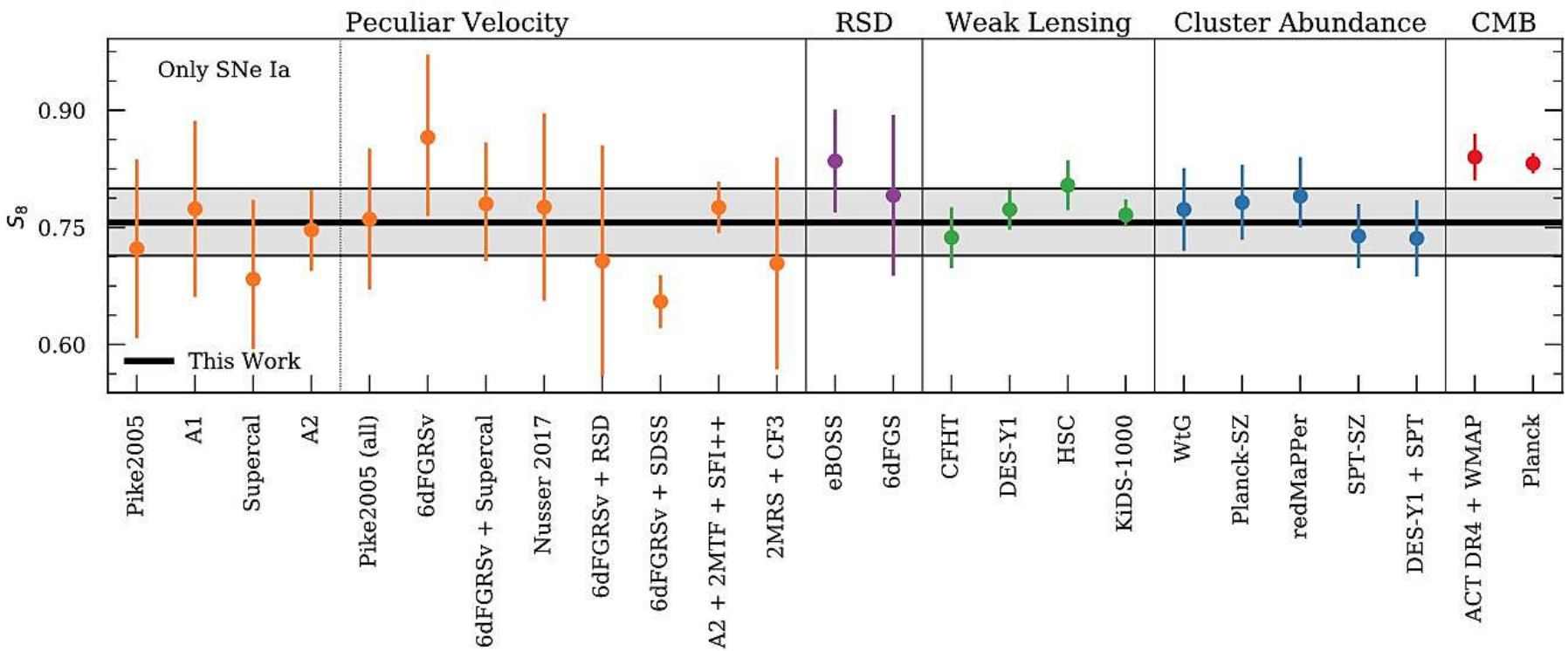
Successes of ΛCDM :

$\rightarrow$ predictive

$\rightarrow$ accurate parameters determination $\sim$ % precision.

Tensions.

The amplitude of matter fluctuations tension, i.e. S_8 tension.



Stahl et al. (2021)

Which measures constrain σ_8 (at $z \sim 0$)?

Which measures constrain σ_8 (at $z \sim 0$)?

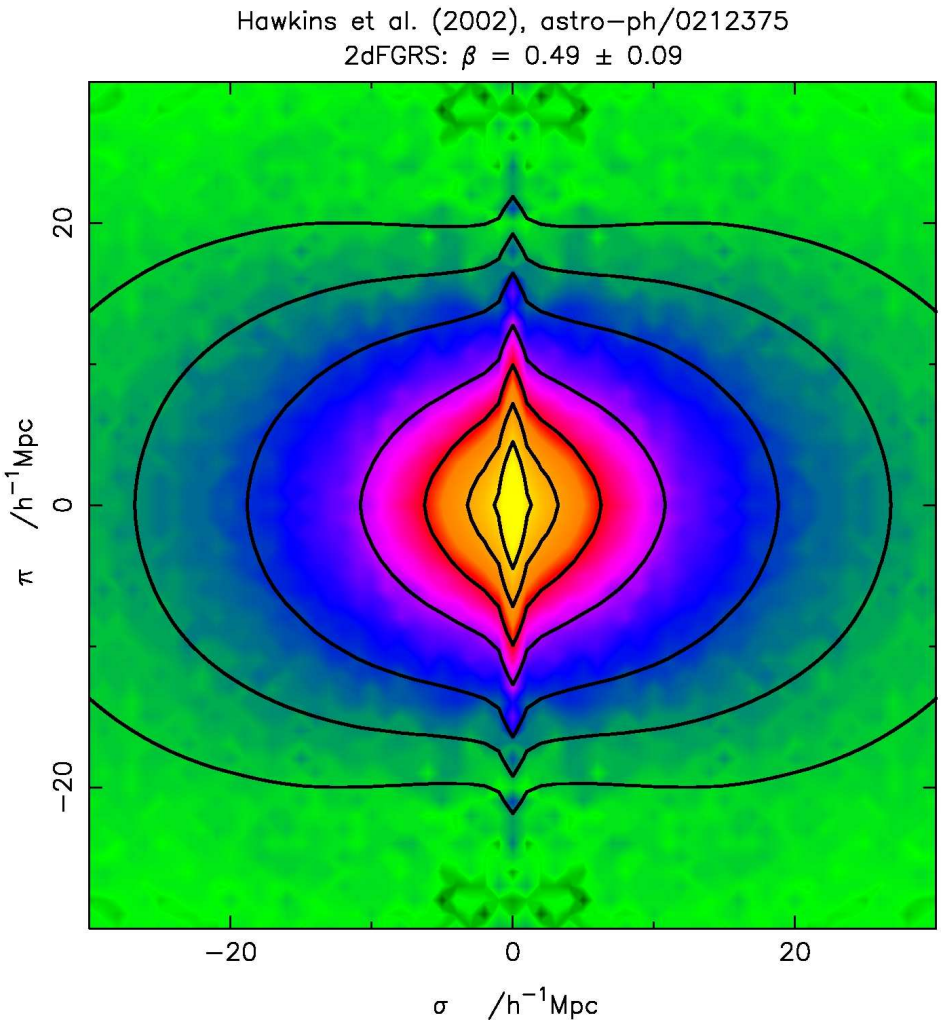
- weak lensing

Which measures constrain σ_8 (at $z \sim 0$)?

