Constraints on cosmological parameters from galaxy clusters

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and Marian Douspis

GALAXY CLUSTERS 2017

Introduction

Galaxy clusters:
Most massive gravitationally bound structure in the Universe

Strong dependence on cosmological parameters:
matter content Ω_m
amplitude matter spectrum σ_8

Constraints on cosmological parameters from galaxy clusters

- through Sunyaev-Zeldovich effect from Planck satellite
- Number counts + Power spectrum
- Matter density and its distribution
  Extensions to LCDM model $(\sum m_\nu, w)$
- comparison / combination with Cosmic Microwave Background (CMB) data

Model

Galaxy Clusters through SZ effect

- Number counts (NC) (observed)
- Power spectrum (PS)

Selection function

$$\frac{dN}{dz} = \int d\Omega \int dM_{500}\, \hat{\chi}(z, M_{500}, l, b)\, \frac{dN(M_{500}, z)}{dM_{500}}\, \frac{dV}{dz\, d\Omega}$$

$$C_\ell^{\rm tSZ} = C_\ell^{\rm 1halo} + C_\ell^{\rm 2halo}$$

$$C_\ell^{\rm 1halo} = \int dz \frac{dV}{dz\, d\Omega} \int dM_{500} \frac{dN(M_{500}, z)}{dM} |\tilde{y}_\ell(M_{500}, z)|^2$$

$$C_\ell^{\rm 2halo} = \int dz \frac{dV}{dz\, d\Omega} \left[\int dM_{500} \frac{dN(M_{500}, z)}{dM} |\tilde{y}_\ell(M_{500}, z)|\, B(M_{500}, z) \right]^2 P(k, z)$$

Mass function

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

Tinker et al., Astrophys. J. 688 (2008) 709

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

Scaling relations

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

$$\theta_{500} = \theta_* \left[\frac{h}{0.7} \right]^{-2/3} \left[\frac{(1-b)\, M_{500}}{3 \cdot 10^{14}\, M_\odot} \right]^{1/3} E^{-2/3}(z) \left[\frac{D_A(z)}{500\, \mathrm{Mpc}} \right]^{-1}$$

Planck 2015 results. XXIV. A&A 594 (2016) A24

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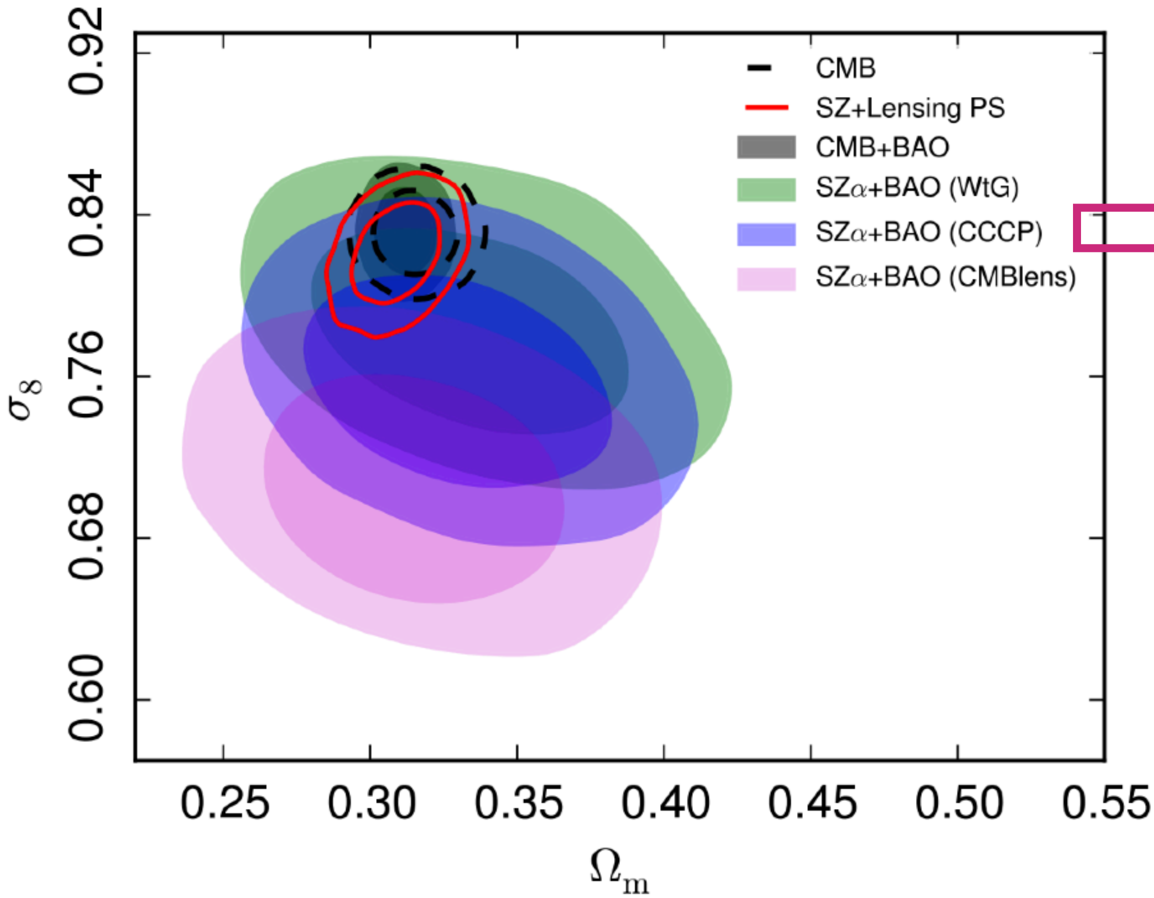
Planck 2015 results. XXIV. A&A 594 (2016) A24

Starting point

Number counts

Planck Collaboration, A&A 594 (2016) A24



discrepancy between CMB data and number counts

$\simeq 2.4\,\sigma$ on σ_8

Prior name	Quantity	Value and Gaussian errors
Weighing the Giants (WtG)	$1-b$	0.688 ± 0.072
Canadian Cluster Comparison Project (CCCP)	$1-b$	0.780 ± 0.092
CMB lensing (CMBlens)	$1/(1-b)$	0.99 ± 0.19

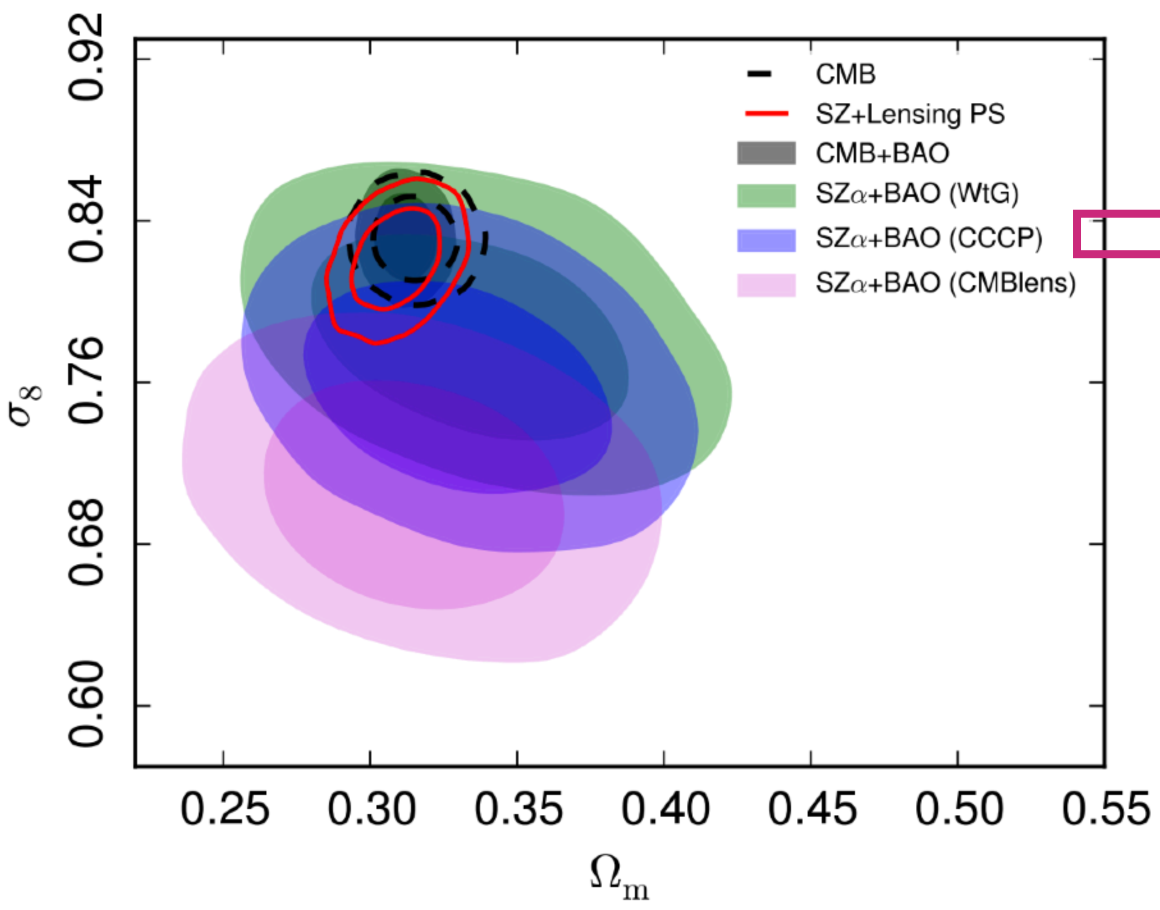
Hoekstra et al., MNRAS 449 (2015) no.1, 685

