

Tensions in Λ CDM: the amplitude of matter fluctuations

A. Blanchard



Toulouse, December 15th, 2021



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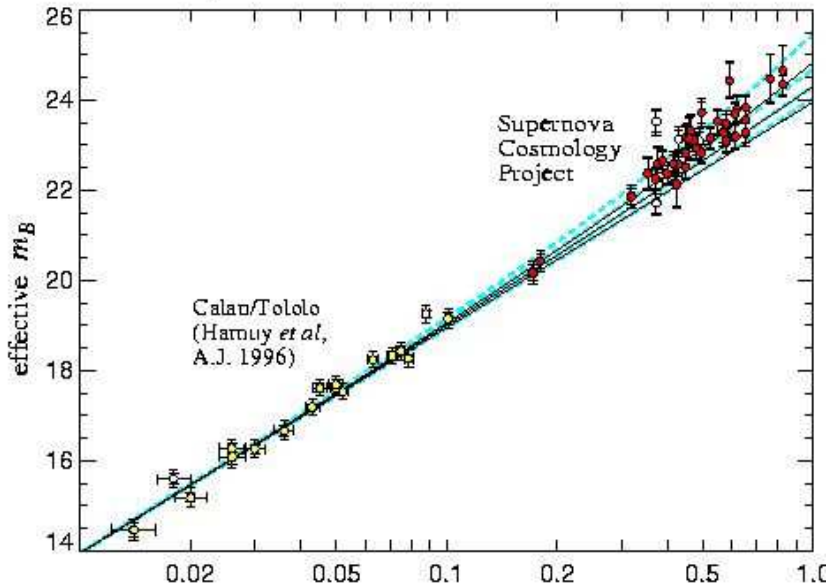
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Peebles & Ratra (1988) cared about Λ and introduced quintessence...

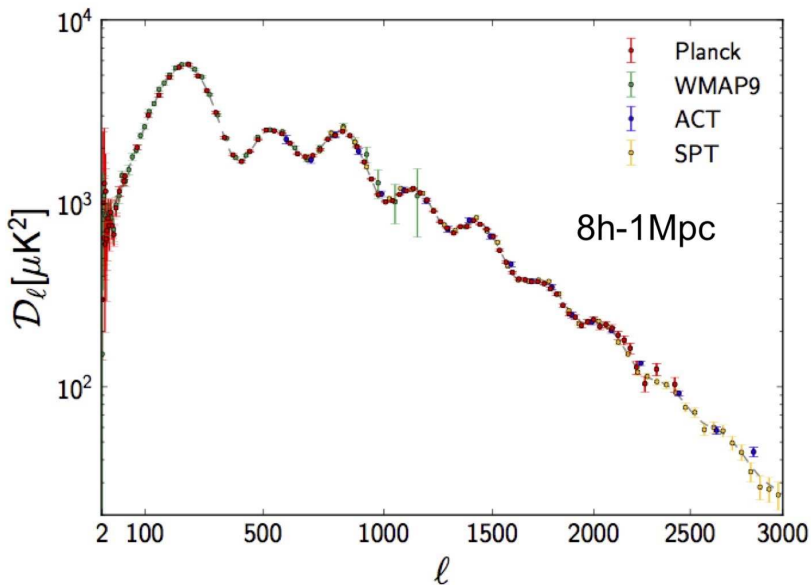
Evidence for acceleration...

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SN Ia Hubble-Lemaître diagramm (1998-1999)



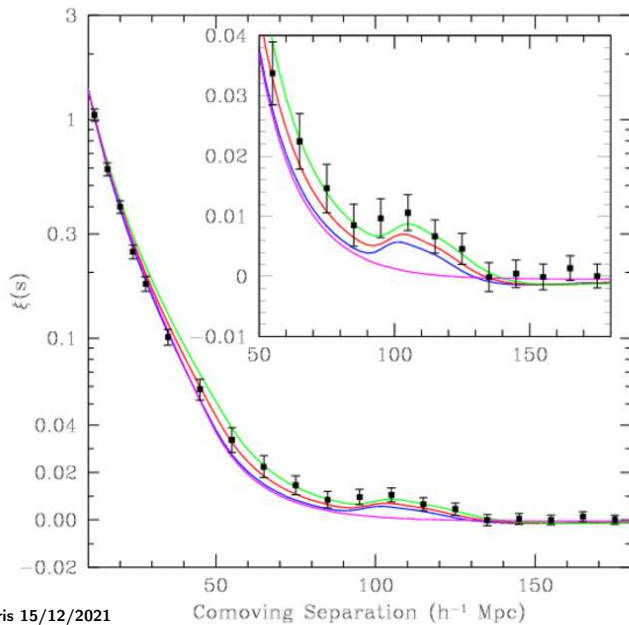
Planck Collaboration: The *Planck* mission



Planck results...