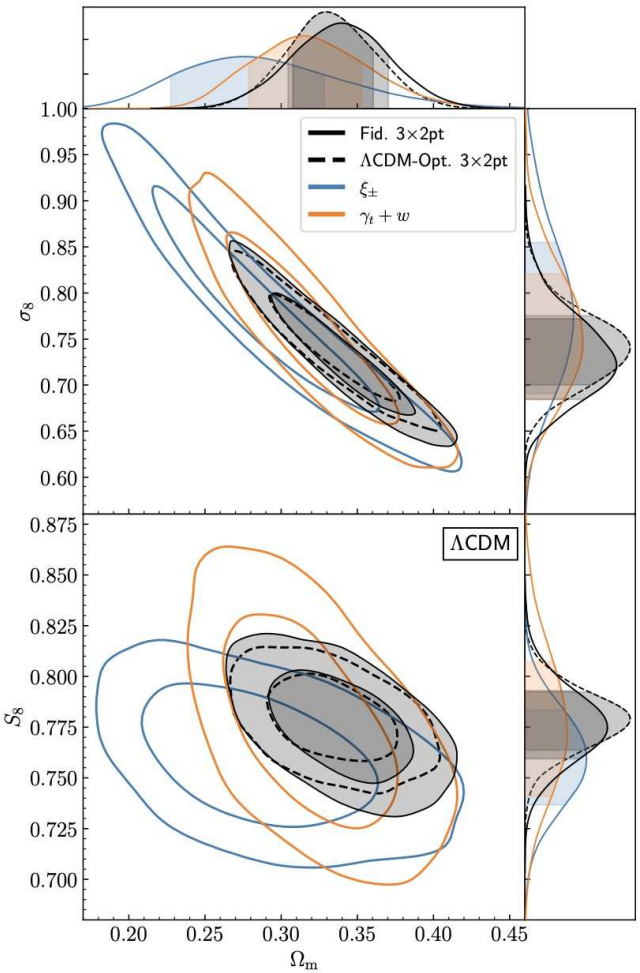
- weak lensing
- RSD (redshift space distorsion) $\boxed{\rightarrow f\sigma_8}$

Which measures constrain σ_8 (at $z \sim 0$)?

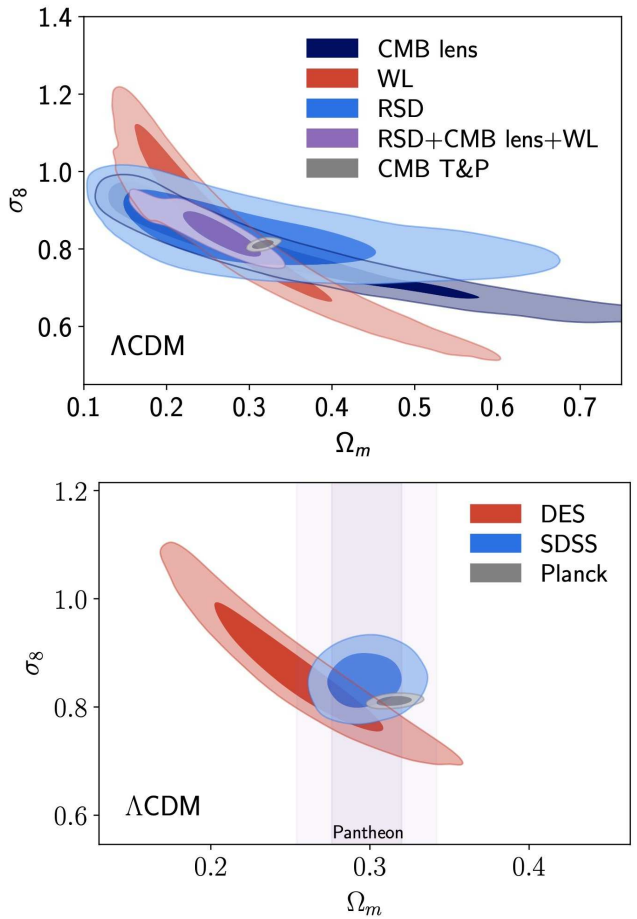
- weak lensing
- RSD (redshift space distorsion) $\boxed{\rightarrow f\sigma_8}$



Which measures constrain σ_8 (at $z \sim 0$)?



(a) DES3yr 3×2pt



(b) eBOSS

Next step: Jean-Yves Héloret & Stéphane Illić

Recipe:

Next step: Jean-Yves Héloret & Stéphane Illić

Recipe:

- use only "local" data i.e. $z << 1000$

Next step: Jean-Yves Héloret & Stéphane Illić

Recipe:

- use only "local" data i.e. $z << 1000$
- work in the ΛCDM framework.

Next step: Jean-Yves Héloret & Stéphane Illić

Recipe:

- use only "local" data i.e. $z << 1000$
- work in the ΛCDM framework.
- RSD

Next step: Jean-Yves Héloret & Stéphane Illić

Recipe:

- use only "local" data i.e. $z << 1000$
- work in the ΛCDM framework.
- RSD
- SNIa diagram Pantheon+,

Next step: Jean-Yves Héloret & Stéphane Illić

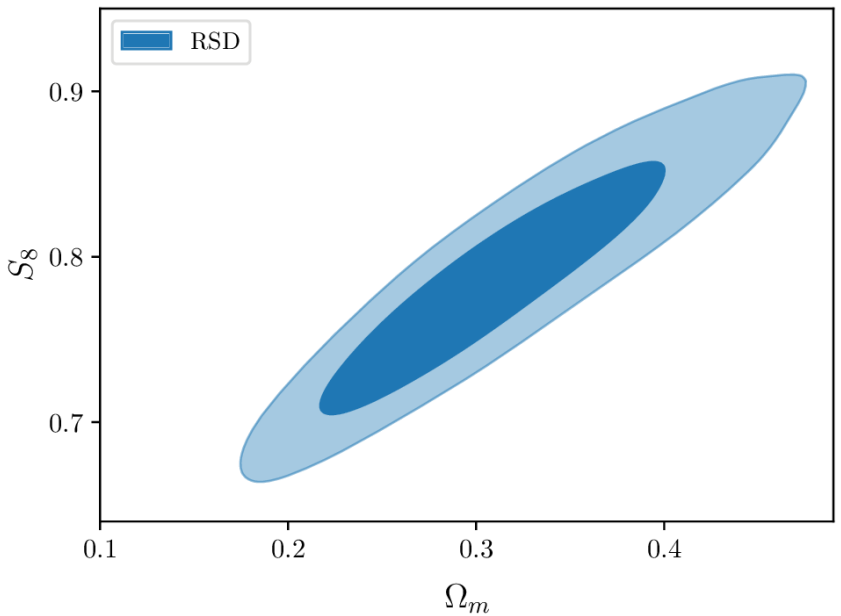
Recipe:

