SZ-Clusters as Cosmological probe Constraints & systematics

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with

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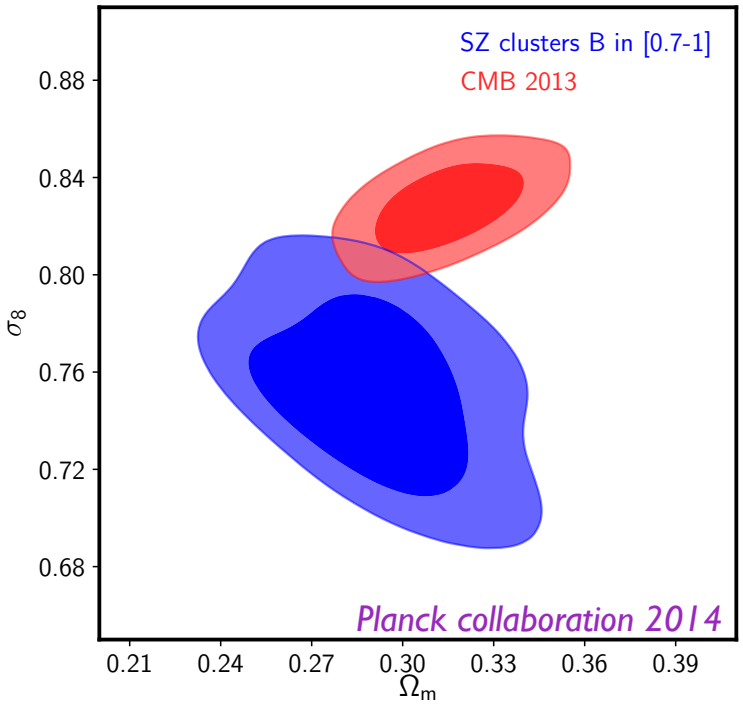
CONSTRAINTS FROM CLUSTERS



PLANCK SZ CLUSTERS TENSION ?

EVOLUTION SINCE 2013
STATUS

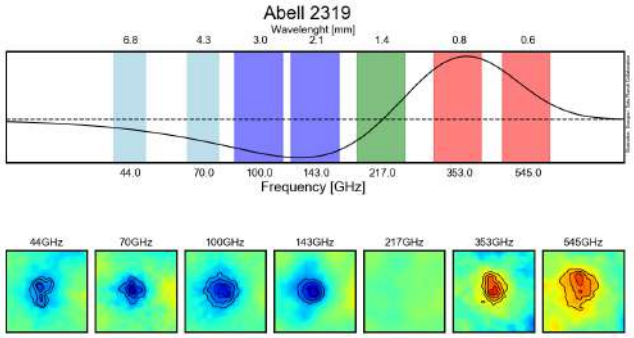
SYSTEMATICS AT PLAY ?

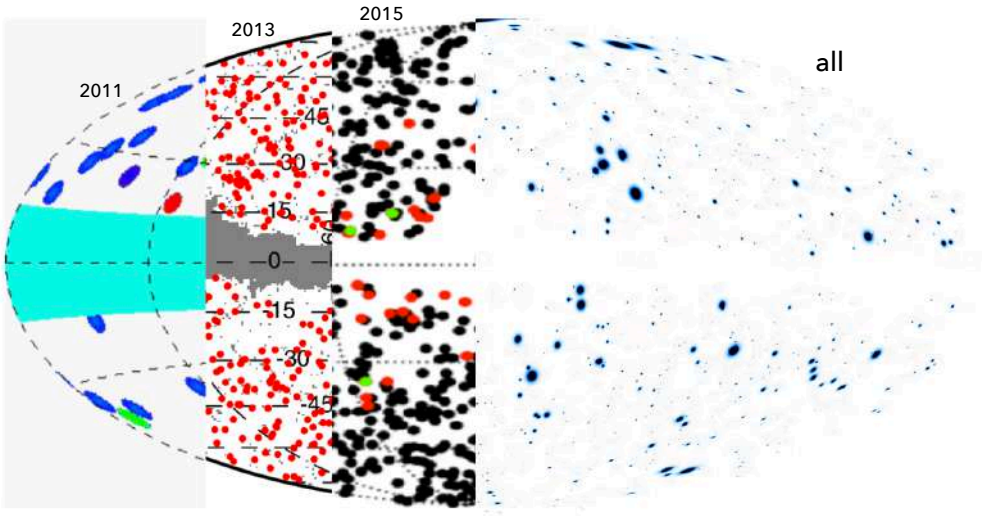
COSMOLOGICAL MODEL
HYDROSTATIC MASS BIAS

FUTURE OPTICAL SURVEYS CLUSTERS

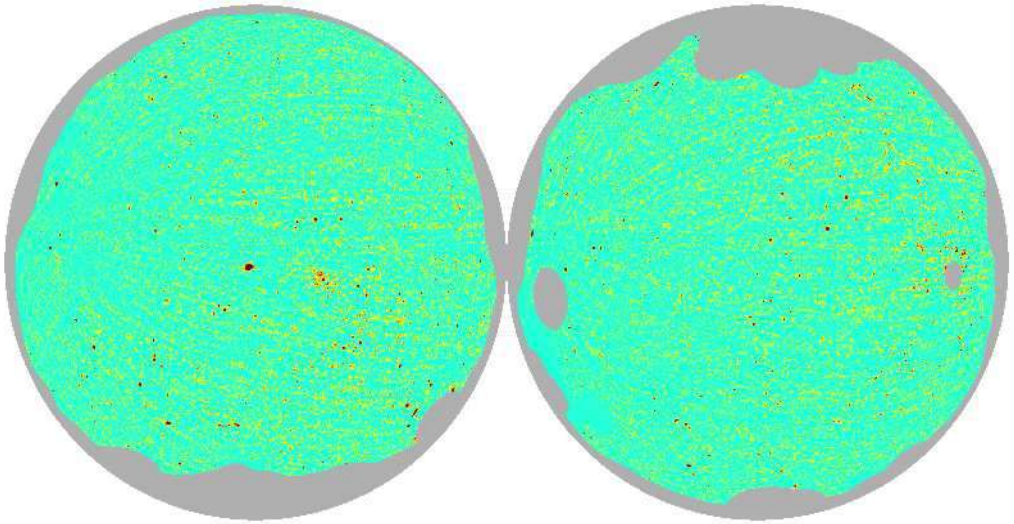
EXPECTED ROLE OF SYSTEMATICS

tSZ Planck signal





1653 cluster candidates, today >1100 with z

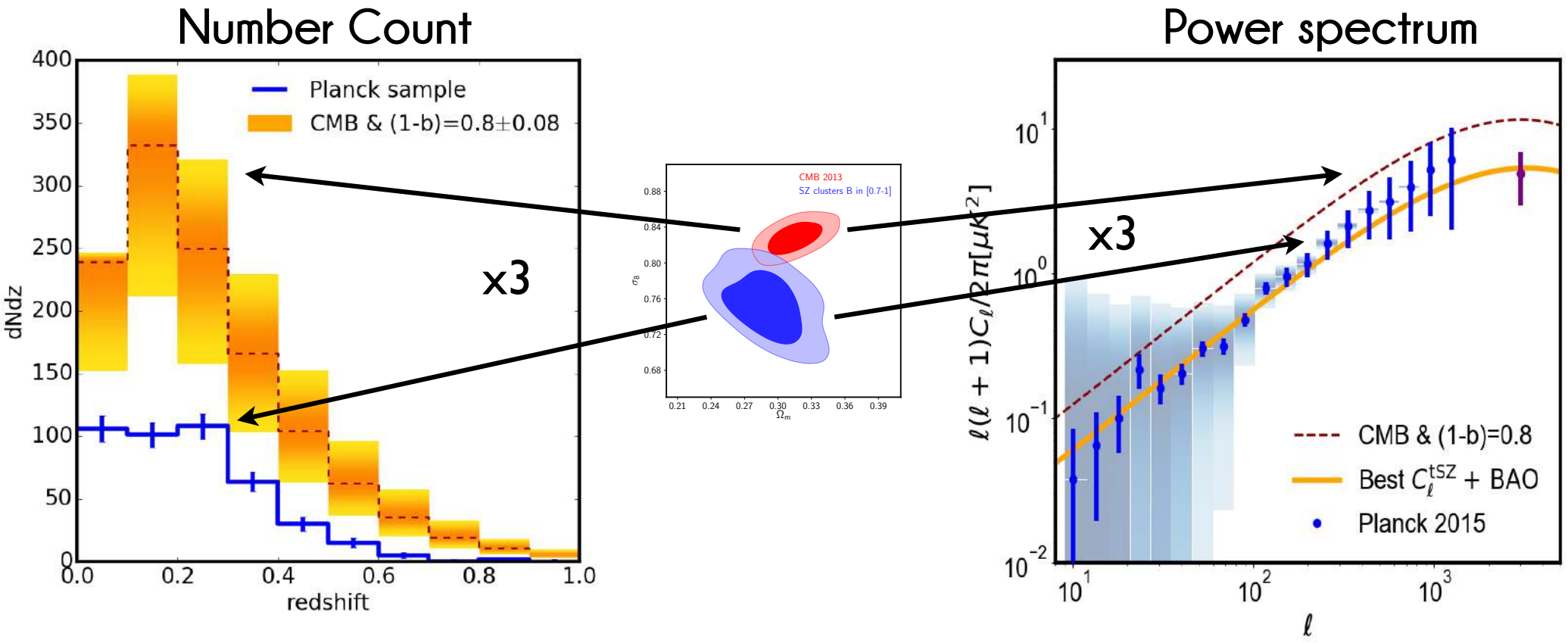


first full sky hot gas map

Planck collaboration 2011, 2014, 2016
compilation available at szcluster-db.ias.u-psud.fr