Parameter	TT+lowE 68% limits	TE+lowE 68% limits	EE+lowE 68% limits	TT,TE,EE+lowE 68% limits	TT,TE,EE+lowE+lensing 68% limits	TT,TE,EE+lowE+lensing+BAO 68% limits
$\Omega_b h^2$	0.02212 ± 0.0002	0.02249 ± 0.00025	0.0240 ± 0.0012	0.02236 ± 0.00015	0.02237 ± 0.00015	0.02242 ± 0.00014
$\Omega_c h^2$	0.1206 ± 0.0021	0.1177 ± 0.0020	0.1158 ± 0.0046	0.1202 ± 0.0014	0.1200 ± 0.0012	0.11933 ± 0.00091
100 θ_{MC}	1.04077 ± 0.00047	1.04139 ± 0.00049	1.03999 ± 0.00089	1.04090 ± 0.00031	1.04092 ± 0.00031	1.04101 ± 0.00029
τ	0.0522 ± 0.0080	0.0496 ± 0.0085	0.0527 ± 0.0090	0.0544 ^{+0.0070} _{-0.0081}	0.0544 ± 0.0073	0.0561 ± 0.0071
$\ln(10^{10} A_s)$	3.040 ± 0.016	3.018 ^{+0.020} _{-0.018}	3.052 ± 0.022	3.045 ± 0.016	3.044 ± 0.014	3.047 ± 0.014
n_s	0.9626 ± 0.0057	0.967 ± 0.011	0.980 ± 0.015	0.9649 ± 0.0044	0.9649 ± 0.0042	0.9665 ± 0.0038
H_0 [km s ⁻¹ Mpc ⁻¹]	66.88 ± 0.92	68.44 ± 0.91	69.9 ± 2.7	67.27 ± 0.60	67.36 ± 0.54	67.66 ± 0.42
Ω_Λ	0.69 ± 0.01	0.699 ± 0.012	0.711 ^{+0.033} _{-0.026}	0.6834 ± 0.0084	0.6847 ± 0.0073	0.6807 ± 0.0036
Ω_m	0.321 ± 0.013	0.301 ± 0.012	0.289 ^{+0.026} _{-0.033}	0.3166 ± 0.0084	0.3153 ± 0.0073	0.3111 ± 0.0056
$\Omega_b h^2$	0.1434 ± 0.0020	0.1408 ± 0.0019	0.1404 ^{+0.0034} _{-0.0039}	0.1432 ± 0.0013	0.1430 ± 0.0011	0.14240 ± 0.00087
$\Omega_c h^2$	0.09589 ± 0.00046	0.09635 ± 0.00051	0.0981 ^{+0.0016} _{-0.0018}	0.09633 ± 0.00029	0.09633 ± 0.00030	0.09605 ± 0.00030
σ_8	0.8118 ± 0.0089	0.793 ± 0.011	0.796 ± 0.018	0.8120 ± 0.0073	0.8111 ± 0.0060	0.8102 ± 0.0060
$S_8 \equiv \sigma_8(\Omega_m/0.3)^{0.5}$	0.840 ± 0.024	0.794 ± 0.024	0.781 ^{+0.022} _{-0.040}	0.834 ± 0.016	0.832 ± 0.013	0.825 ± 0.011
$\sigma_8 \Omega_m^{0.25}$	0.611 ± 0.012	0.587 ± 0.012	0.583 ± 0.027	0.6090 ± 0.0081	0.6078 ± 0.0064	0.6051 ± 0.0058
$\bar{\omega}_8$	7.50 ± 0.82	7.11 ^{+0.91} _{-0.75}	7.10 ^{+0.87} _{-0.73}	7.68 ± 0.79	7.67 ± 0.73	7.82 ± 0.71
10 ¹⁰ A _s	2.092 ± 0.034	2.045 ± 0.041	2.116 ± 0.047	2.101 ^{+0.031} _{-0.034}	2.100 ± 0.030	2.105 ± 0.030
10 ¹⁰ A _s e ^{-2τ}	1.884 ± 0.014	1.851 ± 0.018	1.904 ± 0.024	1.884 ± 0.012	1.883 ± 0.011	1.881 ± 0.010
Age [Gyr]	13.830 ± 0.037	13.761 ± 0.038	13.64 ^{+0.16} _{-0.14}	13.800 ± 0.024	13.797 ± 0.023	13.787 ± 0.020