- use only "local" data i.e. $z << 1000$
- work in the ΛCDM framework.
- RSD
- SNIa diagram Pantheon+,
- WL from DES 3yr

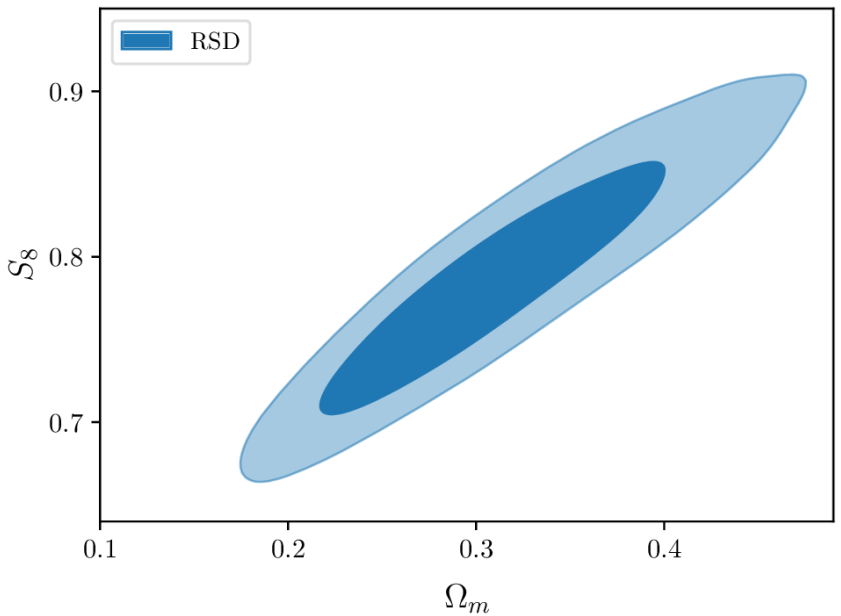
RSD from surveys

Survey	z	$f\sigma_8$	**Refs**
2MFT	0.001	0.51+/-0.085	[19]
6dFGS	0.067	0.423+/-0.055	[20]
SDSS DR13	0.1	0.48+/-0.16	[21]
2dFGRS	0.17	0.51+/-0.06	[22]
GAMA	0.18	0.36 +/- 0.09	[23]
WiggleZ	0.22	0.42+/-0.07	[24]
SDSS LRG60	0.25	0.35+/- 0.06	[25]
BOSS LOW Z	0.32	0.48+/-0.1	[26]
GAMA	0.36	0.44+/- 0.06	[23]
SDSS LRG 200	0.37	0.46+/- 0.04	[25]
WiggleZ	0.41	0.45+/-0.04	[24]
CMASS BOSS	0.57	0.453+/-0.02	[27]
WiggleZ	0.6	0.43+/-0.04	[24]
VIPERS	0.6	0.48+/-0.12	[28]
SDSS IV	0.69	0.447+/-0.039	[29]
VIPERS	0.76	0.44+/-0.04	[30]
SDSS IV	0.77	0.432+/-0.038	[31]
WiggleZ	0.78	0.38+/-0.04	[24]
SDSS IV	0.85	0.52+/-0.10	[32]
VIPERS	0.86	0.48+/-0.10	[28]
SDSS IV	0.978	0.379+/-0.176	[31]
SDSS IV	1.23	0.385+/-0.1	[31]
Fastsound	1.4	0.494+/-0.123	[33]
SDSS IV	1.52	0.426 +/-0.077	[34]
SDSS IV	1.944	0.364+/-0.106	[31]

RSD from surveys: constraints

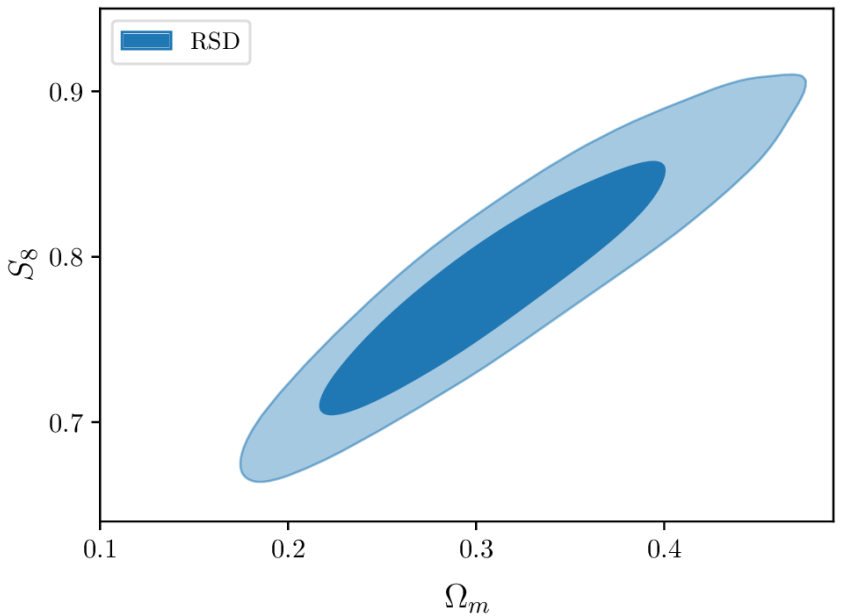


RSD from surveys: constraints



Not surprisingly strong degeneracy

RSD from surveys: constraints



Not surprisingly strong degeneracy
Need to combine with other $low - z$ data

RSD from surveys+ DES3yr+ Pantheon+

Pantheon+: SNIa Hubble diagram (Brout et al., 2022), for ΛCDM):

$$\Omega_M = 0.338 \pm 0.018$$

RSD from surveys+ DES3yr+ Pantheon+

Pantheon+: SNIa Hubble diagram (Brout et al., 2022), for ΛCDM):