Data	$\sigma_8\left(\frac{\Omega_m}{0.31}\right)^{0.3}$	Ω_m	σ_8
WtG + BAO + BBN	0.806 ± 0.032	0.34 ± 0.03	0.78 ± 0.03
CCCP + BAO + BBN **[Baseline]**	0.774 ± 0.034	0.33 ± 0.03	0.76 ± 0.03
CMBlens + BAO + BBN	0.723 ± 0.038	0.32 ± 0.03	0.71 ± 0.03

Starting point

Number counts

Planck Collaboration, A&A 594 (2016) A24



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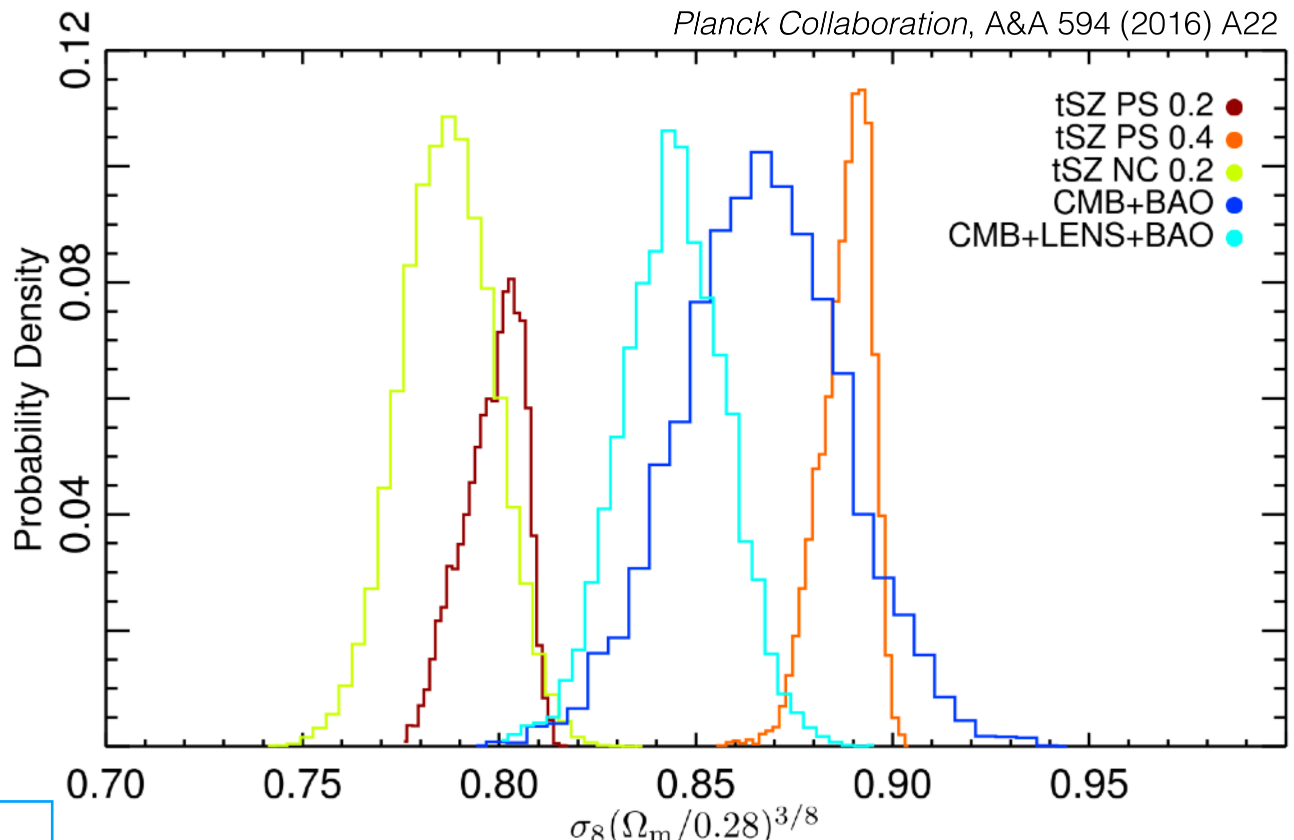
Planck Collaboration, A&A 594 (2016) A22



Power spectrum

Planck Collaboration, A&A 594 (2016) A22

$(1-b) = 0.8 \longrightarrow \sigma_8(\Omega_m/0.28)^{3/8} = 0.80^{+0.01}_{-0.03}$

$(1-b) = 0.6 \longrightarrow \sigma_8(\Omega_m/0.28)^{3/8} = 0.90^{+0.01}_{-0.03}$

CMB

Planck Collaboration, A&A 594 (2016) A13

$\sigma_8 = 0.821 \pm 0.013$

$\Omega_m = 0.3156 \pm 0.0091$

Dataset - Method

Salvati et al. 2017
in preparation

Number counts

- PSZ2 cosmological sample
- 438 clusters (MMF3) *Planck Collaboration*, A&A 594 (2016) A24
- $z = [0, 1]$
- $M_{500} = [10^{14} M_\odot, 2 \cdot 10^{15} M_\odot]$

\+

Power spectrum

- $z = [0, 3]$
- $M_{500} = [10^{13} M_\odot, 5 \cdot 10^{15} M_\odot]$
- $\ell = 10 - 1000$
- 50% of sky

Sampling at the same time on **cosmological** and **nuisance** parameters

Baseline

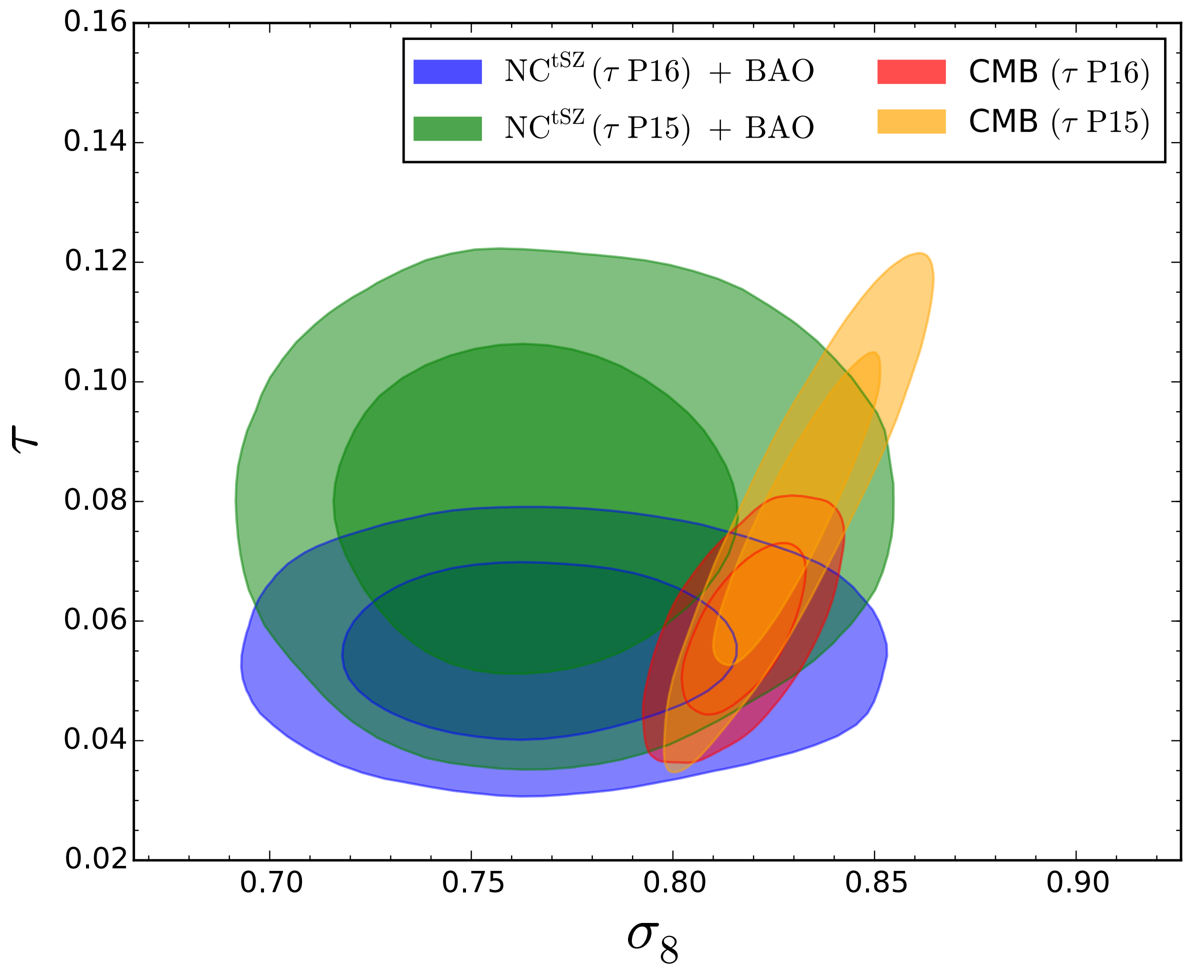
- Tinker mass function
- cccp prior on mass bias