Planck collaboration 2014, 2016

tSZ Cosmological Probes



$$dN \propto \sigma_8^9\ \Omega_m^3\ (1-b)^{3.6}$$

$$C_\ell \propto \sigma_8^{8.1}\ \Omega_m^{3.2}\ (1-b)^{3.2}$$

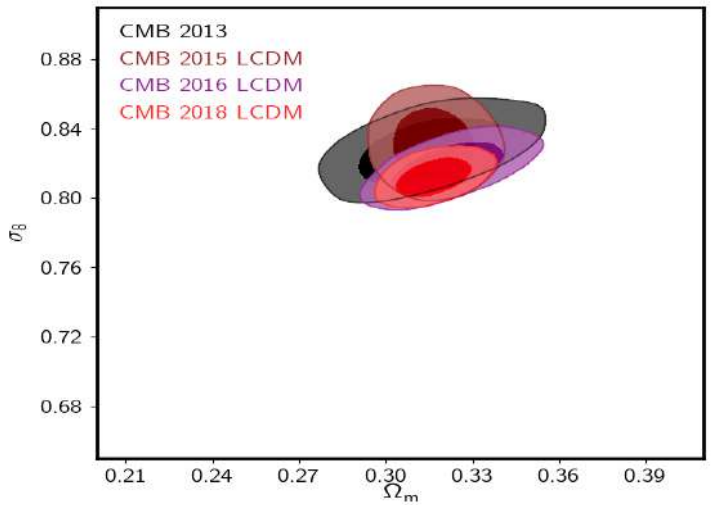
Salvati, Douspis, Aghanim (2018)

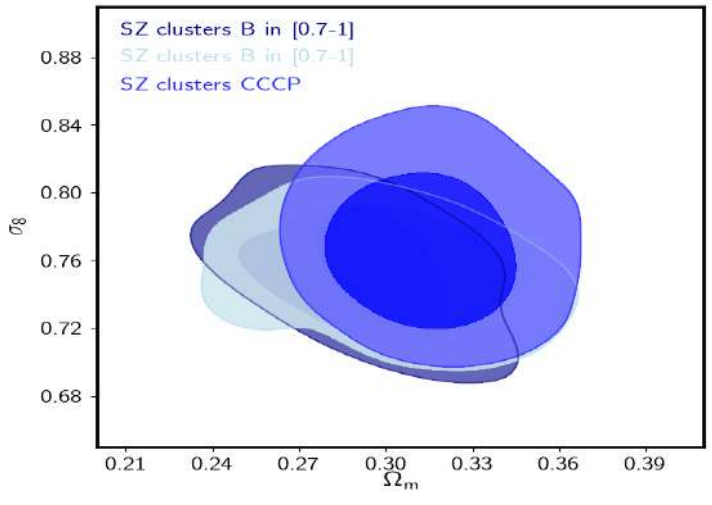
SINCE 2013

- CMB 2013
  - polarisation from WMAP
- CMB 2015
  - Polarisation from LFI
- CMB 2016 (2018)
  - Polarisation from HFI

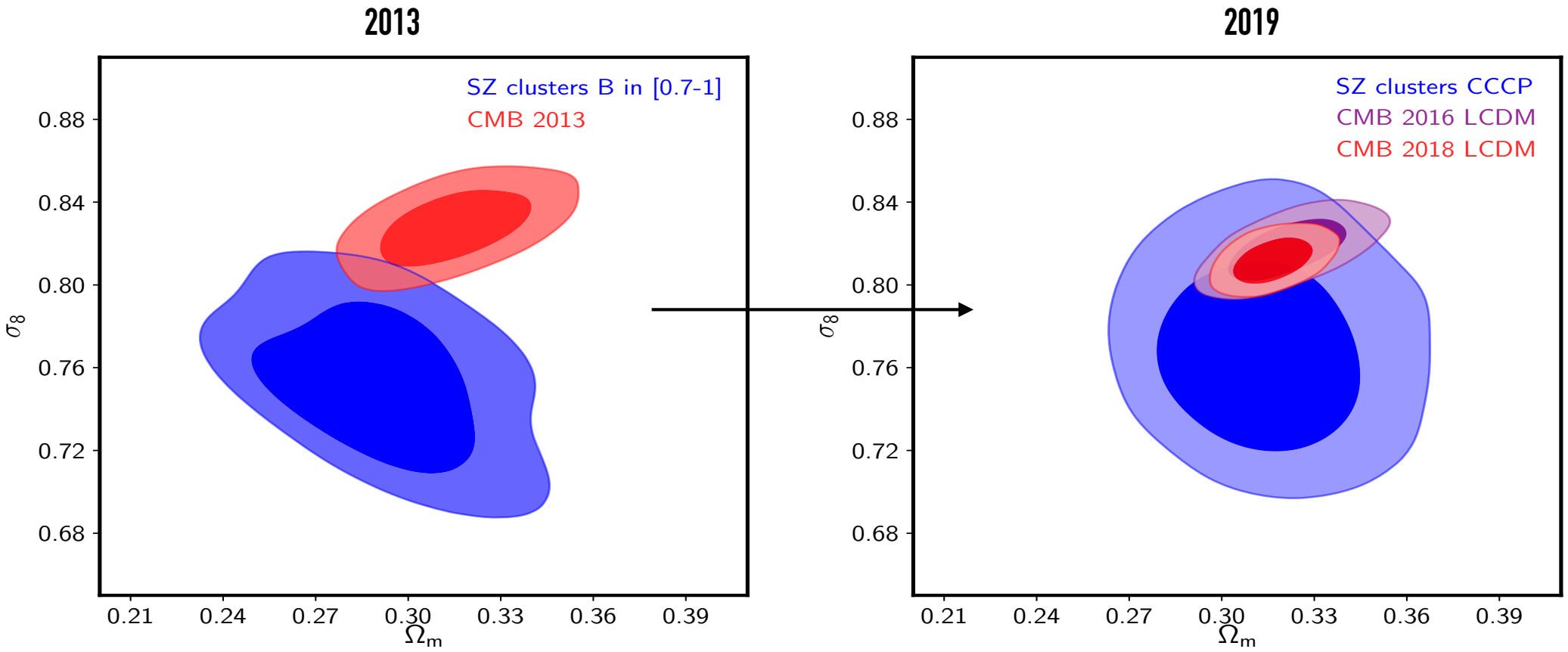
→ better estimation of τ (low reionisation optical depth)

- Clusters 2013 (189)
  - slope Y-M from 71 clusters
  - amplitude from <12 sims>
  - (1-b) in [0.7-1]: <>=0.8
- Clusters 2015 (439)
  - CCCP lensing bias estimate
  - (1-b) ~ 0.78±0.1
  - no z evolution, dN(z,q)





STATUS 2018 A



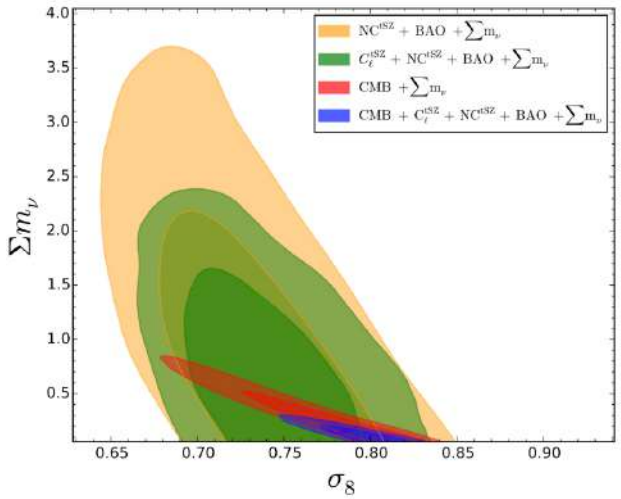
Planck Collaboration 2014

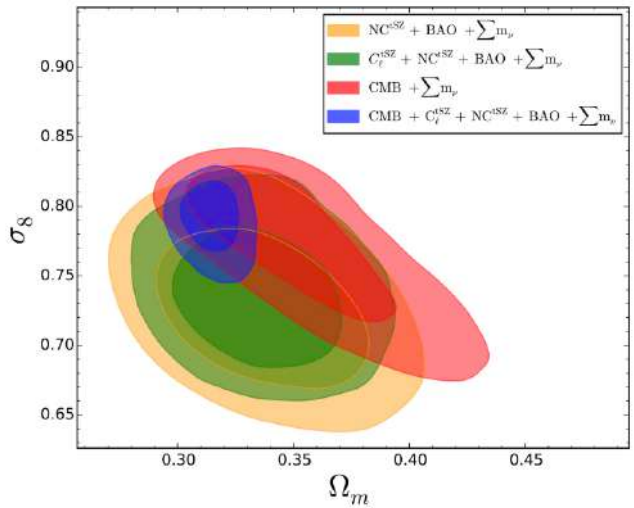
Salvati, Douspis, Aghanim (2018)

Since 2018 Tension σ_8-Ω_m is reduced !