$$\Omega_M = 0.338 \pm 0.018$$

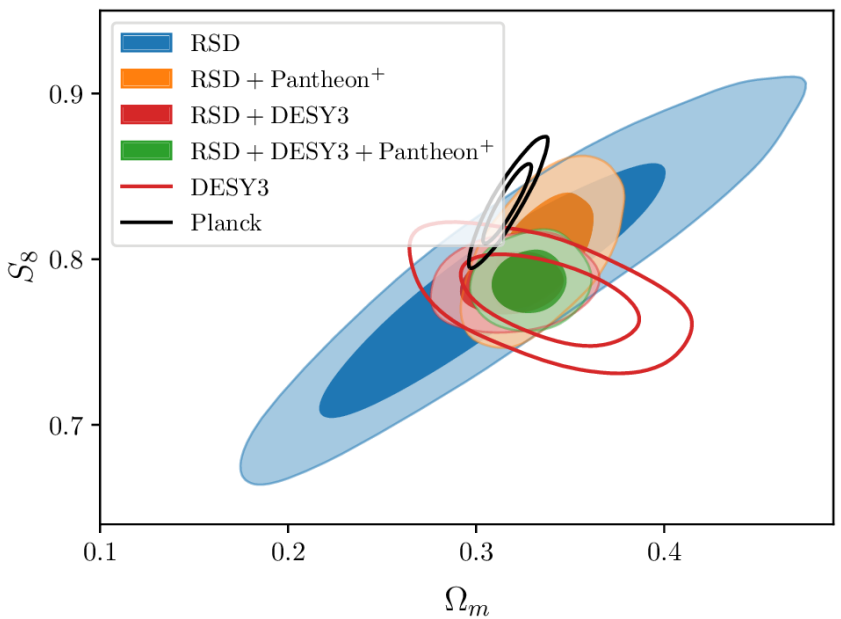
DES 3yr

RSD from surveys+ DES3yr+ Pantheon+

Pantheon+: SNIa Hubble diagram (Brout et al., 2022), for ΛCDM):

$$\Omega_M = 0.338 \pm 0.018$$

DES 3yr

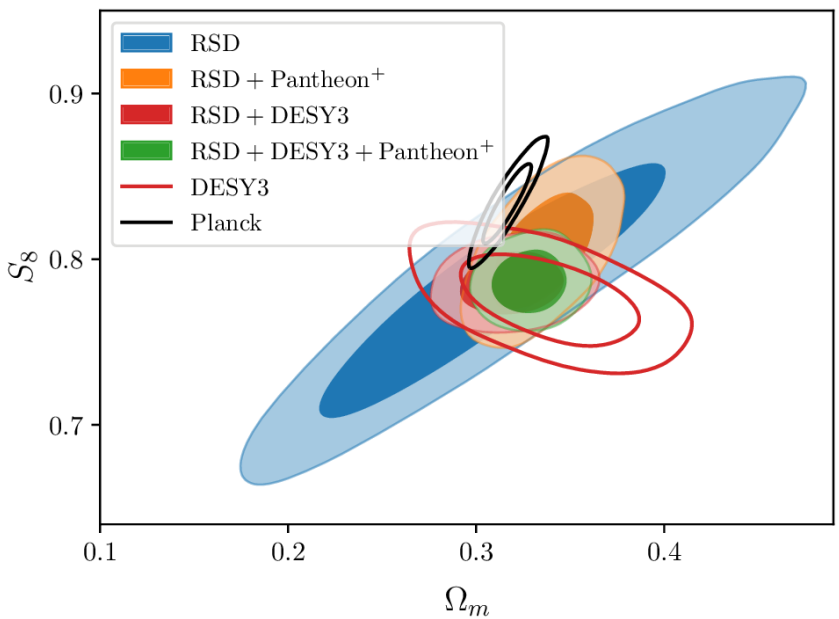


RSD from surveys+ DES3yr+ Pantheon+

Pantheon+: SNIa Hubble diagram (Brout et al., 2022), for ΛCDM):

$$\Omega_M = 0.338 \pm 0.018$$

DES 3yr



$$\boxed{S_8 = 0.788 \pm 0.012}$$

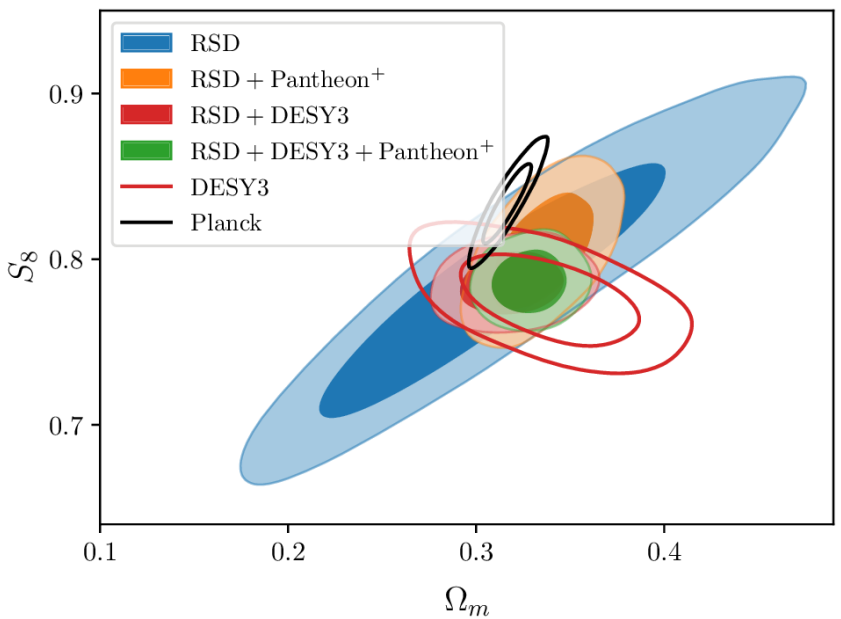
(DES3yr $S_8 = 0.776 \pm 0.018$)