$$(1 - b) = 0.780 \pm 0.092$$

Hoekstra et al., MNRAS 449 (2015) no.1, 685

- $\tau = 0.055 \pm 0.009$

Planck Collaboration, A&A 596 (2016) A107



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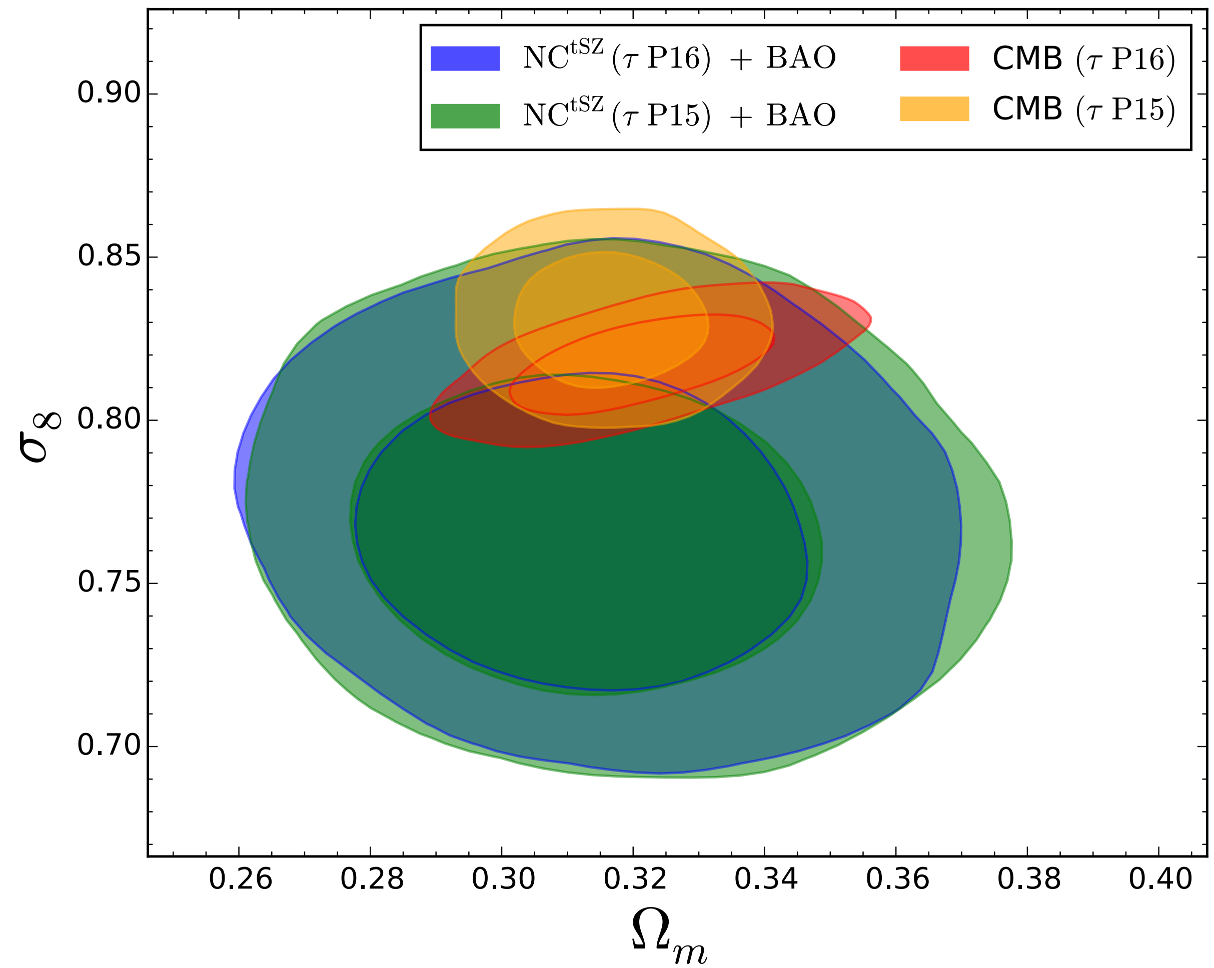
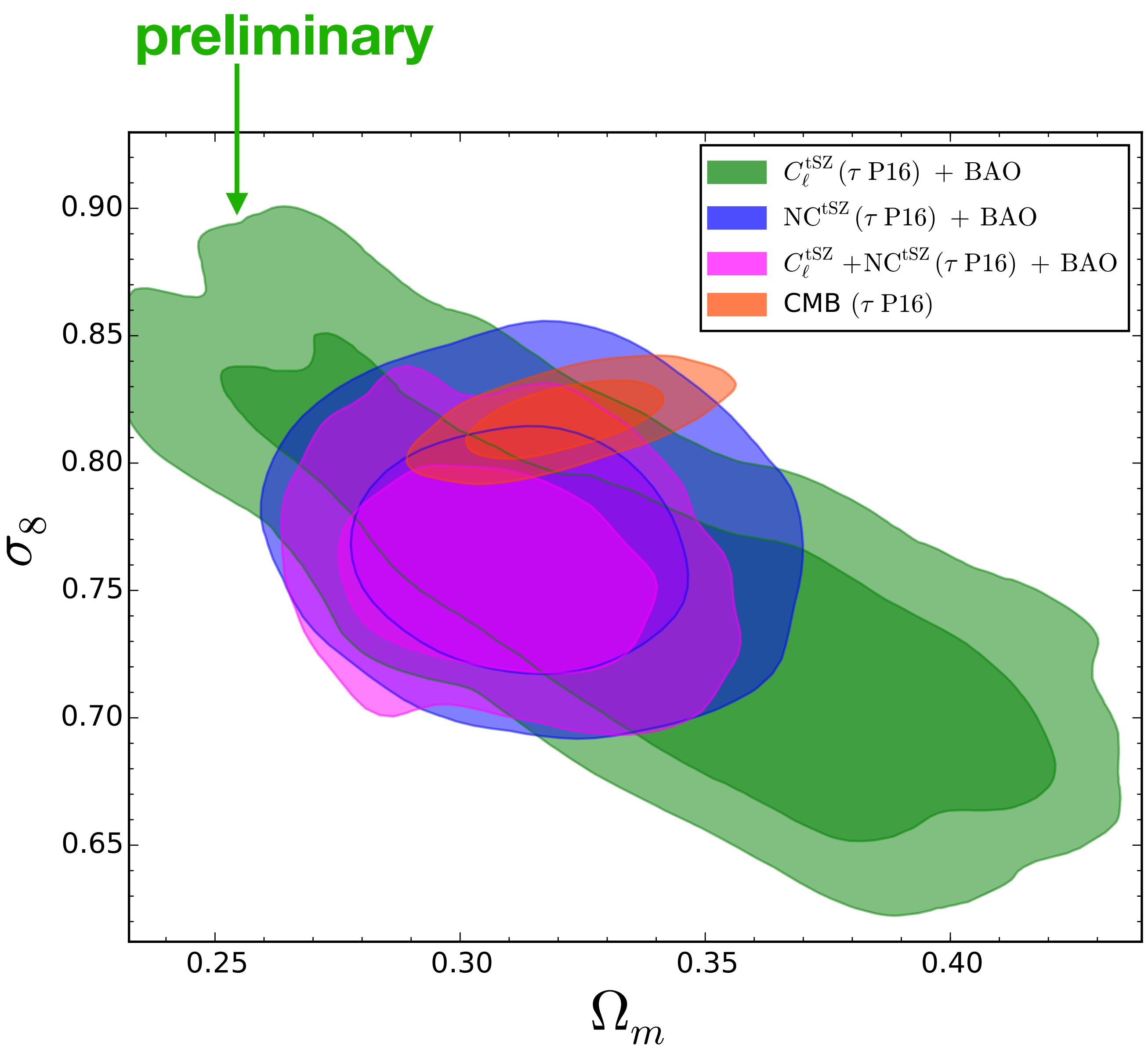
Planck Collaboration, A&A 596 (2016) A107