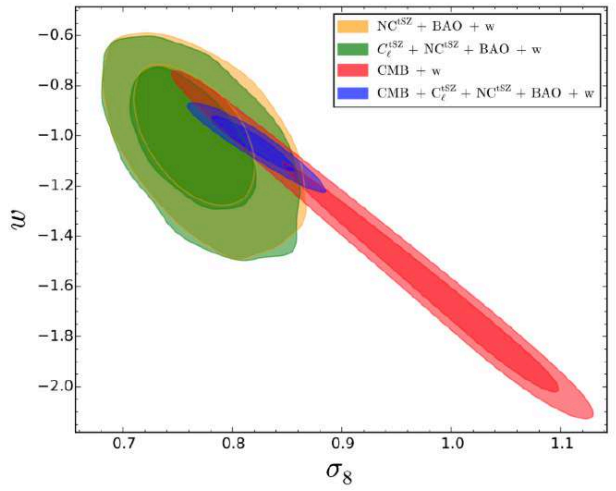
COSMOLOGY WITH TSZ

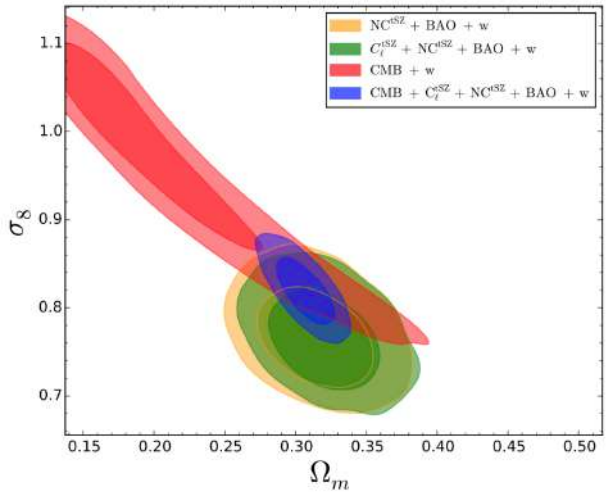
νCDM





wCDM

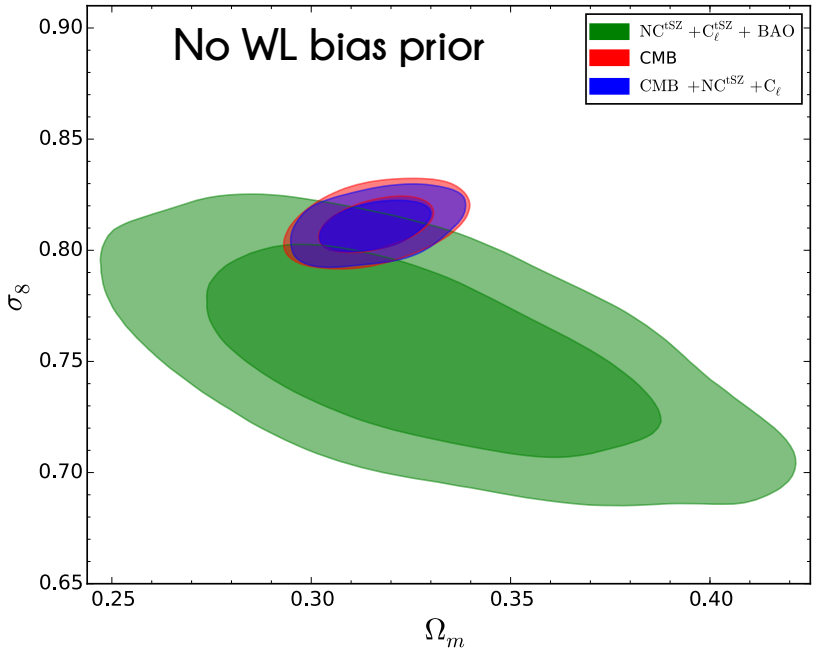


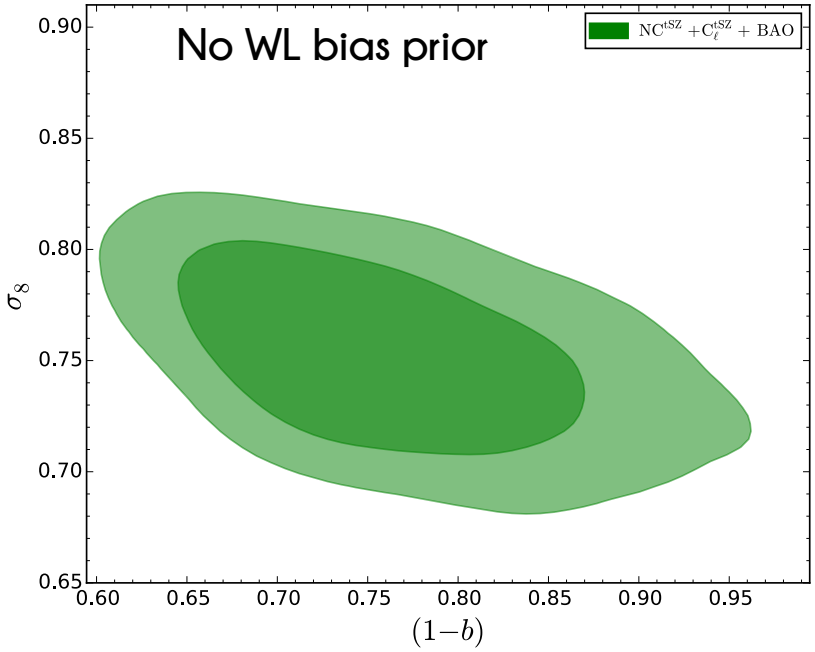


Salvati, Douspis, Aghanim (2018)

STATUS 2018 B

Combination Number Count + Power Spectrum





Salvati, Douspis, Aghanim (2018)

tSZ determination of the mass bias ~0.75

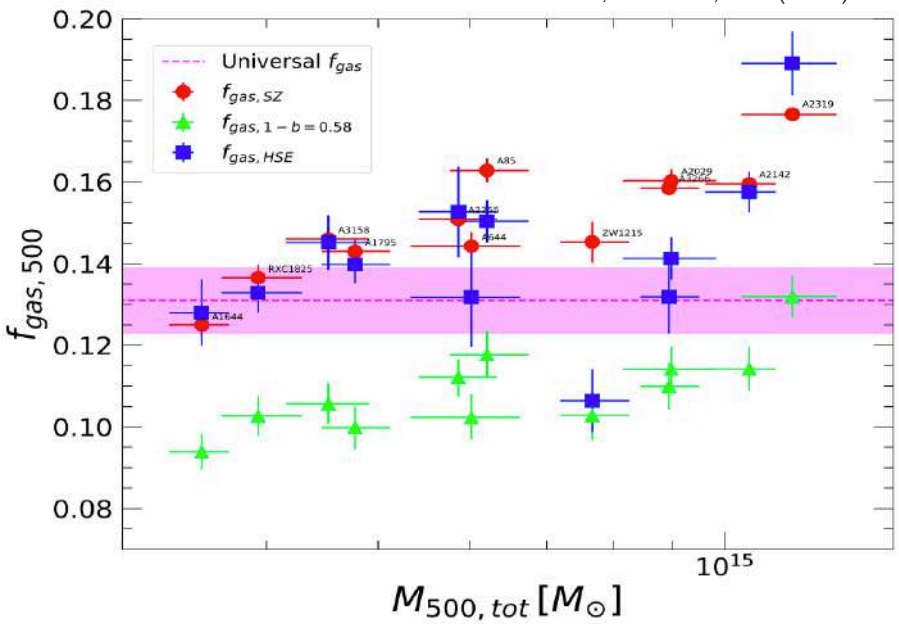
$\sigma_8\,(\Omega_m/0.3)^{1/3} \sim 0.78 \pm 0.03$ SZ (Clusters+CI)+BAO (1-b) ~ 0.75±0.10

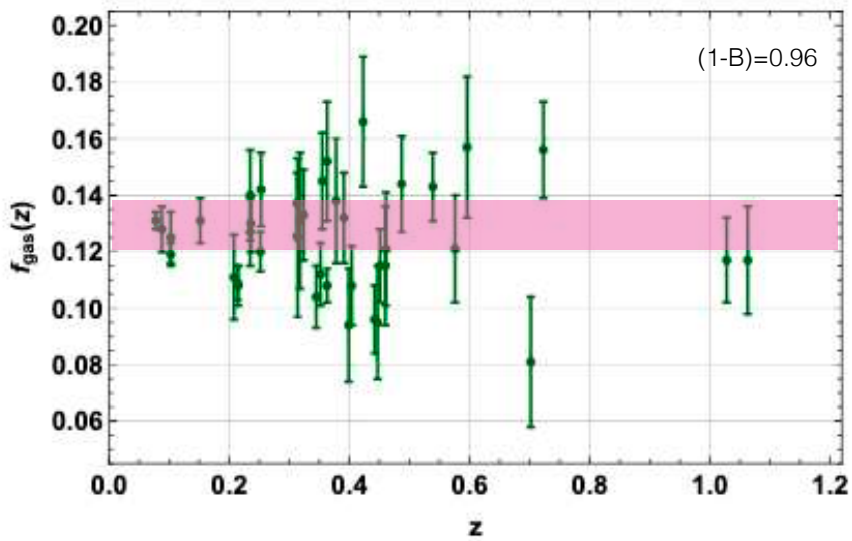
$\sigma_8\,(\Omega_m/0.3)^{1/3} \sim 0.84 \pm 0.02$ SZ (Clusters+CI)+CMB (1-b) ~ 0.64±0.03

Is it Significant ?

- Cosmological parameters
  - $\sigma_8\ (\Omega_m/0.3)^{1/3}$ at ~2 σ
- Mass Bias
  - CMB+SZ: (1-b)<0.8 (2σ)
  - low values of 1-b implies low baryon fraction in clusters !
  - ➡ uncomfortably low value of (1-b)
  - Evolution ? see later
- Planck cluster only problem ?