Parameter	TT+lowE	TT, TE, EE+lowE	TT, TE, EE+lowE+lensing	TT, TE, EE+lowE+lensing+BAO
Ω_E	-0.056 ^{+0.044} _{-0.050}	-0.044 ^{+0.033} _{-0.034}	-0.011 ^{+0.013} _{-0.012}	0.0007 ^{+0.0037} _{-0.0037}
Σm_ν [eV]	< 0.537	< 0.257	< 0.241	< 0.120
N_{eff}	3.00 ^{+0.37} _{-0.53}	2.92 ^{+0.36} _{-0.37}	2.89 ^{+0.36} _{-0.38}	2.99 ^{+0.34} _{-0.33}
Y_p	0.246 ^{+0.039} _{-0.041}	0.240 ^{+0.024} _{-0.025}	0.239 ^{+0.024} _{-0.025}	0.242 ^{+0.023} _{-0.024}
$dn_s/d \ln k$	-0.001 ^{+0.015} _{-0.015}	-0.006 ^{+0.013} _{-0.013}	-0.005 ^{+0.013} _{-0.013}	-0.004 ^{+0.013} _{-0.013}
$r_{0.002}$	< 0.102	< 0.107	< 0.101	< 0.106
w_0	-1.56 ^{+0.60} _{-0.48}	-1.58 ^{+0.52} _{-0.41}	-1.57 ^{+0.50} _{-0.40}	-1.04 ^{+0.10} _{-0.10}



The location of the BAO peak is well measured.

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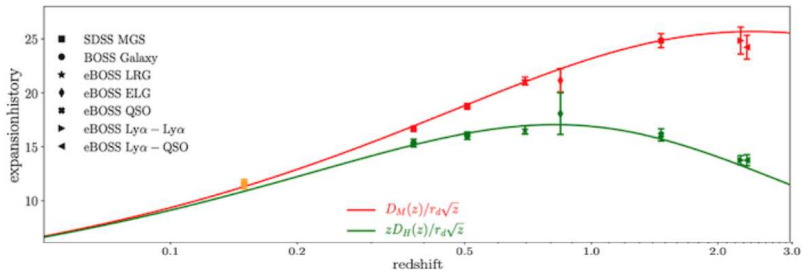
Physical origin simple -> sound horizon:

$$r_s = \int_{z_*}^{+\infty} \frac{c_s(t) dt}{R(t)} \propto \int_{z_*}^{+\infty} \frac{c_s(z) dz}{\rho(z)} \quad (1)$$

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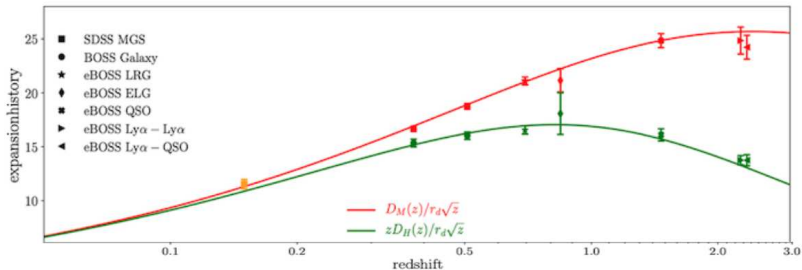
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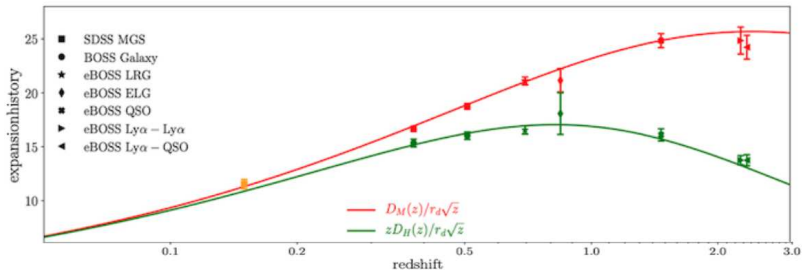
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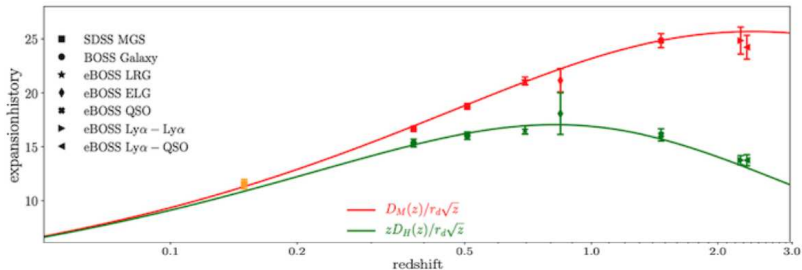
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CMB (T) + BBN + SNIa