Results



Number counts 68% c.l.

$$\Omega_m = 0.314^{+0.020}_{-0.024}$$
$$\sigma_8 = 0.768^{+0.028}_{-0.035}$$

discrepancy $\sim 1.5\,\sigma$ on σ_8

CMB 68% c.l.

$$\Omega_m = 0.321^{+0.012}_{-0.014}$$
$$\sigma_8 = 0.817 \pm 0.010$$

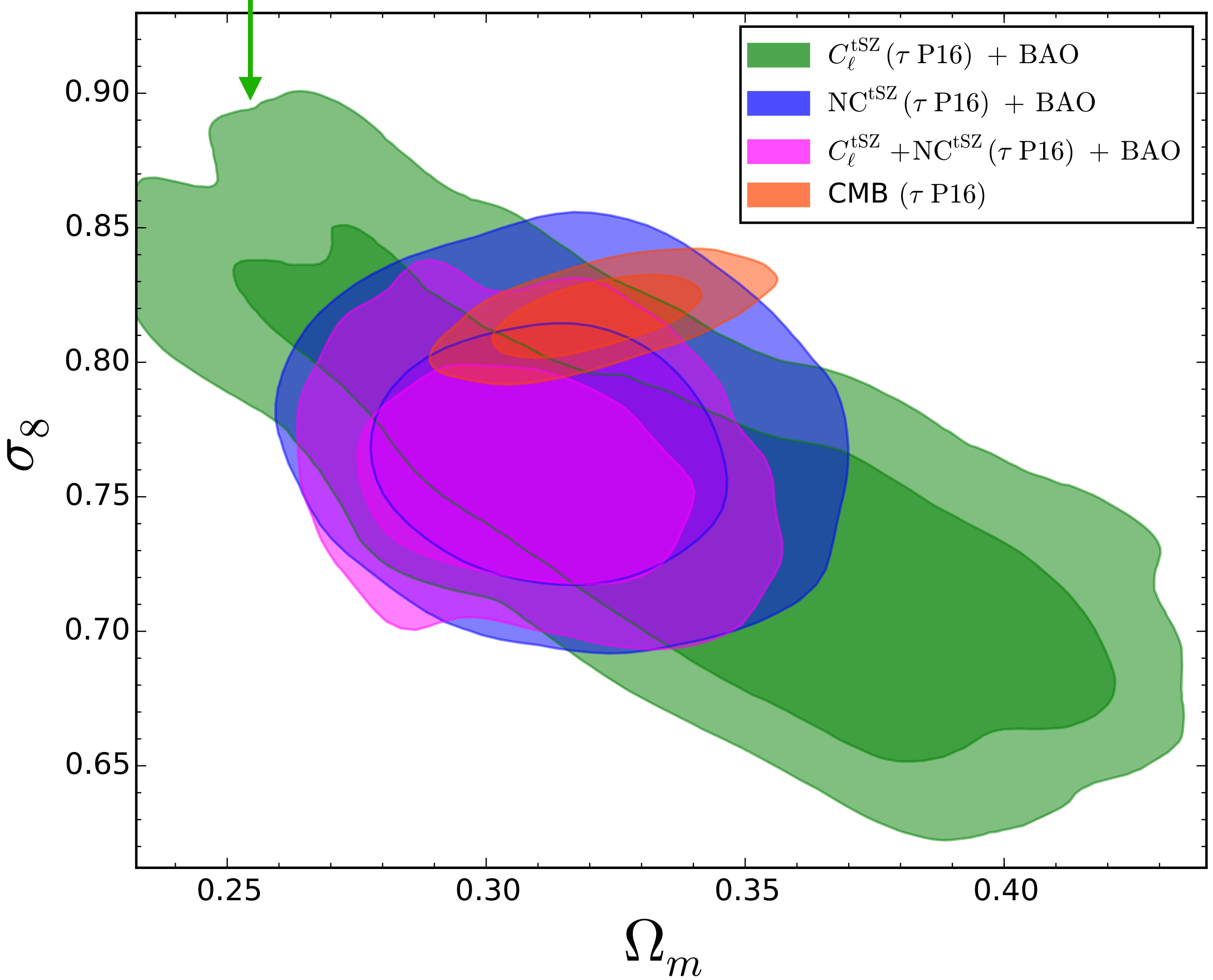
discrepancy $\sim 2.1\,\sigma$ on σ_8

Number counts + Power spectrum

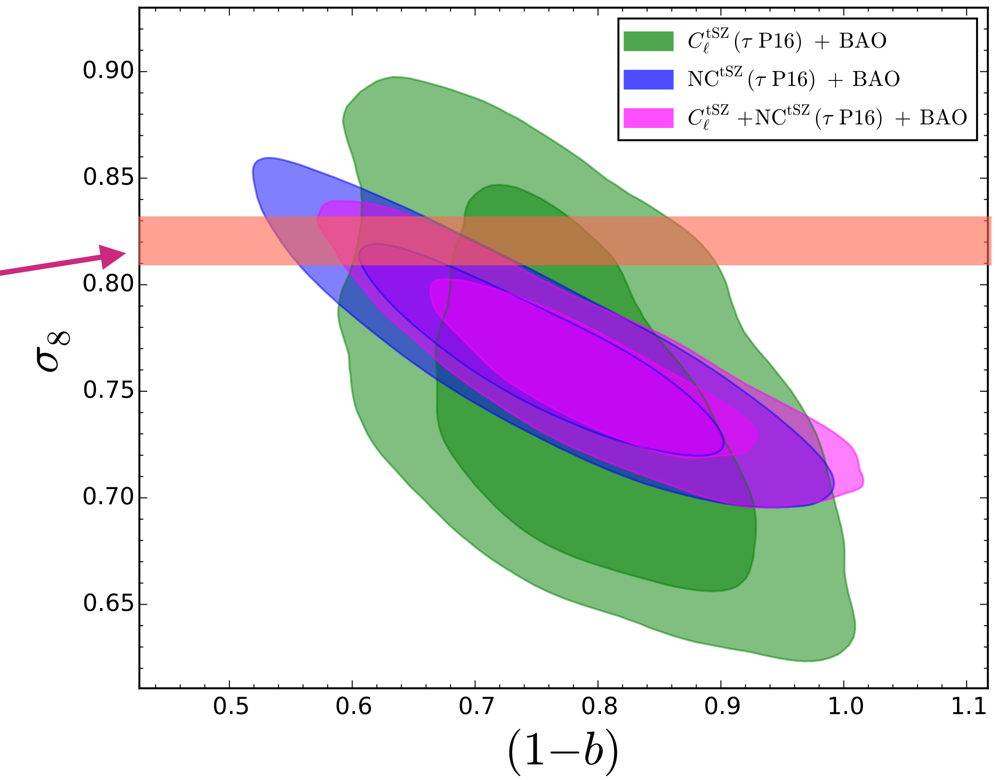
$$\Omega_m = 0.308^{+0.019}_{-0.022}$$
$$\sigma_8 = 0.759^{+0.025}_{-0.030}$$

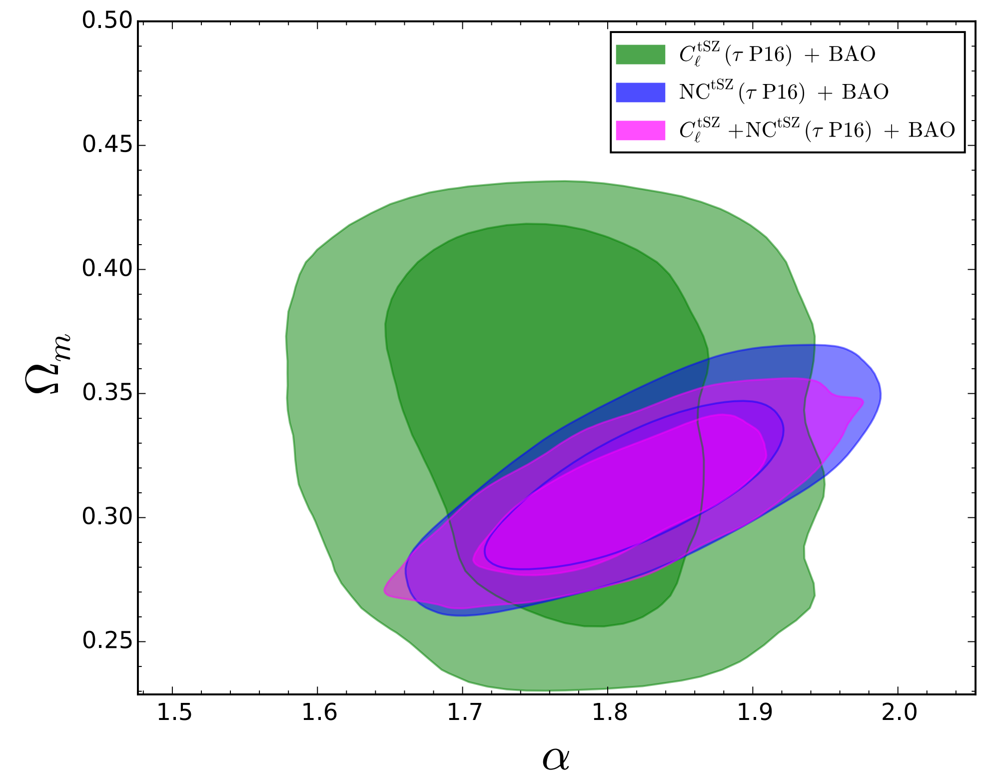
68% c.l.