RSD from surveys+ DES3yr+ Pantheon+

Pantheon+: SNIa Hubble diagram (Brout et al., 2022), for ΛCDM):

$$\Omega_M = 0.338 \pm 0.018$$

DES 3yr



$$\boxed{S_8 = 0.788 \pm 0.012}$$

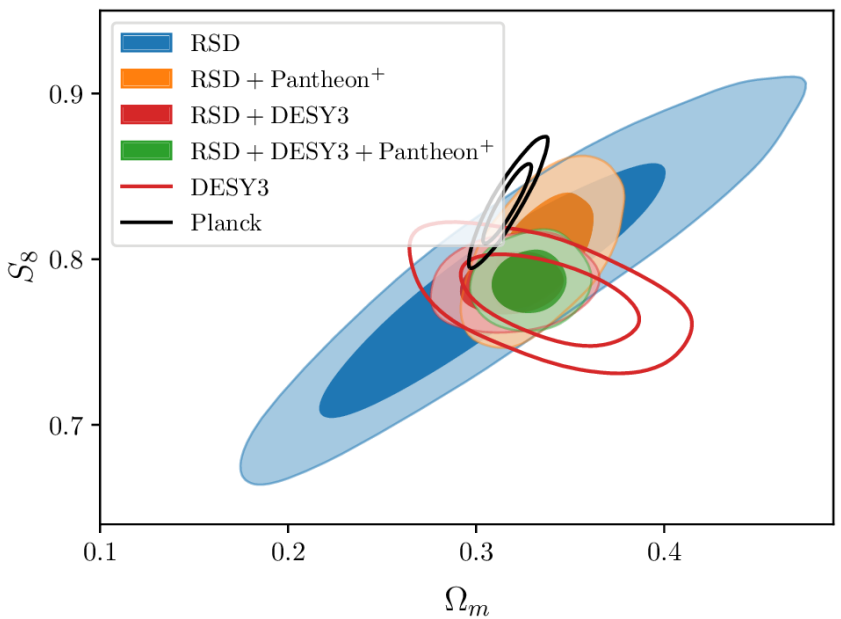
(DES3yr $S_8 = 0.776 \pm 0.018$) Final tension with Planck: 2.3 σ

RSD from surveys+ DES3yr+ Pantheon+

Pantheon+: SNIa Hubble diagram (Brout et al., 2022), for ΛCDM):

$$\Omega_M = 0.338 \pm 0.018$$

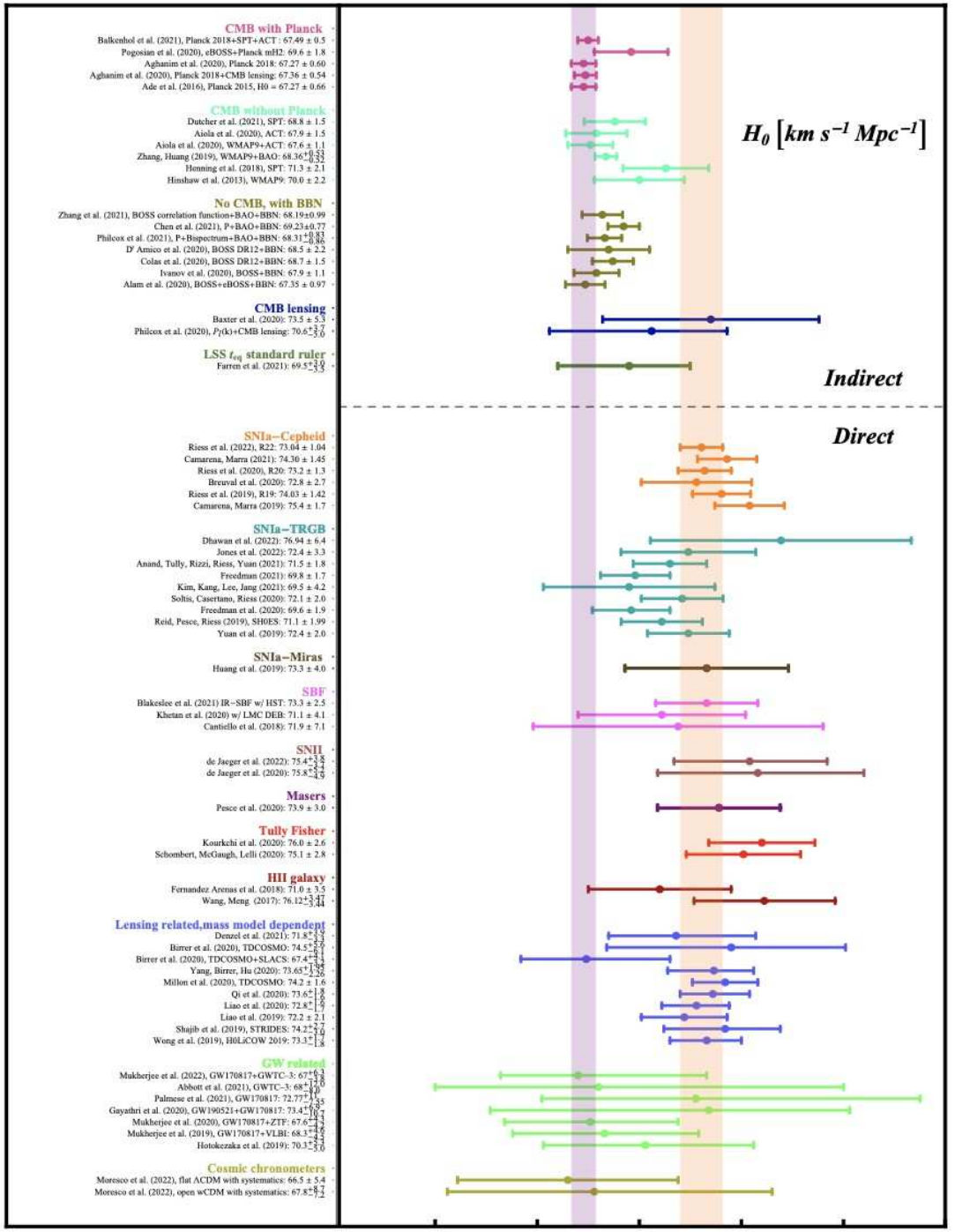
DES 3yr



$$\boxed{S_8 = 0.788 \pm 0.012}$$

(DES3yr $S_8 = 0.776 \pm 0.018$) Final tension with Planck: 2.3 σ

$$\boxed{\Omega_M = 0.327 \pm 0.013}$$


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$^{+0.33}_{-0.33}$
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$^{+0.82}_{-0.86}$
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_T(k)+CMB lensing: 70.6$^{+3.7}_{-3.0}$
LSS t_{eq} standard ruler
Farren et al. (2021): 69.5$^{+1.9}_{-3.3}$
H_0 [km s^{-1} Mpc^{-1}]
Indirect
Direct
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$^{+3.8}_{-3.9}$
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$^{+1.84}_{-2.26}$
Millon et al. (2020), TDCOSMO: 74.2 ± 1.6
Qi et al. (2020): 73.6$^{+1.8}_{-1.7}$
Liao et al. (2020): 72.8$^{+1.7}_{-1.7}$
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$^{+6.3}_{-5.5}$
Abbott et al. (2021), GWTC-3: 68$^{+8.5}_{-4.5}$
Palmese et al. (2021), GW170817: 72.77$^{+6.99}_{-7.55}$
Gayathri et al. (2020), GW190521+GW170817: 73.4$^{+12.7}_{-10.7}$
Mukherjee et al. (2020), GW170817+ZTF: 67.6$^{+4.3}_{-4.6}$
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$^{+9.1}_{-7.2}$
60
65
70
75
80
85