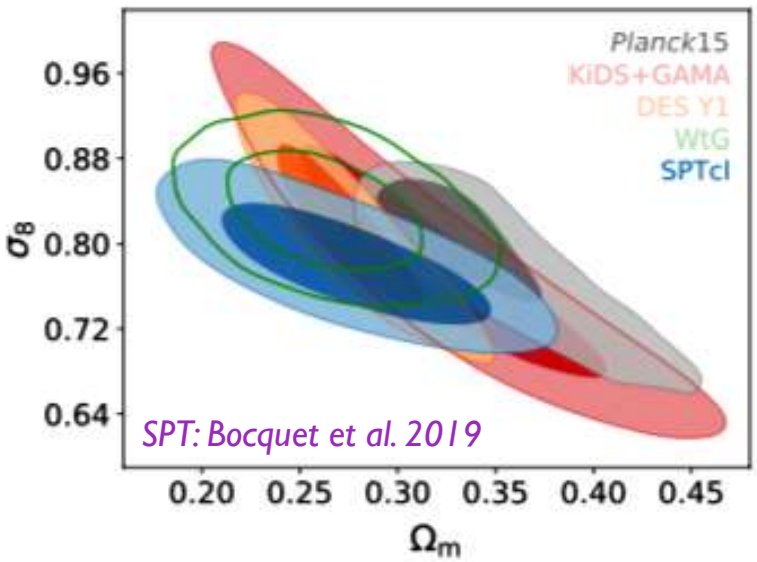
Eckert et al, A&A 621, A40 (2019)

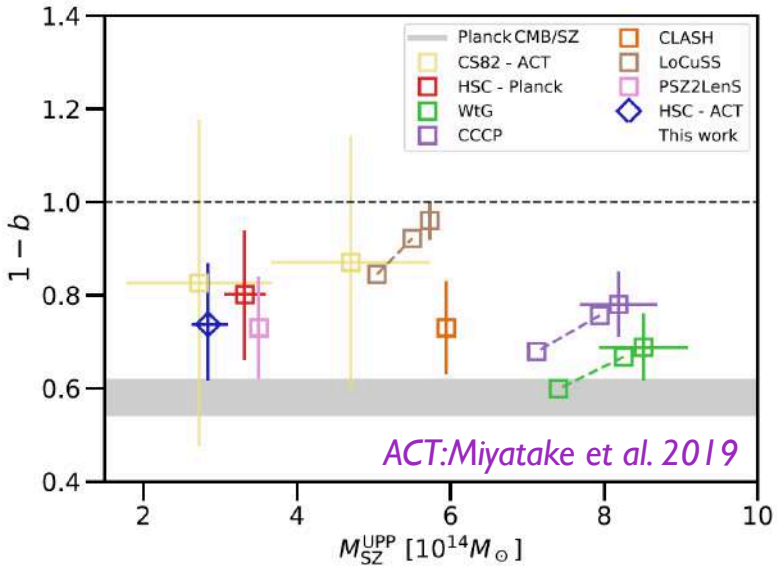




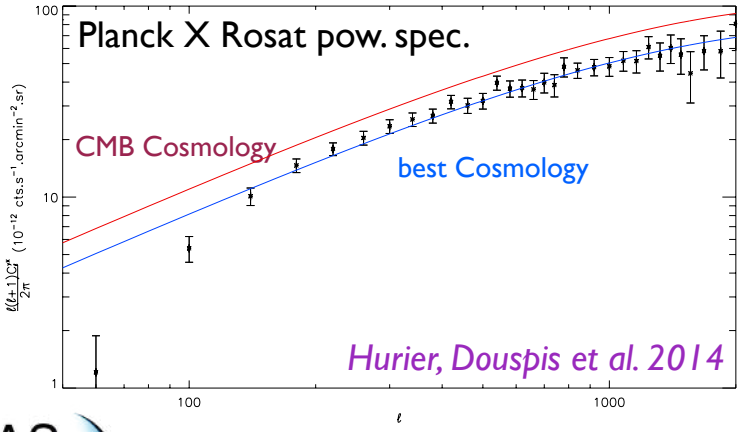
Holanda et al, JCAP (2014)

Other SZ Probes





SPT contours compatible with Planck (1-b)=0.8

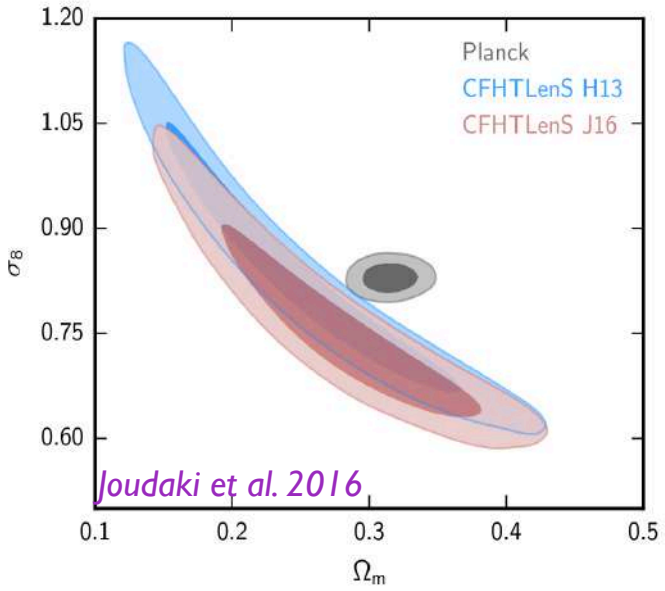


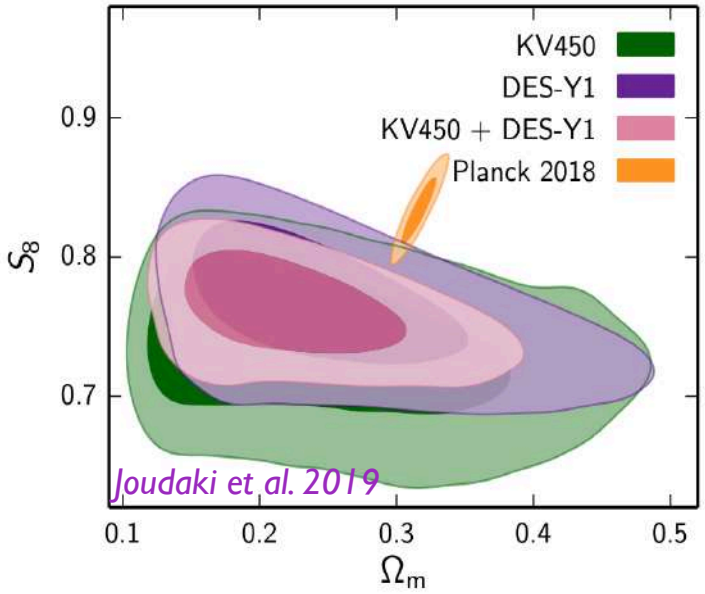
- 1-PDF — *Planck 2014 XXI*
  - PLCK: $\sigma_8 = 0.779 \pm 0.02$
  - ACT: $\sigma_8 = 0.793 \pm 0.04$ — *Colin Hill, 2014*
- Bispectrum — *Hurier & Lacasa, 2017*
  - PLCK: $\sigma_8 = 0.74 \pm 0.04$
  - SPT: $\sigma_8 = 0.787 \pm 0.03$ — *Crawford, 2014*

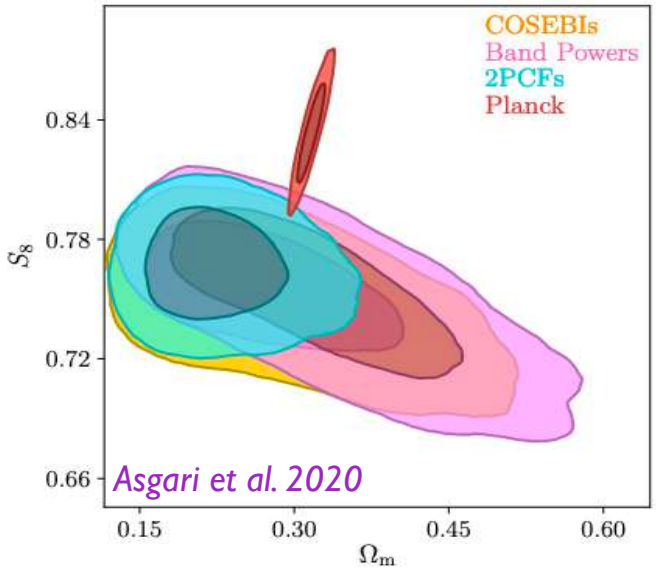
Agreement with other SZ probes, is it SZ pb?