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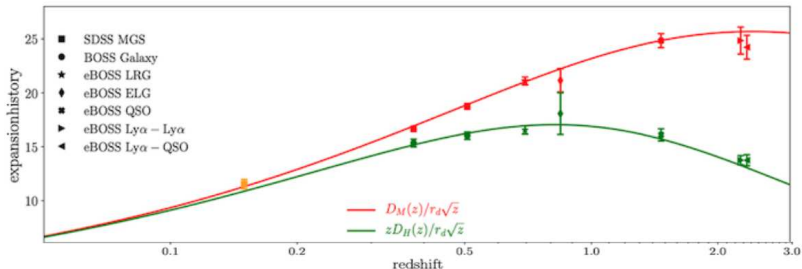


CMB (T) + BBN + SNIa

Provides independent measure of H_0 ...

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Provides independent measure of $H_0 \dots = 67.5 \pm 1$ km/s/Mpc

Where the tensions come...

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H_0 can be measured “locally”...

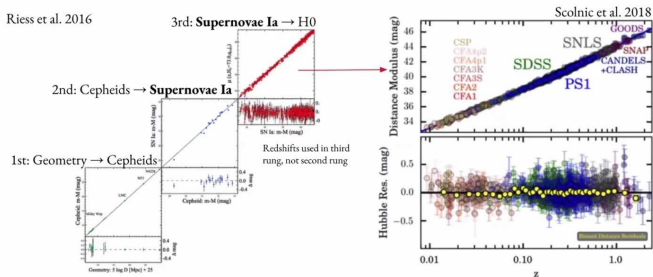
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Recording

(Merci, Brahim!)

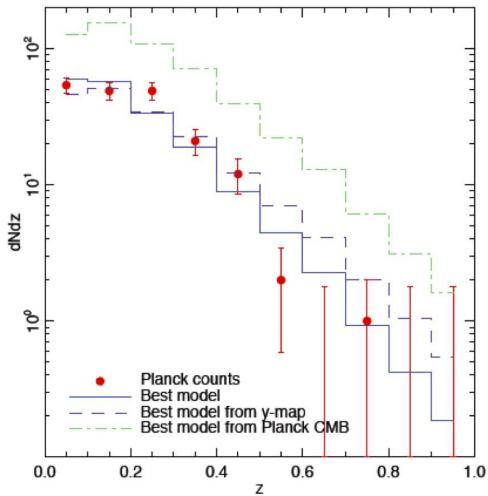
Type Ia Supernovae (SNe Ia) and Cepheids are standardizable candles



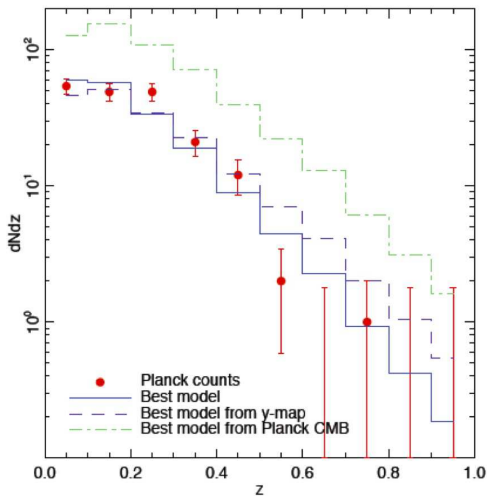
$H_0 = 73,04 \pm 1$ km/s/Mpc

The key (of our work) is to make SNe Ia (or Cepheids) consistent between their respective rungs, so impact of systematics is small. Only impact if there is a difference between objects in their different rungs.