Measuring the Tension

Simple:

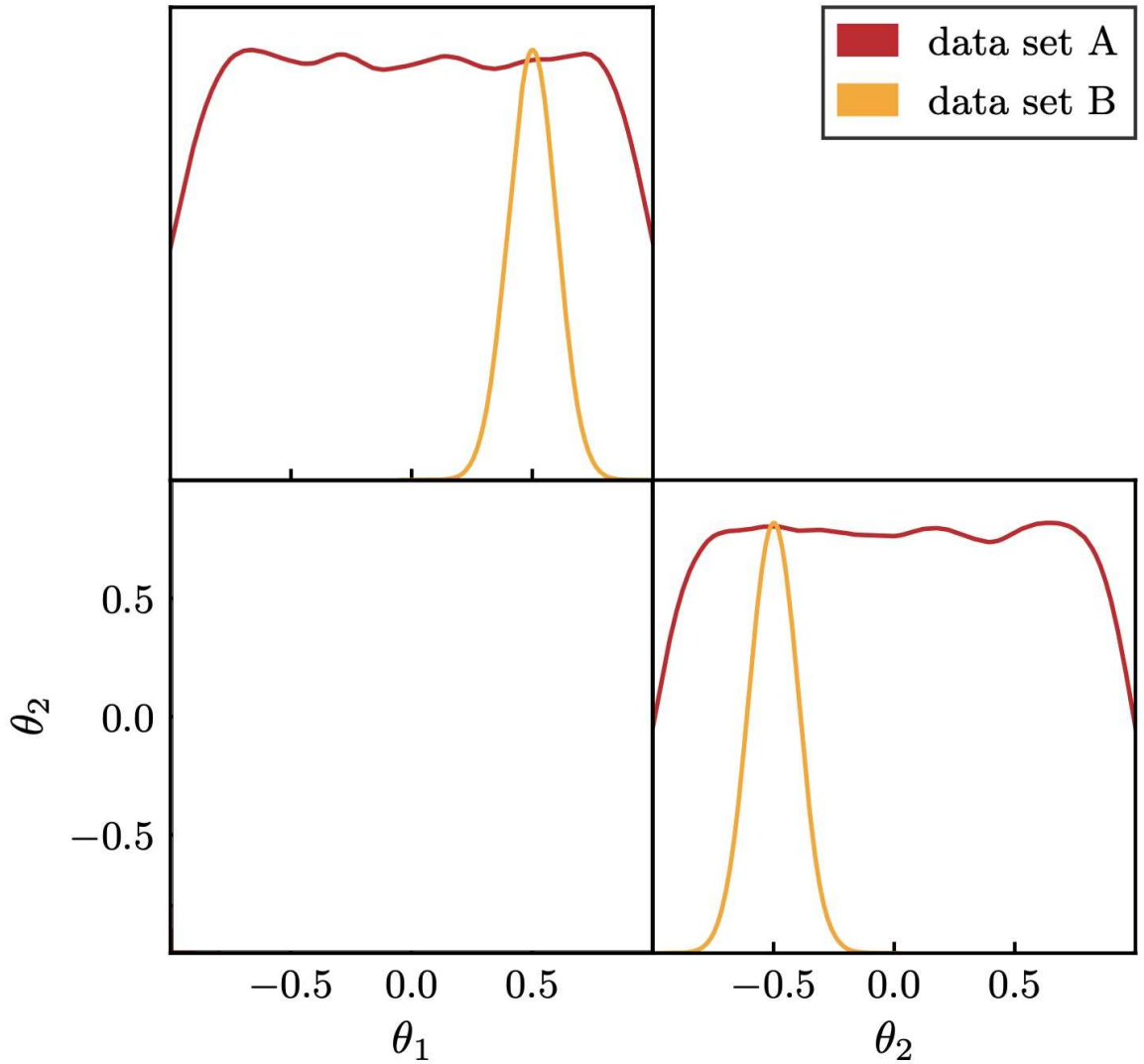
$$\nu = \frac{O_1 - O_2}{\sqrt{\sigma_1^2 + \sigma_2^2}}$$