Other Probes

Cosmic shear tomography measurements



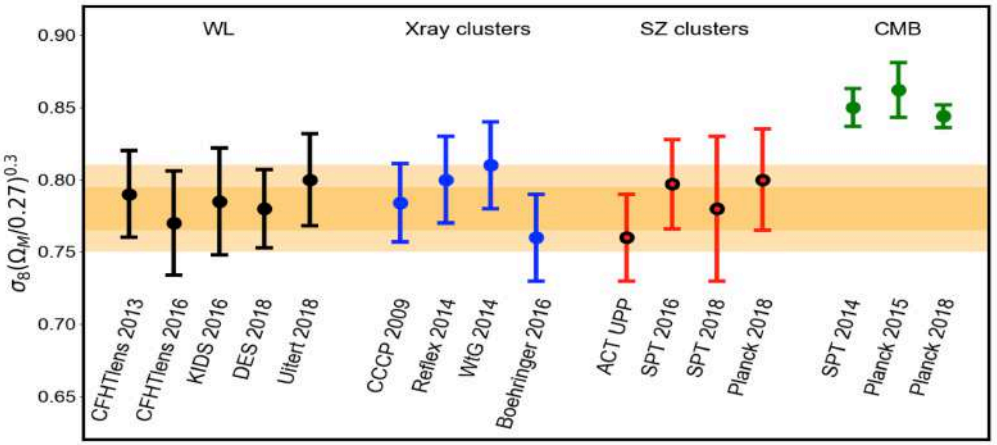




See also Troster al arXiv:2010.16416

Consistency with Xray clusters

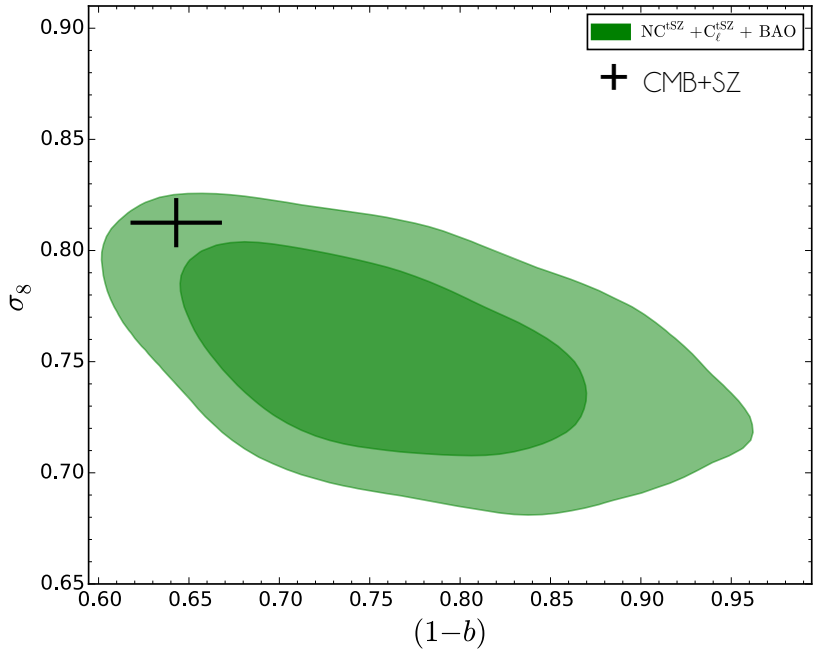
- local sample — *Ilic et al. 2015*
- high mass sample — *Boehringer et al. 2016*



Consistency of SZ with other analyses

Trends for low value of $\sigma_8\,(\Omega_m/0.3)^{1/3}$

CAN WE IMPROVE EVEN MORE THE AGREEMENT SZ-CMB?



SYSTEMATICS ?

SYSTEMATICS ?

SYSTEMATICS ?

SYSTEMATICS ?

WHICH DOMINATES ?

SZ NC SYSTEMATICS

$$dN/Cls[\Theta] \equiv \int\int\int dMdz \; dV \; \chi(obs) \; S(obs-M) \; \frac{dN}{dMdz} \; p(M,z)$$

Selection function

How much clusters your probe finds compare to the true number / mask on the sky : given by experiment

Scaling relation

Needed to relate the observable (flux, size) to the mass and redshift. Given by comparison HM with simulations or WL measurements *[Planck 2013., Nagai et al., ...]*

$$E^{-\beta}(z)\left[\frac{D_A^2(z)\,Y_{500}}{10^{-4}\,\mathrm{Mpc}^2}\right] = Y_*\left[\frac{h}{0.7}\right]^{-2+\alpha}\left[\frac{(1\text{-}b)\,M_{500}}{6\cdot 10^{14} M_\odot}\right]^{\alpha}$$

▶ <10% (chandra vs XMM)

Cosmology

Clusters and SZ power spectrum are both geometrical and growth probes

Mass function

Number of halos in bins of mass and redshift. From numerical simulations, known 10% scatter between teams *[Tinker et al., Watson et al., Despali et al.]*

$$\frac{dN(M_{500},z)}{dM_{500}} = f(\sigma)\frac{\rho_m(z=0)}{M_{500}}\frac{d\ln\sigma^{-1}}{dM_{500}}$$

$$f(\sigma) = A\left[1+\left(\frac{\sigma}{b}\right)^{-a}\right]\exp\left(-\frac{c}{\sigma^2}\right)$$

▶ ~10% scatter, baryonic effects ?

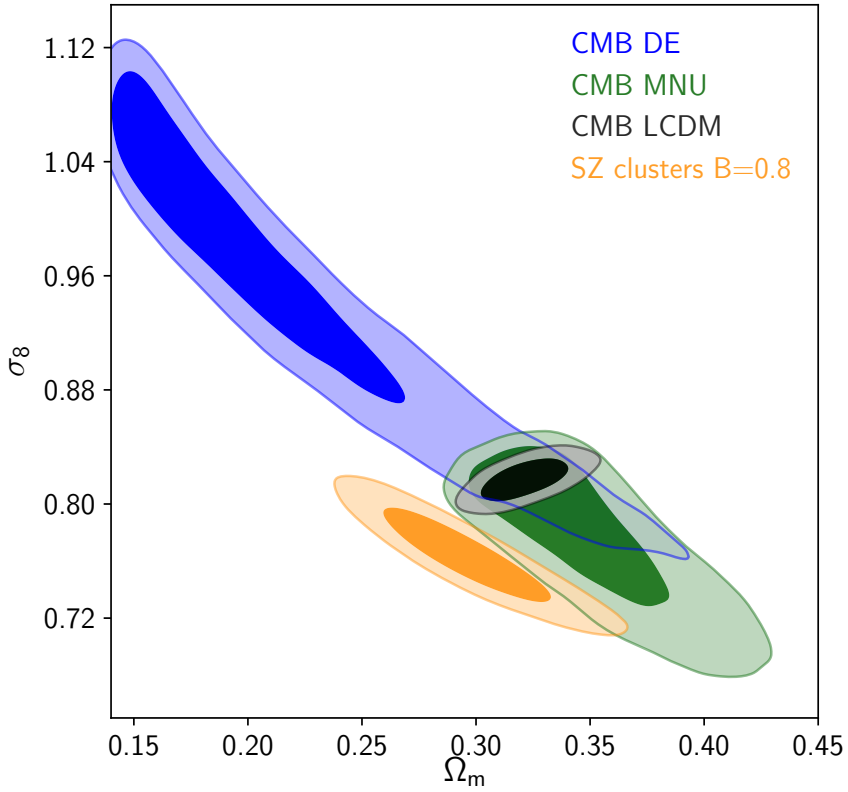
Profile

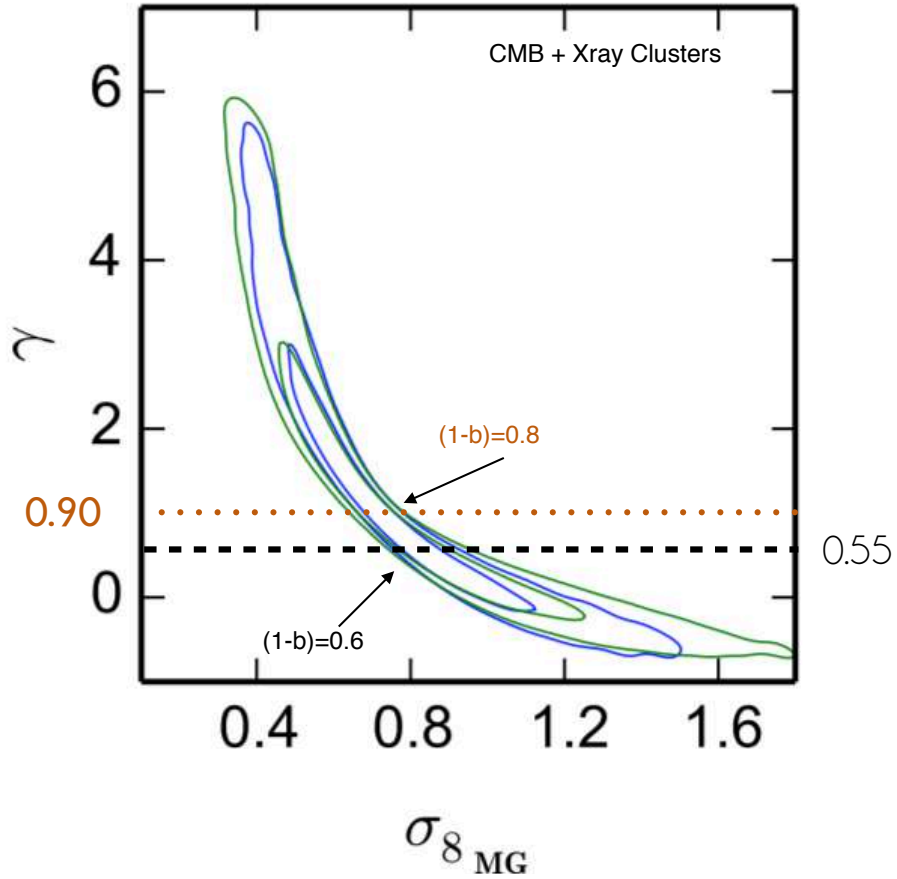
Describes the spatial distribution of the hot gas (for Cls). Assume Universal pressure profile, the GNFW *[Nagai et al., Arnaud et al., Planck 2014]*

▶ <<10%

Planck Early XI, A&A, 2011 *eg. Martizzi 2013* *eg. Israel 2015* *Salvati et al 2019*

EXTENSIONS OF LCDM?