The Planck clusters-CMB tension

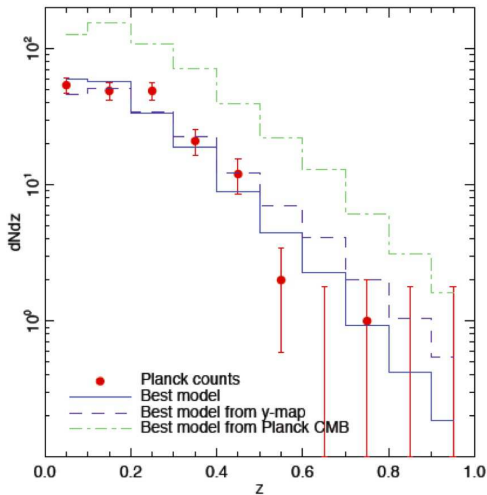


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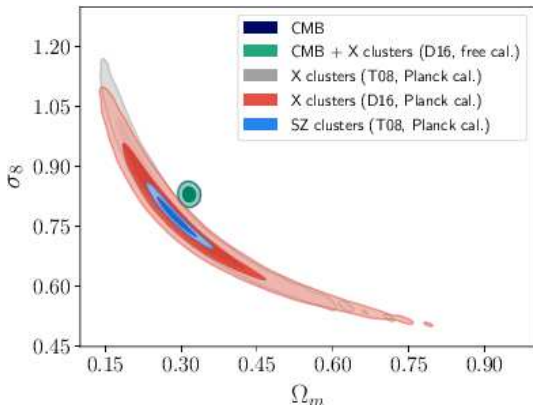
The "tension" is relieved if $\sigma_8 \sim 0.75$.

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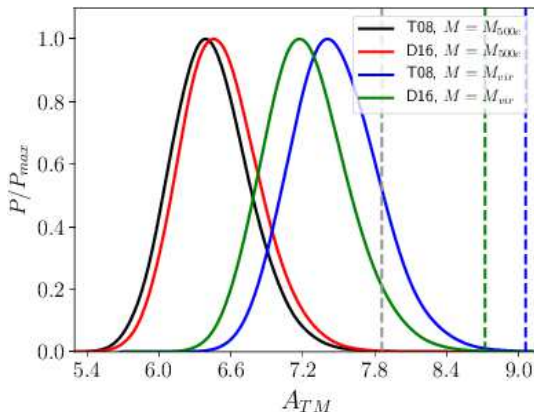
The cluster-CMB tension (in Λ CDM)



No sign of systematics between x-ray clusters ($z \sim 0.05$) and SZ clusters ($z \sim 0.25$)

How strong is the tension ?

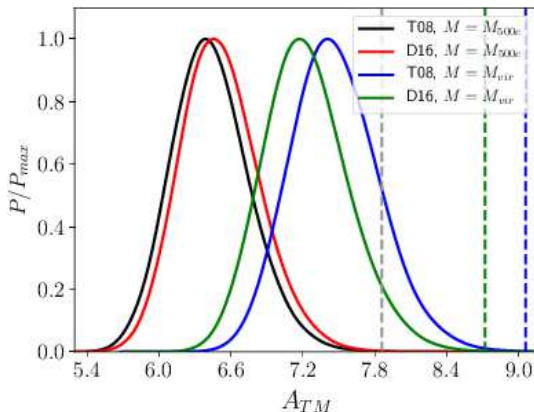
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Sakr, Ilić & Blanchard(2018)

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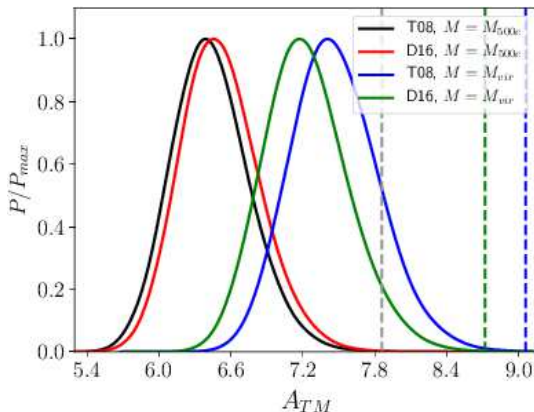
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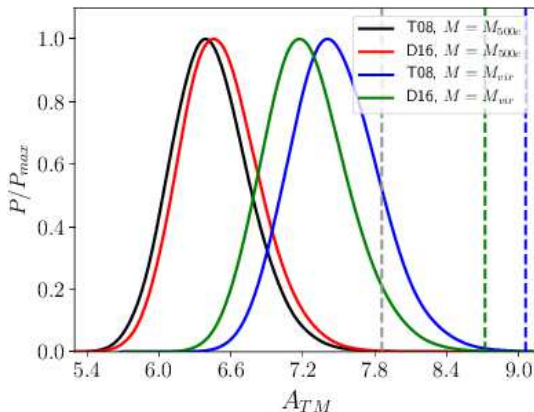
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From $\geq 6\sigma$...down to 0!