Measuring the Tension

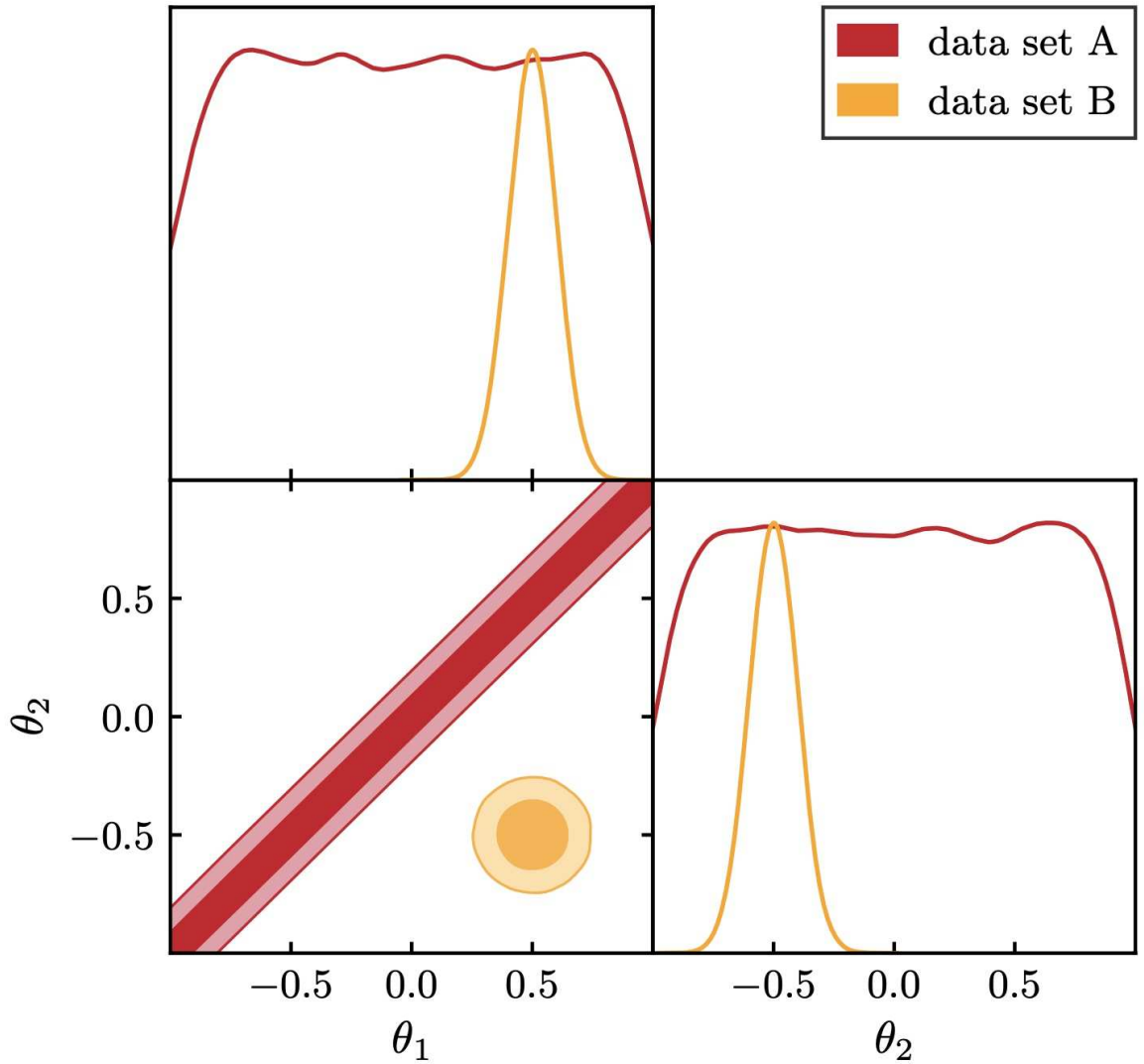
Simple:

$$\nu = \frac{O_1 - O_2}{\sqrt{\sigma_1^2 + \sigma_2^2}}$$

Not necessarily measuring the full tension...

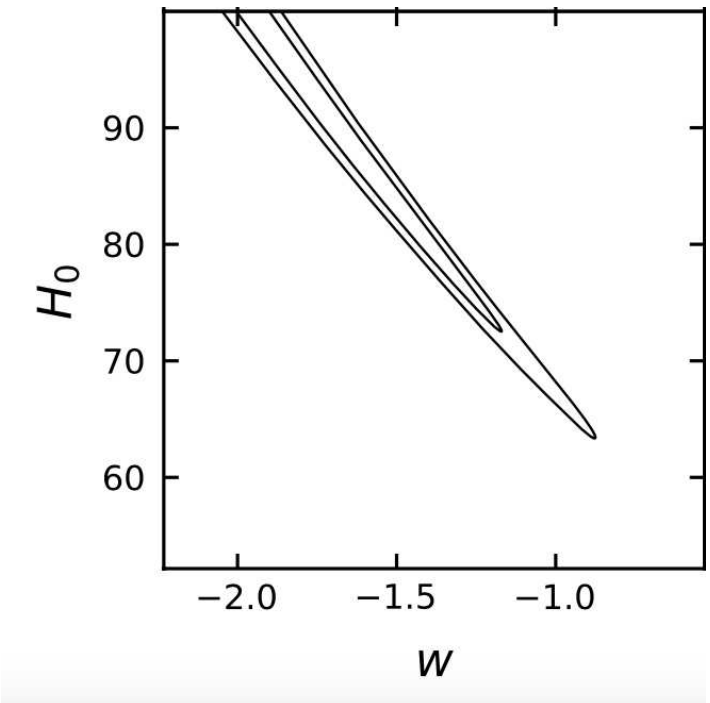


Lemos et al. (2021)