Neutrinos and wCDM do not help

Strong Modified Gravity may help

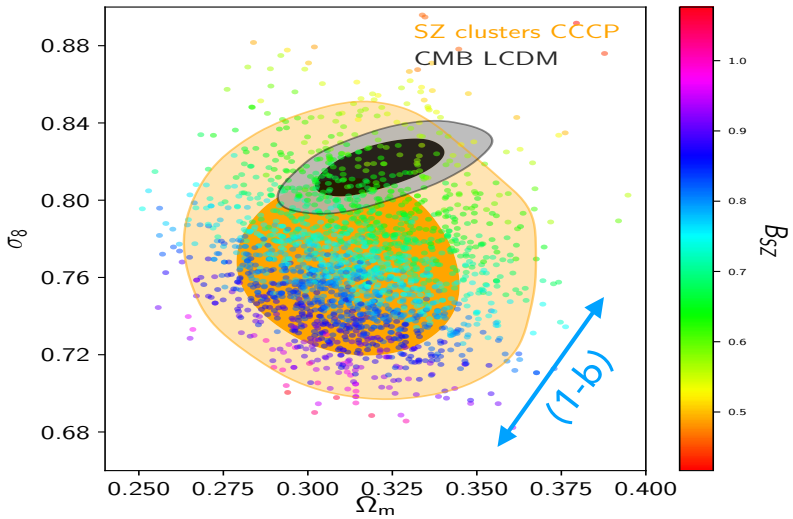
Salvati, Douspis, Aghanim (2018)

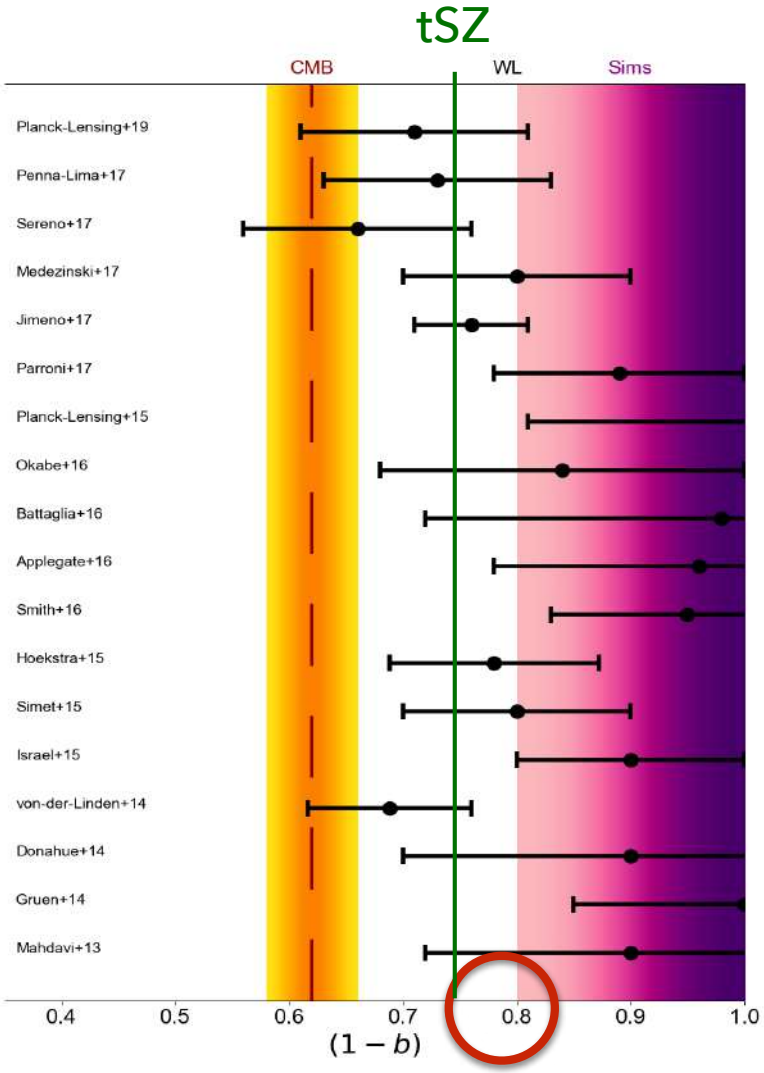
Sakr , Ilić, Blanchard (2018)

SYSTEMATICS : MASS BIAS

- Degeneracy Bias / Cosmology $M_{500}^{\rm HE} = (1-b)\, M_{500}$

$$dN \propto \sigma_8^9\, \Omega_m^3\, (1-b)^{3.6}$$





Salvati, Douspis, Aghanim (2018)

➡ WL: small not necessarily representative samples (high mass, high z), unbiased ?

➡ <(1-b)> ~ 0.79±0.09 ↘

SYSTEMATICS : MASS BIAS EVOLUTION ?

Is assuming a unique constant mass bias valid ?

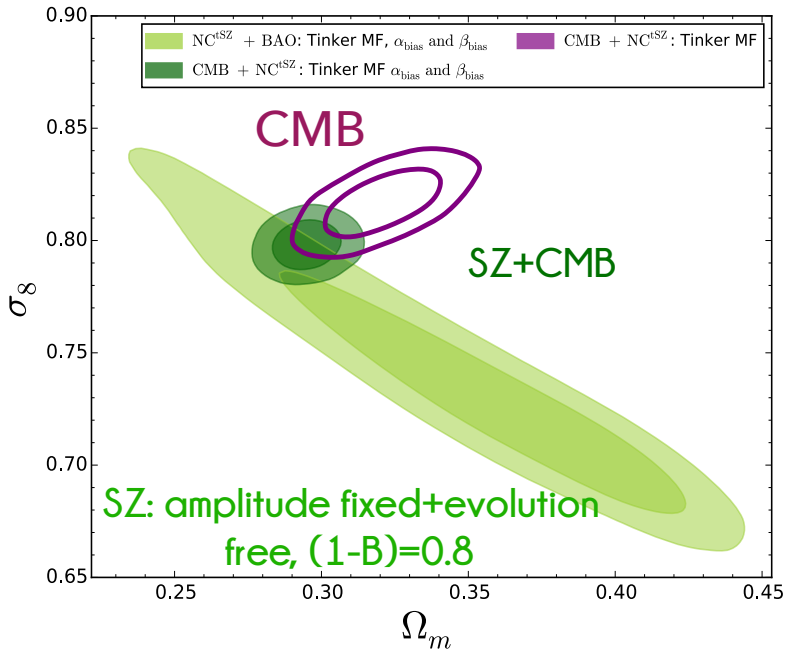
Does some evolution of the mass bias help reducing the remaining tension?

$$(1-b)_{\rm var} = (1-\mathcal{B}) \cdot \left(\frac{M}{M_*}\right)^{\alpha_b} \cdot \left(\frac{1+z}{1+z_*}\right)^{\beta_b}$$

Bias amplitude at M* and z*

$4.82 \cdot 10^{14} M_\odot$ mean mass of PSZ2 catalogue

0.22 median redshift of PSZ2 catalogue

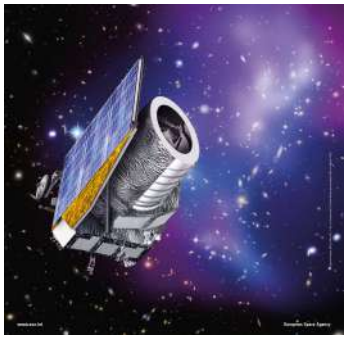


Answer is No: CMB+tSZ (0.8) gives bad chi² whatever the evolution

Salvati, Douspis, Ritz, Aghanim, Babul (2019)

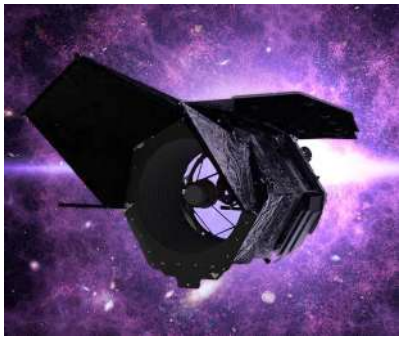
IMPROVEMENT WITH FUTURE GALAXY SURVEYS

Future surveys: ~ thousands of clusters ⟶ Accuracy/precision on cosmological parameters: dominated by systematic uncertainties