preliminary



Degeneracy cosmological - nuisance parameters





Massive neutrinos

<u>Impact of massive neutrinos on LSS</u>:

- Early Universe: relativistic particles

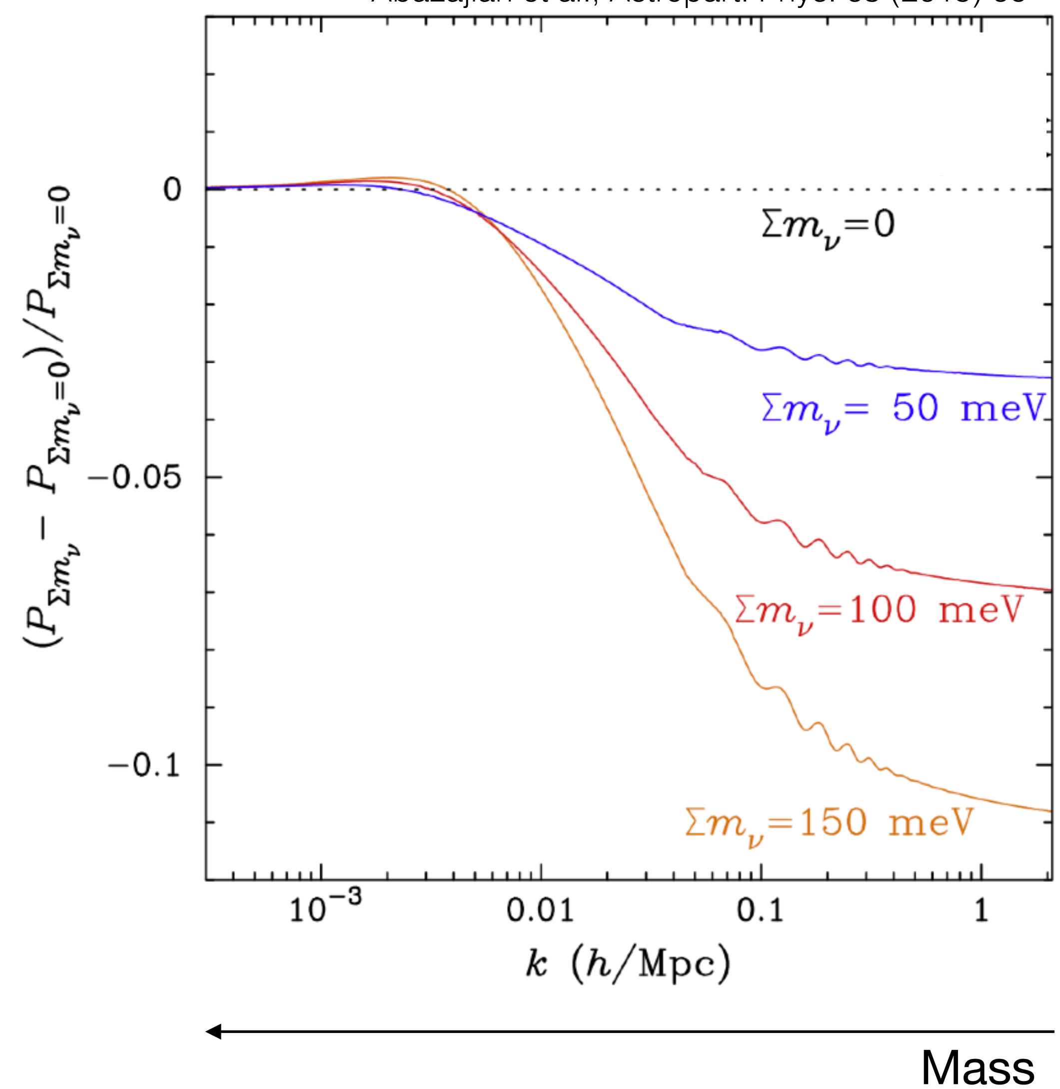
$$z_{\rm nr} \sim \frac{2000\, m_\nu}{1\,{\rm eV}}$$