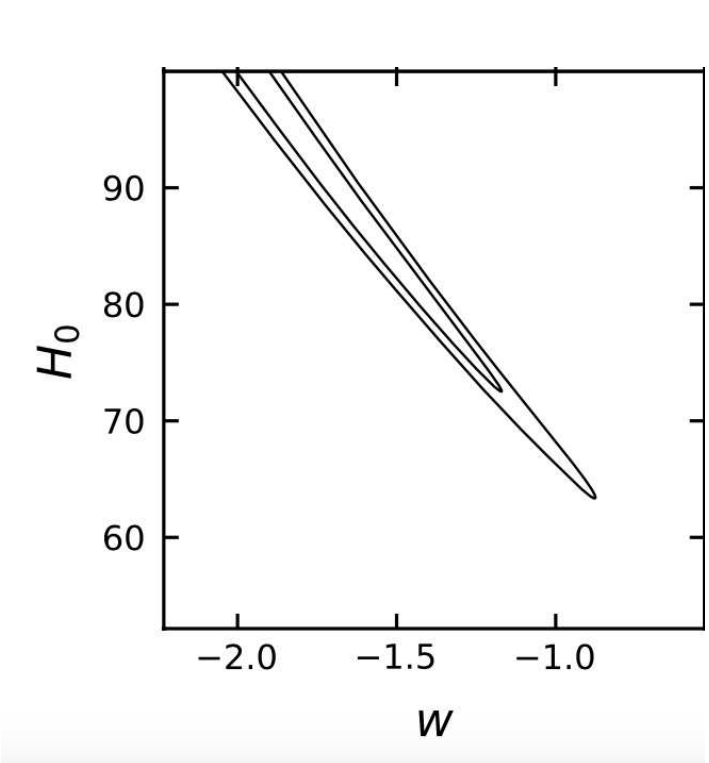


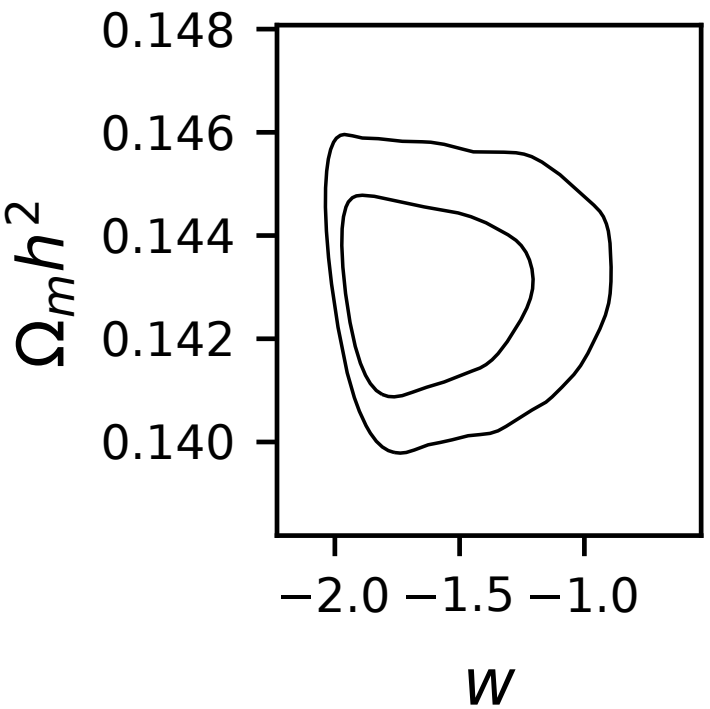
Lemos et al. (2021)

CMB with SH0ES



CMB with SH0ES





A (new) stress test for extensions...

With :

$$\Omega_M = 0.327 \pm 0.013$$

A (new) stress test for extensions...

With :

$$\Omega_M = 0.327 \pm 0.013$$

using SH0ES: $H_0 = 73.3 \pm 1.04$ km/s/Mpc

A (new) stress test for extensions...

With :

$$\Omega_M = 0.327 \pm 0.013$$

using SH0ES: $H_0 = 73.3 \pm 1.04$ km/s/Mpc we can infer :

$$\omega_M = 0.1753 \pm 0.0069$$

A (new) stress test for extensions...

With :

$$\Omega_M = 0.327 \pm 0.013$$

using SH0ES: $H_0 = 73.3 \pm 1.04$ km/s/Mpc we can infer :

$$\omega_M = 0.1753 \pm 0.0069$$

compared to Planck (+ext):

$$\omega_M = 0.1425 \pm 0.0012$$

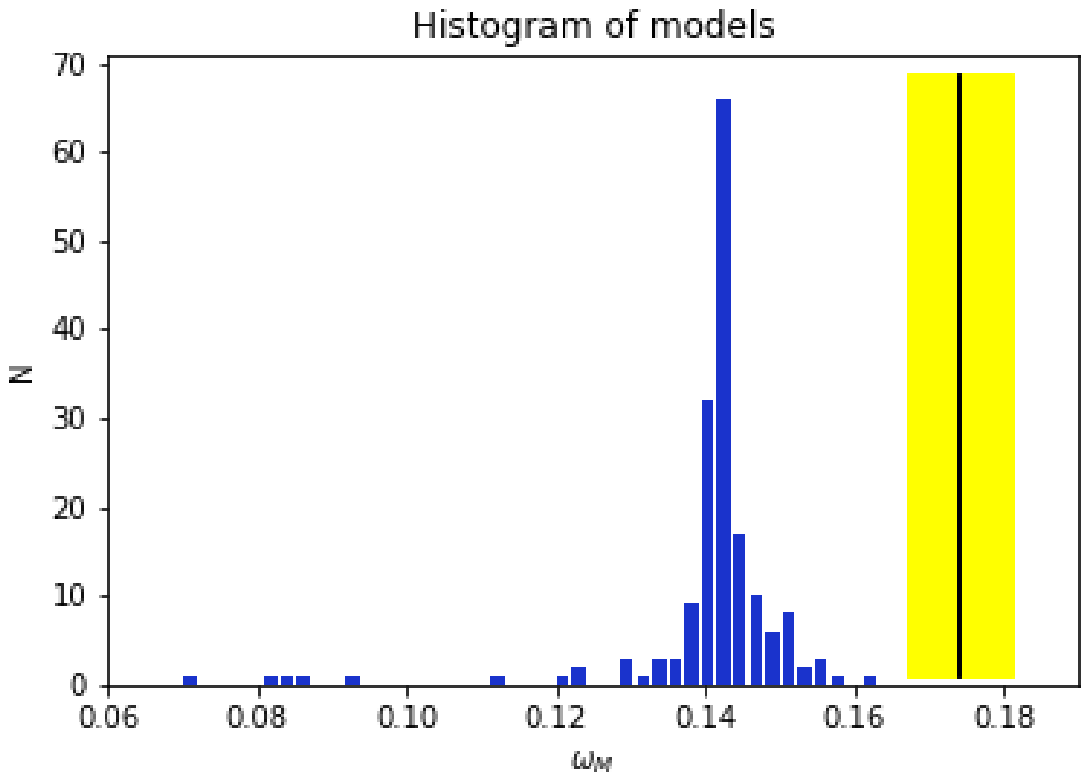
4.7 σ away for ΛCDM

A (new) stress test for extensions...

Let's take the $\sim$ 200 models summarized in Di Valentino et al. (2021) In the realm of the Hubble tension – a review of solutions

A (new) stress test for extensions...

Let's take the $\sim$ 200 models summarized in Di Valentino et al. (2021) In the realm of the Hubble tension – a review of solutions



Conclusions

- ΛCDM is a 40-years old theory that matches remarkably well data at cosmological scales.

Conclusions

- ΛCDM is a 40-years old theory that matches remarkably well data at cosmological scales.
- Tensions are a serious concern anyway.

Conclusions

- ΛCDM is a 40-years old theory that matches remarkably well data at cosmological scales.
- Tensions are a serious concern anyway.
- S_8 tension seems not strong enough, i.e. no tension!

Conclusions

- ΛCDM is a 40-years old theory that matches remarkably well data at cosmological scales.
- Tensions are a serious concern anyway.
- S_8 tension seems not strong enough, i.e. no tension!
- Low redhsift universe seems to have $\Omega_M \sim 0.32$

Conclusions

- ΛCDM is a 40-years old theory that matches remarkably well data at cosmological scales.
- Tensions are a serious concern anyway.
- S_8 tension seems not strong enough, i.e. no tension!
- Low redhsift universe seems to have $\Omega_M \sim 0.32$
- ω_M provides a metric for extensions likely to be more discriminant.

Conclusions

- ΛCDM is a 40-years old theory that matches remarkably well data at cosmological scales.
- Tensions are a serious concern anyway.
- S_8 tension seems not strong enough, i.e. no tension!
- Low redhsift universe seems to have $\Omega_M \sim 0.32$
- ω_M provides a metric for extensions likely to be more discriminant.
- This would mean for $H_0 \sim 73$ in serious conflict with Planck.

Thank You