Euclid satellite

LSST -
Vera Rubin telescope



WFIRST -
Nancy Grace Roman
space telescope

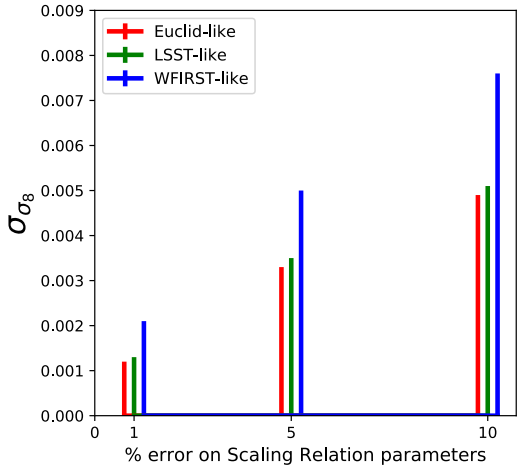
IMPACT ON COSMOLOGY OF THEORETICAL/OBSERVATIONAL MODELLING

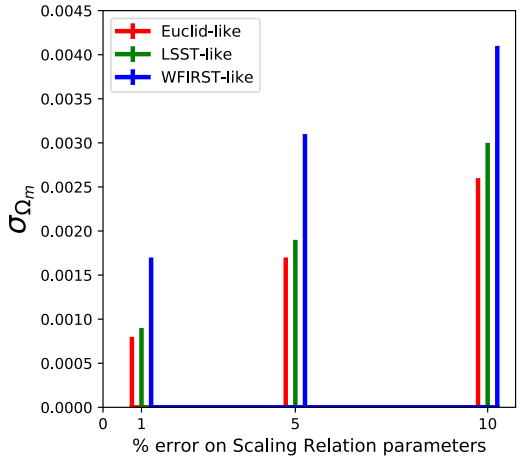
SCALING RELATION PRECISION

MASS FUNCTION ASSUMPTION

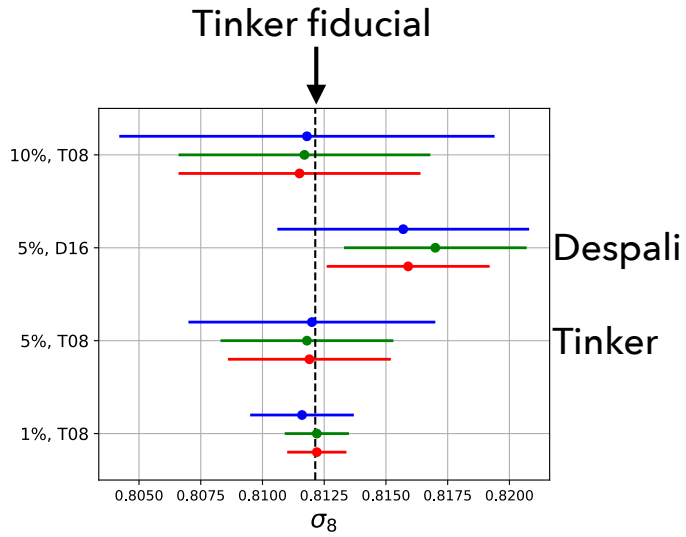
MCMC forecast approach

IMPACT OF SYSTEMATICS IN LCDM

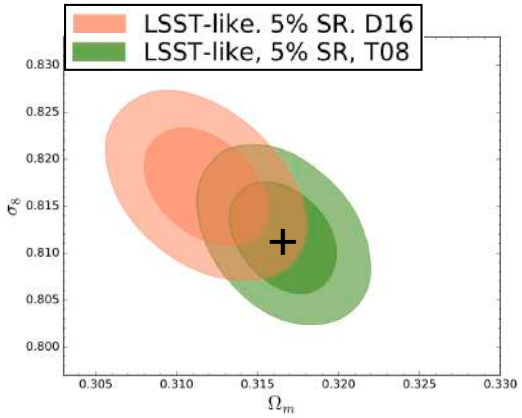


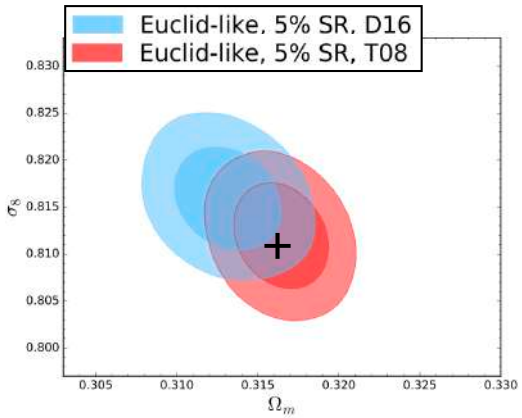


Potentially factor 4 precision if scaling is known at percent level



Wrong mass function assumption may bias 1-2σ level

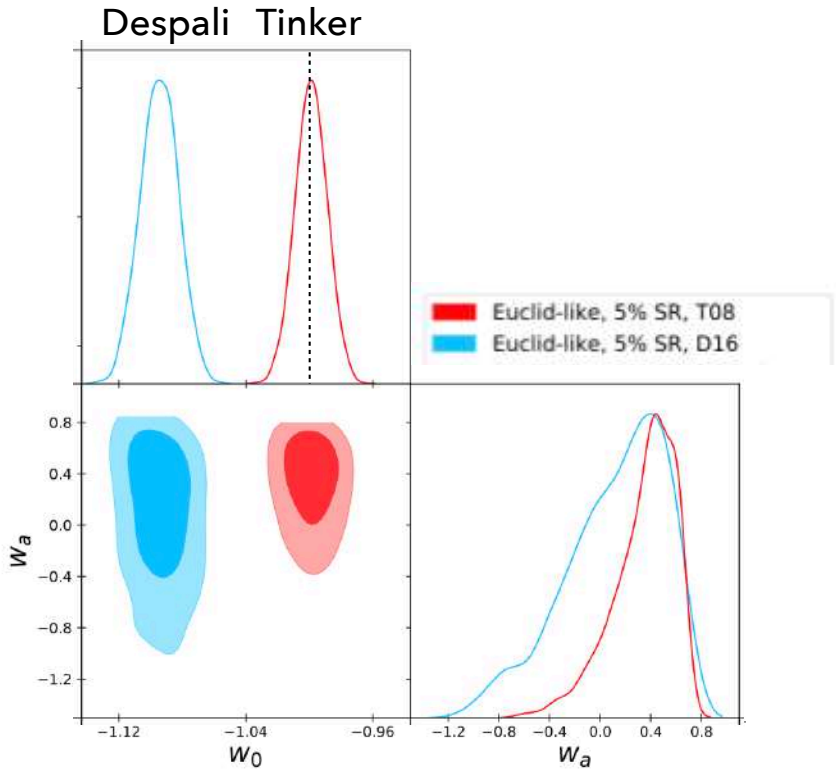




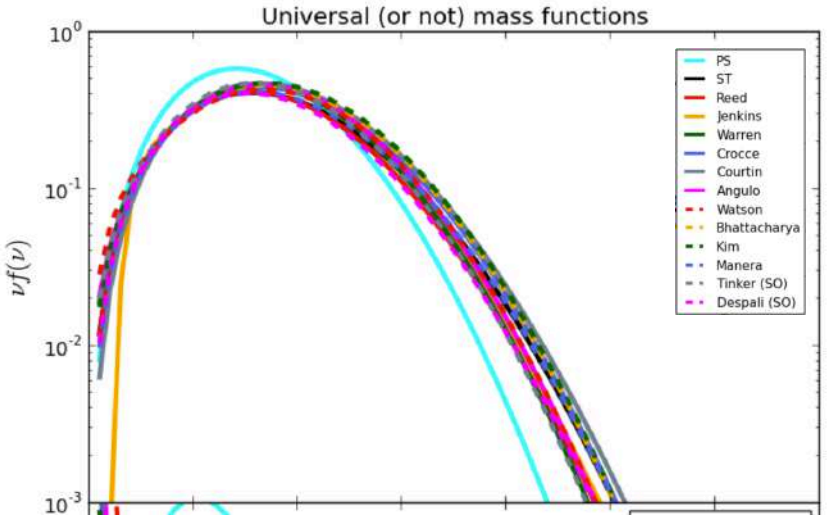
Salvati, Douspis, Aghanim (2020)

IMPACT OF SYSTEMATICS WCDM

$$w = w_0 + (1 - a)w_a$$



Salvati, Douspis, Aghanim (2020)