- Late Universe: non-relativistic matter-like particles

$$\Omega_\nu \simeq \frac{\sum m_\nu}{93\,{\rm eV}}$$

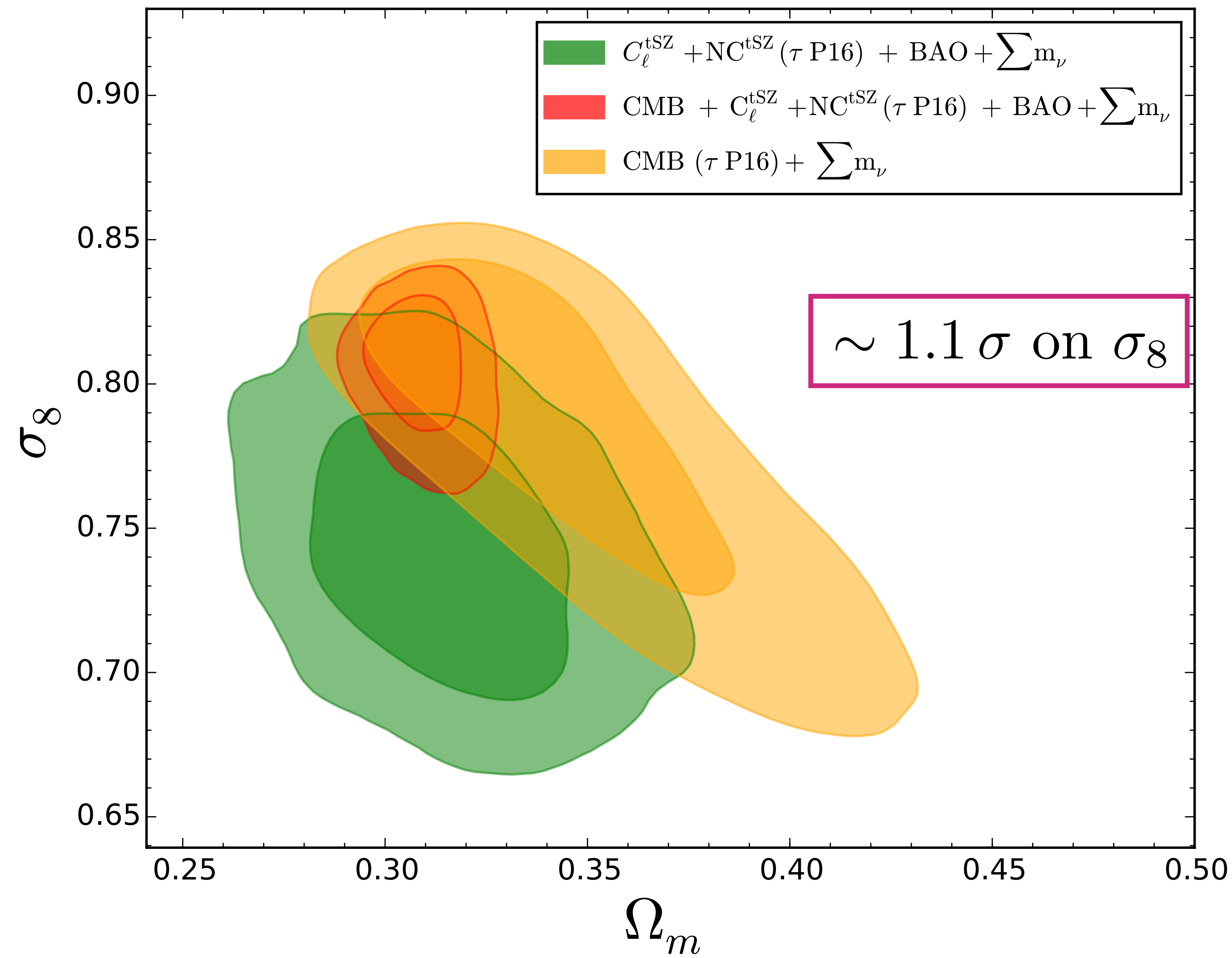
Inhibition of CDM clustering

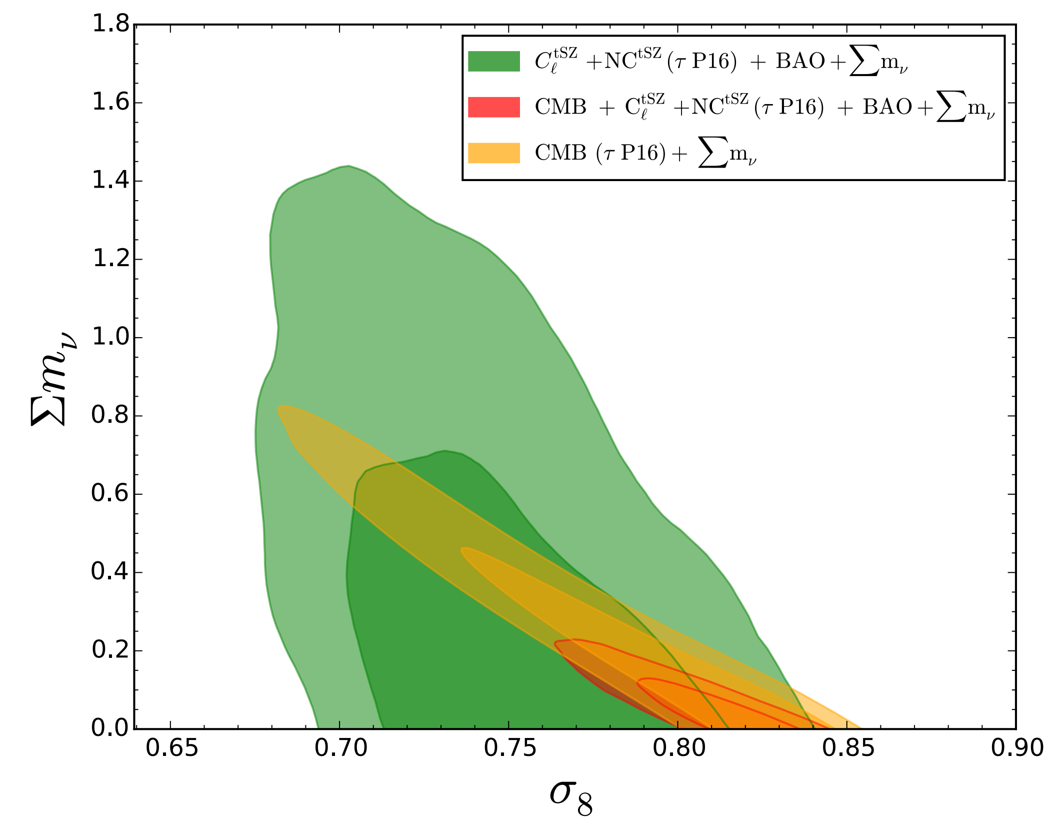
Abazajian et al., Astropart. Phys. 63 (2015) 66

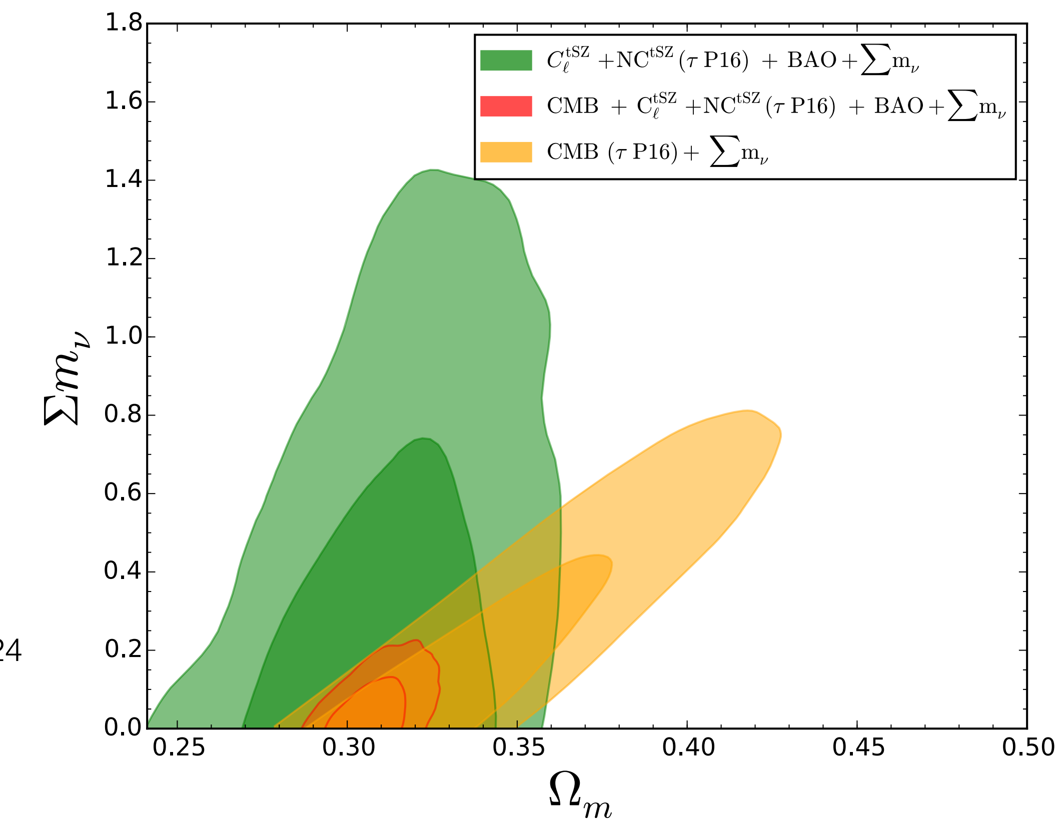


Massive neutrinos

Salvati et al. 2017
in preparation







95% c.l.

NC + PS + BAO

$\sum m_\nu < 1.23\,\mathrm{eV}$

NC + PS + CMB + BAO

$\sum m_\nu < 0.18\,\mathrm{eV}$

CMB

$\sum m_\nu < 0.65\,\mathrm{eV}$

↔

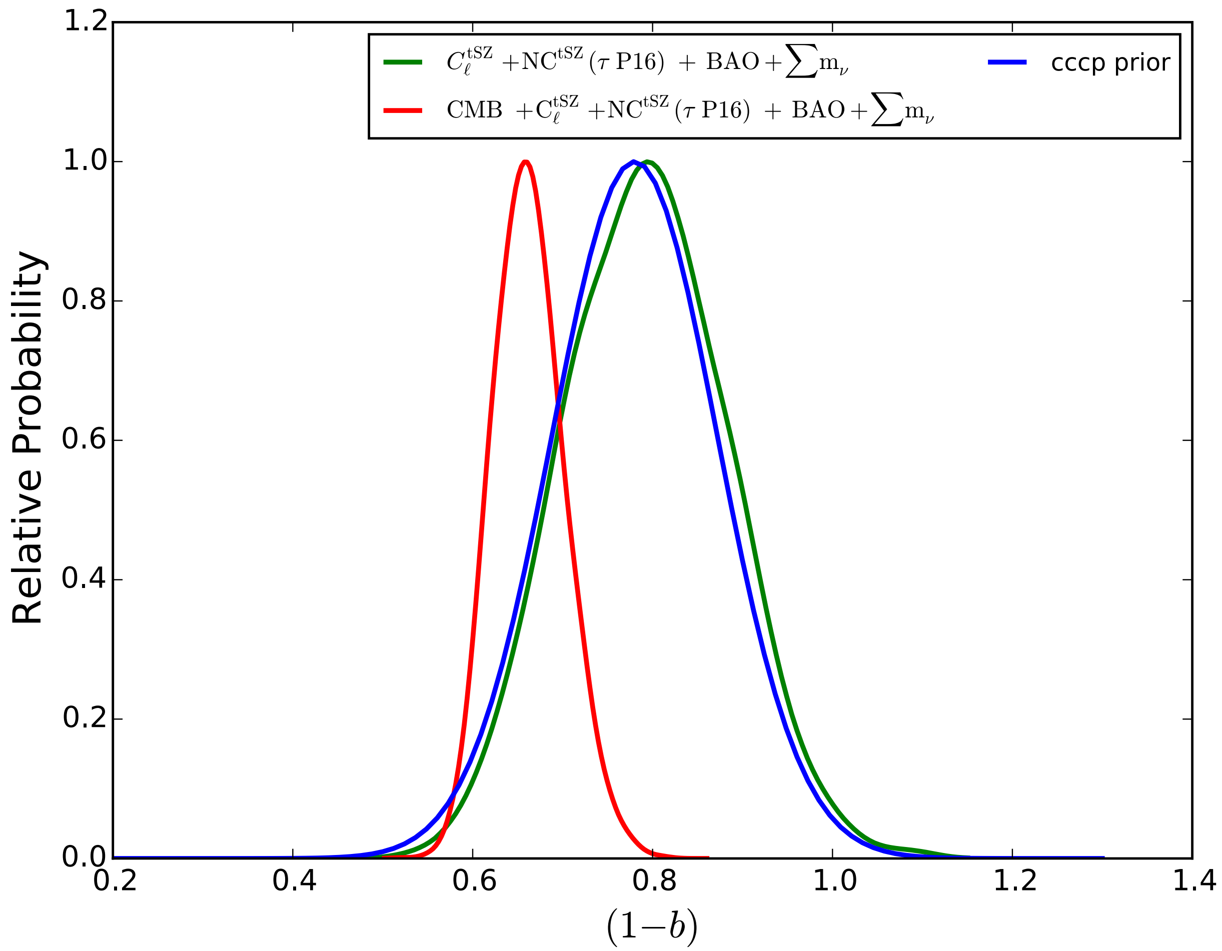
95% c.l.