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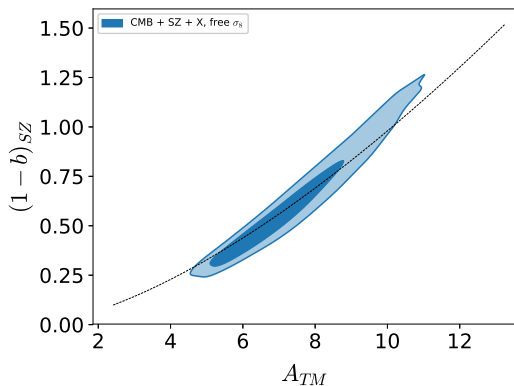
Astrophysics

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- Modification in the gravitational sector (MG).

X-ray+SZ+CMB but free σ_8 .



Ilić, Sakr & Blanchard(2019)

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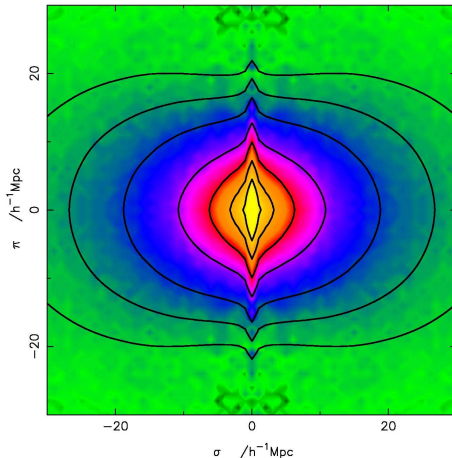
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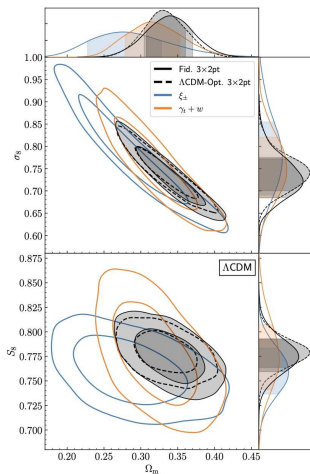
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Hawkins et al. (2002), astro-ph/0212375

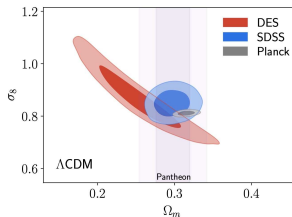
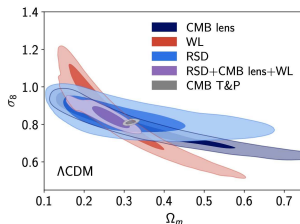
2dFGRS: $\beta = 0.49 \pm 0.09$



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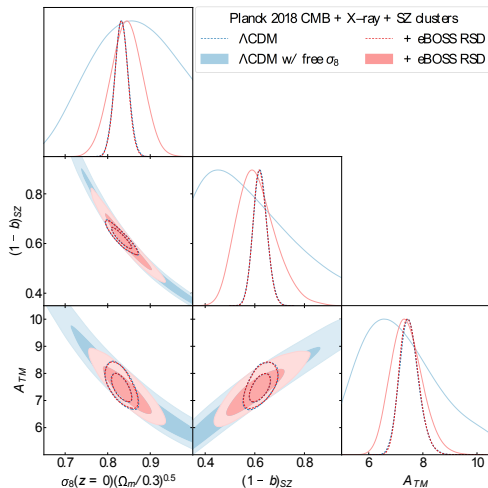
(a) DES3yr 3x2pt



(b) eBOSS

Planck+eBOSS+X-ray+SZ

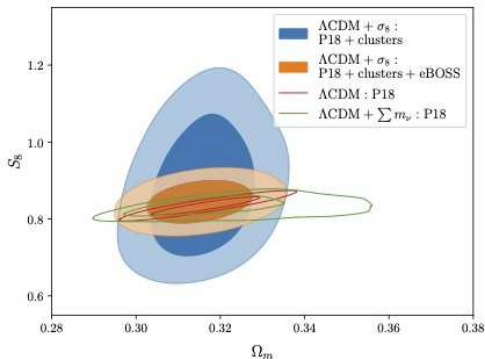
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Blanchard & Ilić (2021)

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- No tension on σ_8 at low z ...

Thank You