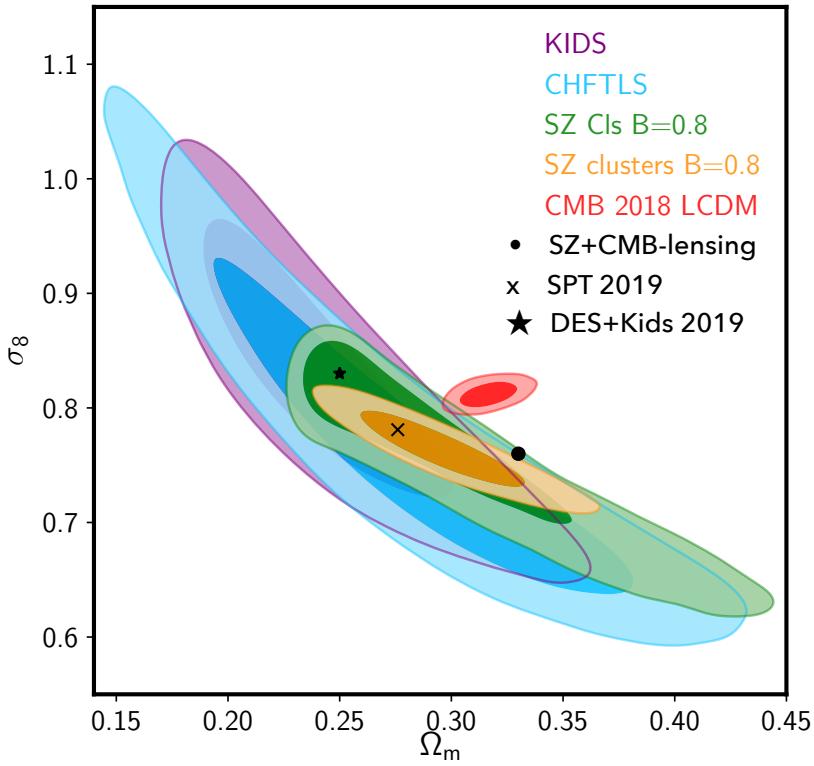


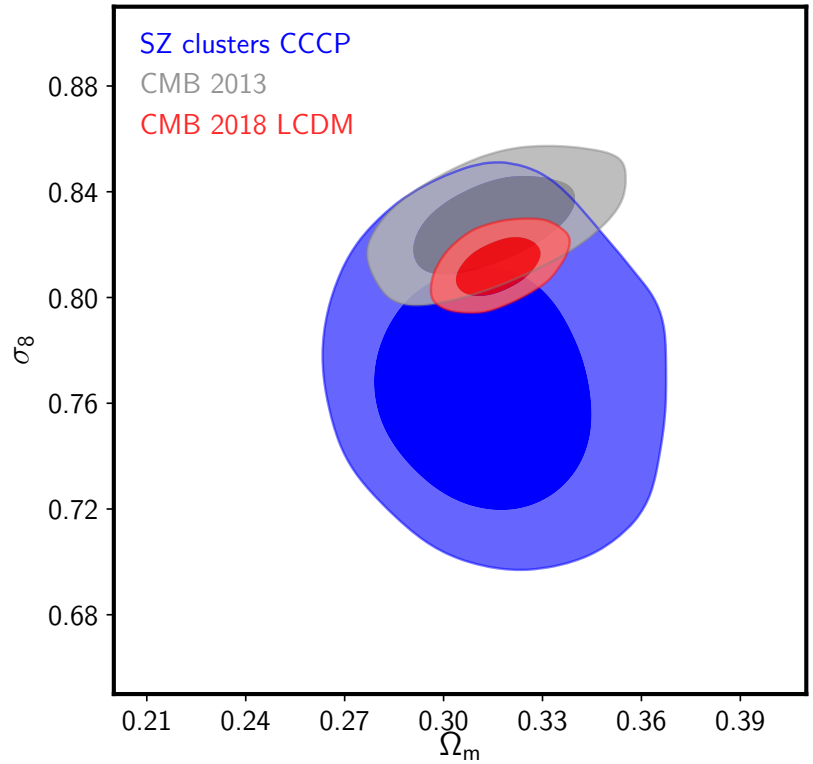
Monaco, 2016, Galaxies, 4, 53

- Wrong mass function assumption may bias 8σ level dark energy parameters
- Degeneracy between DE and mass function
- Need work on (Universal) mass function

Conclusions

- Tension between SZ Clusters and CMB is reduced by the new value of reionisation optical depth

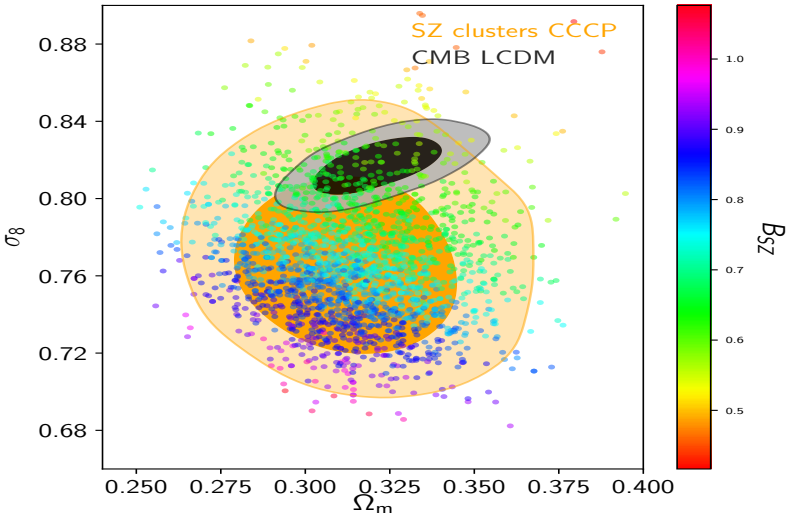


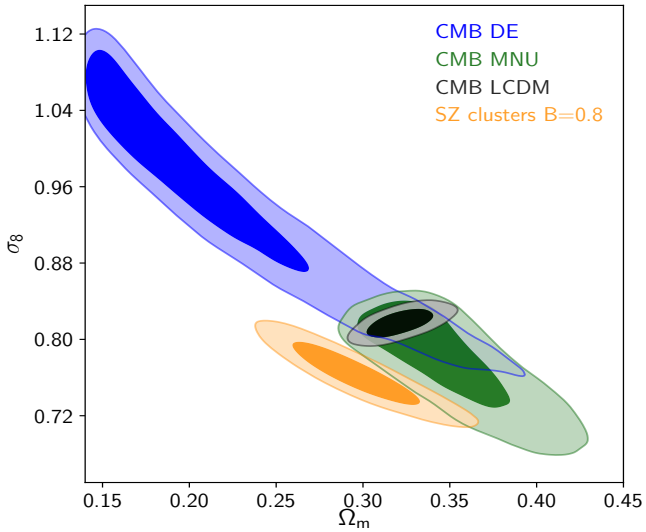


- Mild tension exists with other LSS probes at the same level (all low sigma8)
- obvious systematics are discarded (eg. MF)

Conclusions

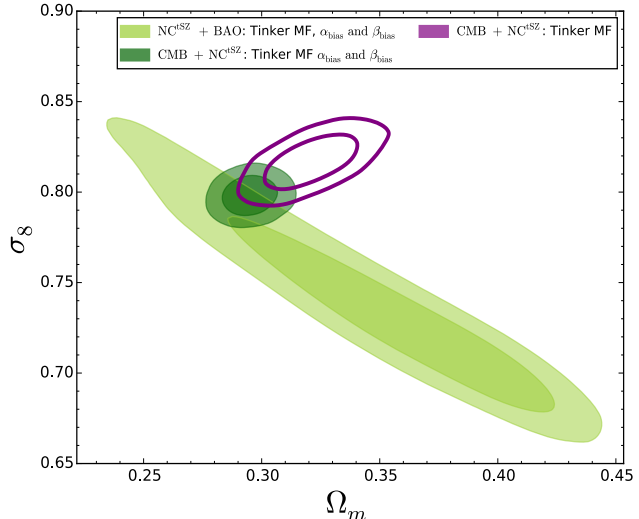
- Extensions of LCDM need to be extreme (or not yet tried)





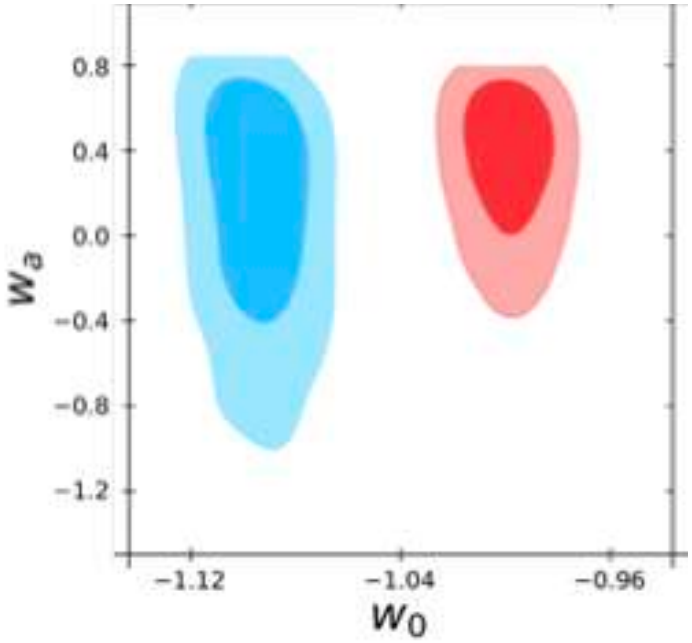
- constant bias has to be big ~ 0.6 (≠ sims and most of WL mass estimates) → baryon fraction 1/2 smaller than universal *(Eckert et al 18)*

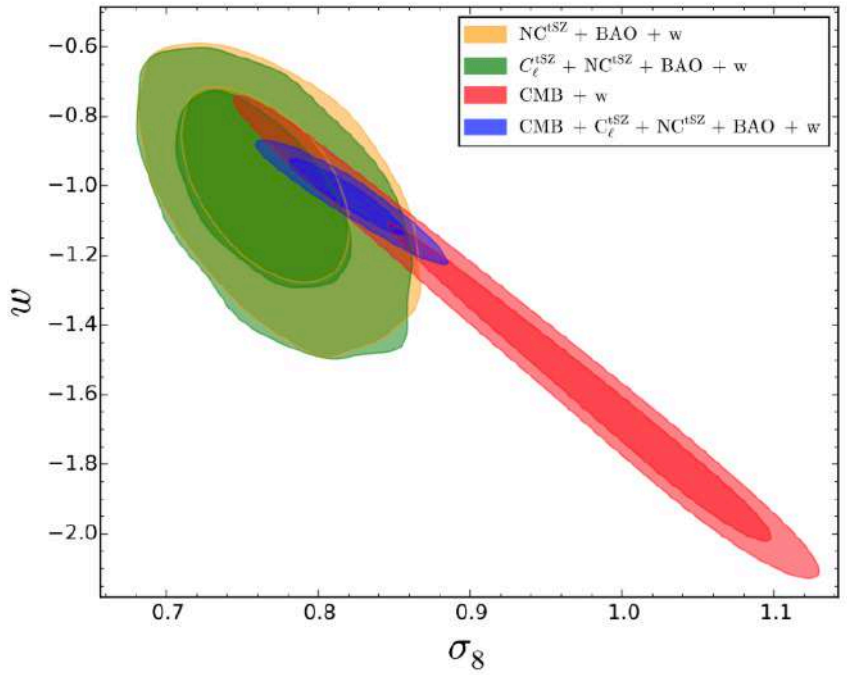
- Evolving bias not helping reconciling bias observations and CMB



Conclusions

- Still clusters including their systematics bring cosmological information





- Future surveys will probe higher redshifts (SZ and optical). Need for multiwavelenght studies and theoretical work to tackle systematics and show clusters as one of the competitive cosmological probe

Thank You !

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