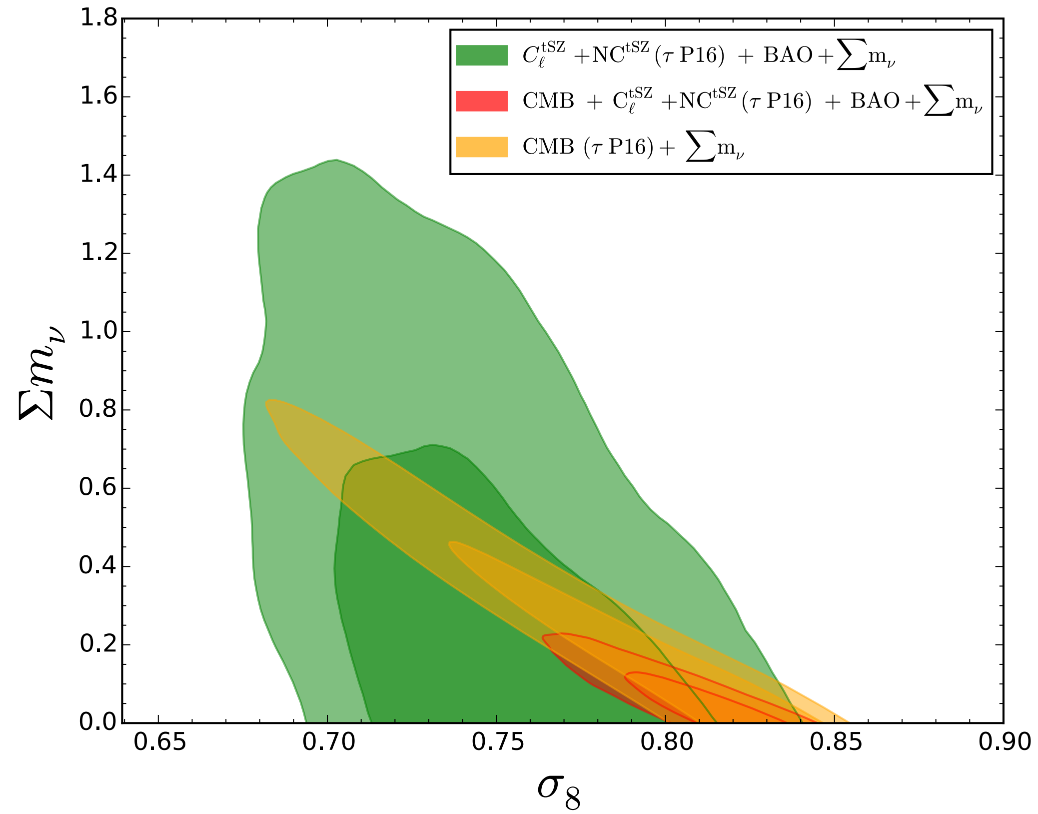
NC + CMB + BAO

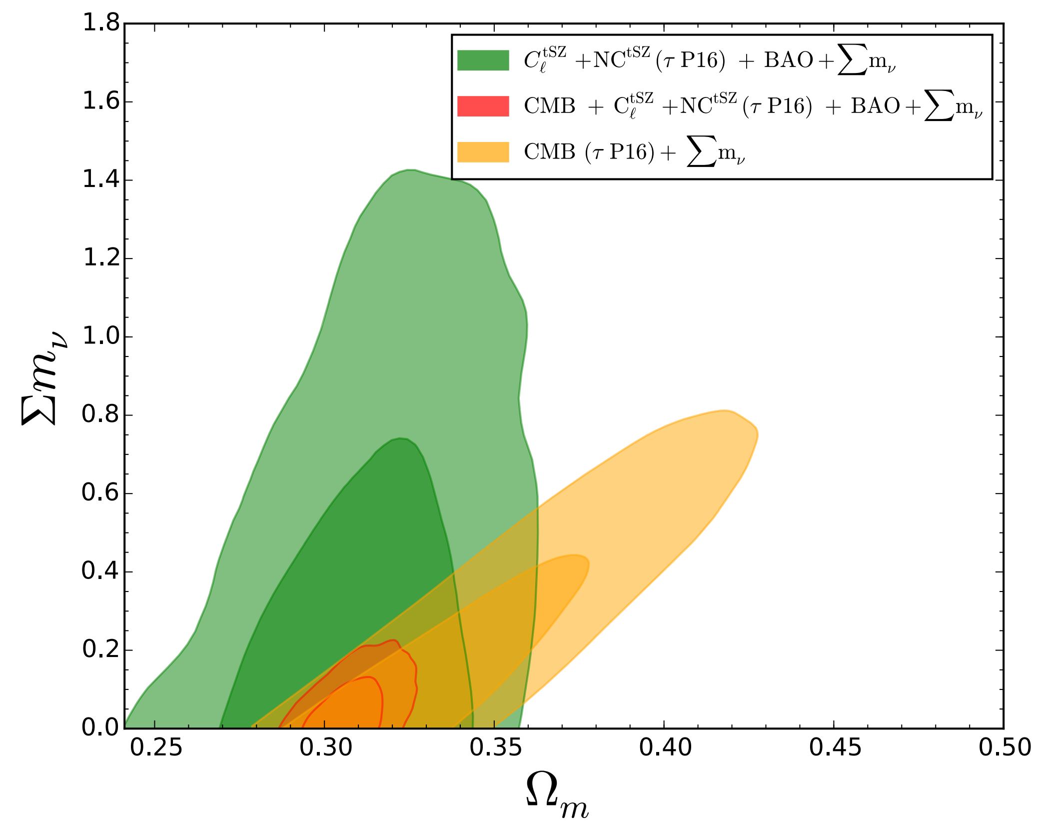
$\sum m_\nu < 0.20\,\mathrm{eV}$

Planck Collaboration, A&A 594 (2016) A24

Massive neutrinos







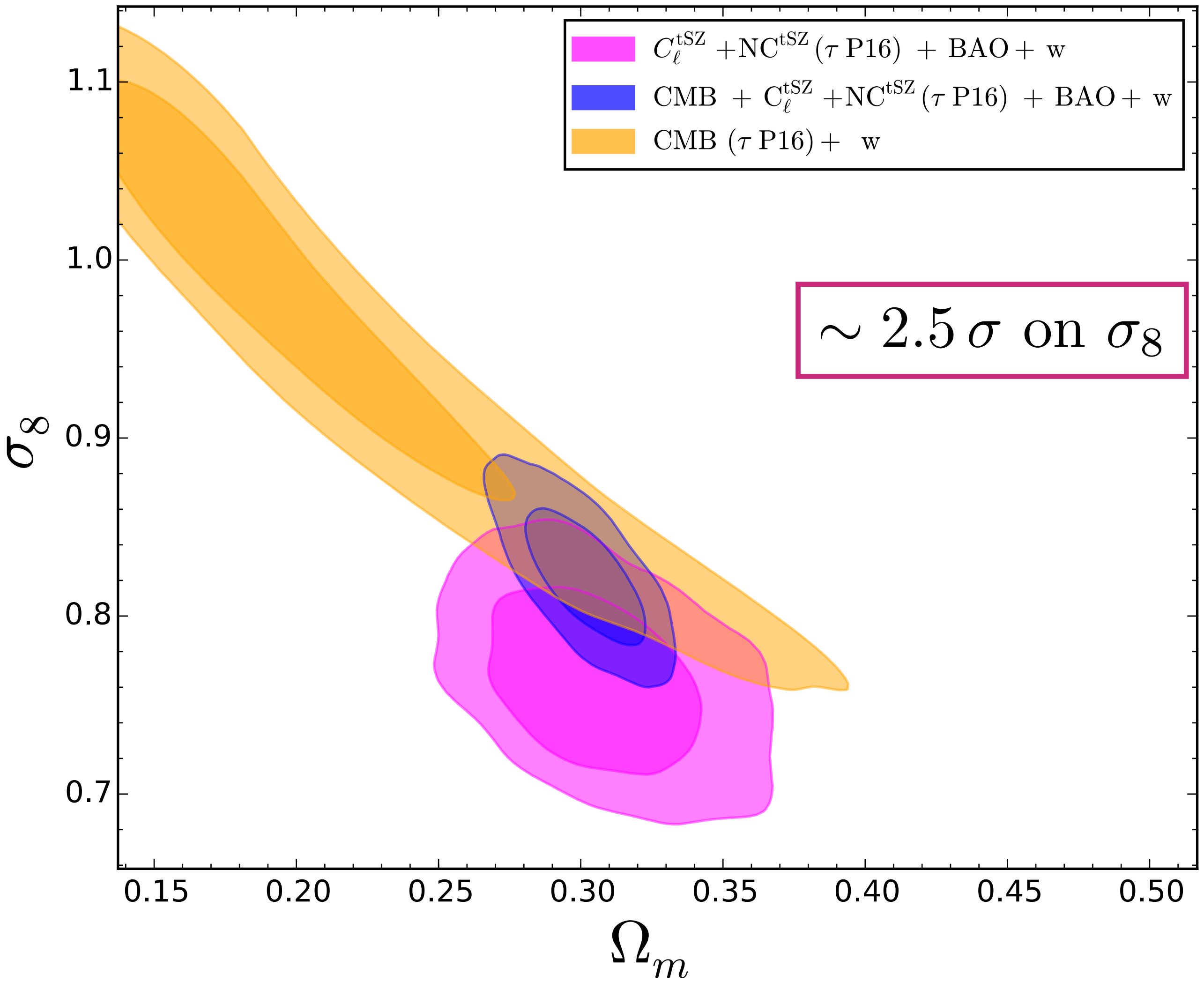
<u>Number counts + Power spectrum + CMB</u> 68% c.l.

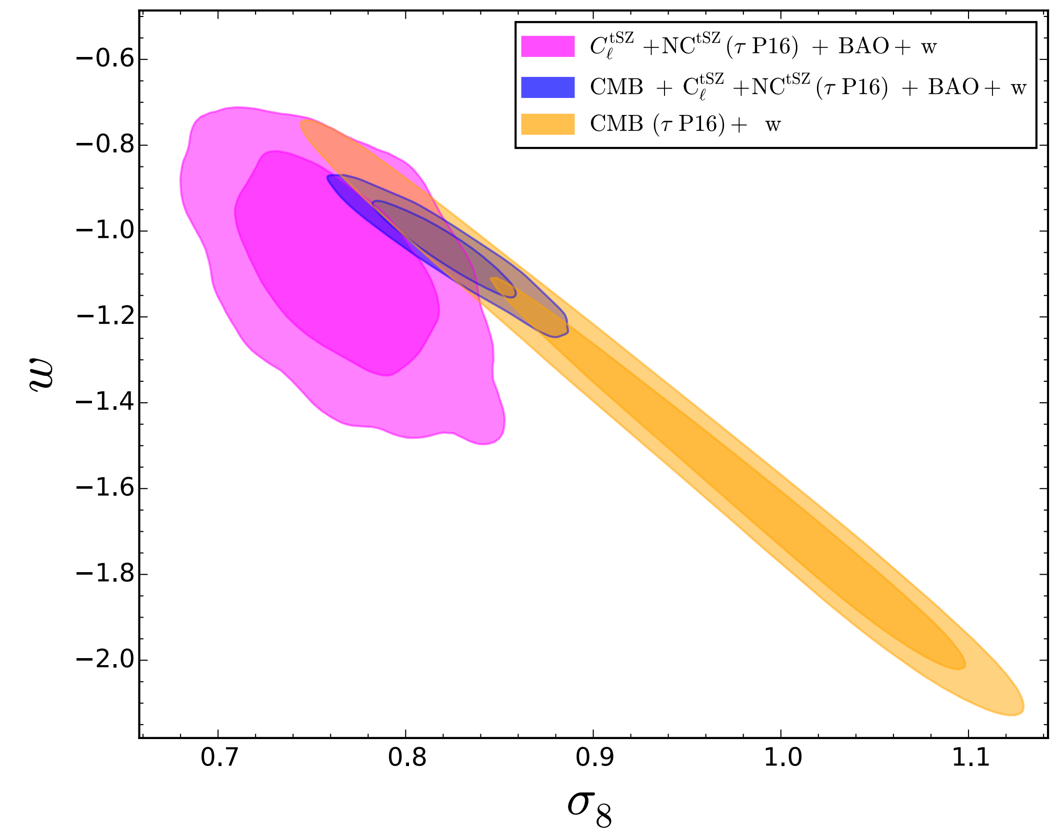
$$(1-b) = 0.663^{+0.036}_{-0.045}$$

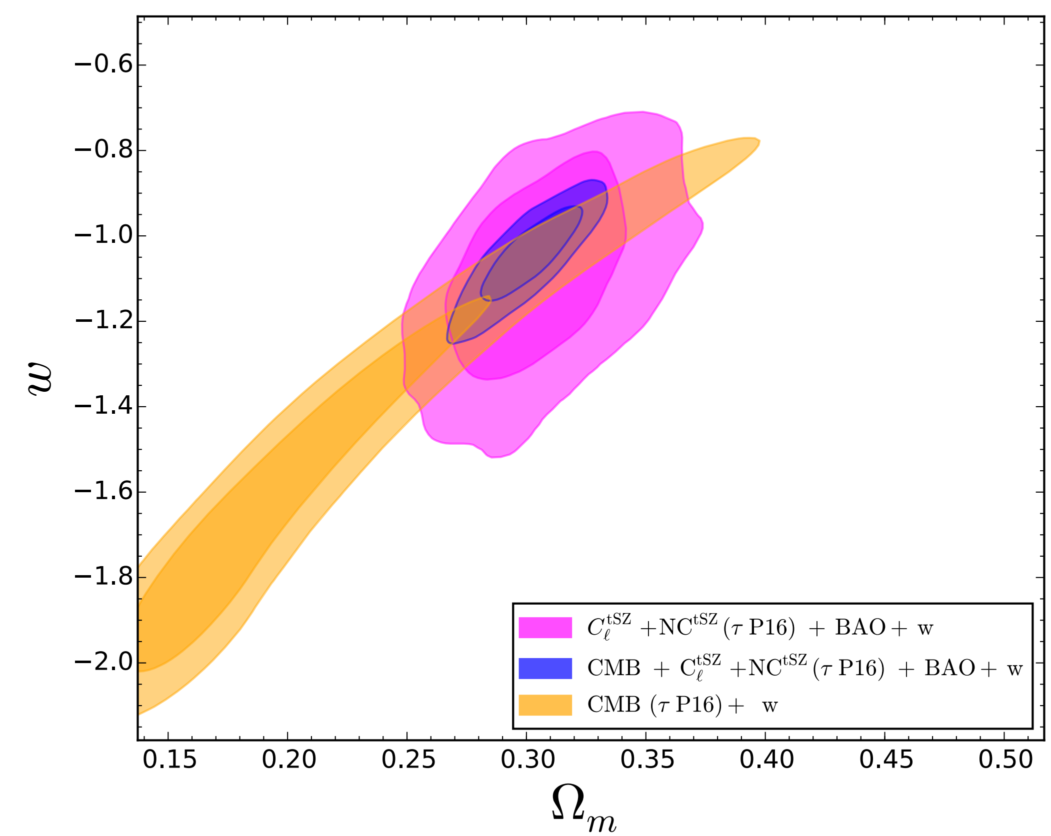
Dark energy EoS

Salvati et al. 2017
in preparation

varying EoS parameter w → constant-w model







NC + PS + BAO

$w = -1.11^{+0.17}_{-0.15}$

68% c.l.

NC + BAO

$w = -1.01 \pm 0.18$

Planck Collaboration, A&A 594 (2016) A24

NC + PS + CMB + BAO

$w = -1.06^{+0.08}_{-0.06}$

CMB

$w = -1.56^{+0.21}_{-0.40}$

Conclusions

Cosmological parameters from galaxy clusters

Number counts
+
Power spectrum

⇒

- improvement in constraining power
- still discrepancy between galaxy clusters and CMB results

Necessity of better knowledge of clusters physics

- degeneracy between nuisance and cosmological parameters

↓

- reduce systematics uncertainties

Testing extensions to LCDM model

- Number counts + Power spectrum able to constrain non standard models
- Still evidence for discrepancy with CMB