Constraining cosmological parameters and hydrostatic mass bias with the gas mass fraction in galaxy clusters

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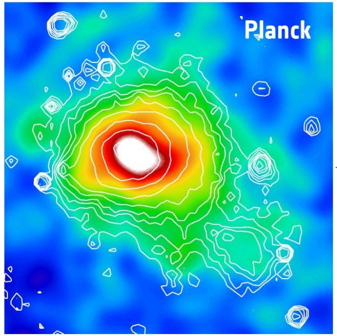
OUTLINE

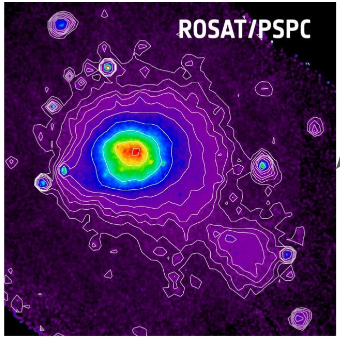
- INTRODUCTION : Galaxy clusters and their gas mass fraction
- Investigating the redshift evolution of the mass bias
- The gas mass fraction as a cosmological probe
- CONCLUSION

Galaxy clusters and their gas mass fraction

SZ effect



X-ray



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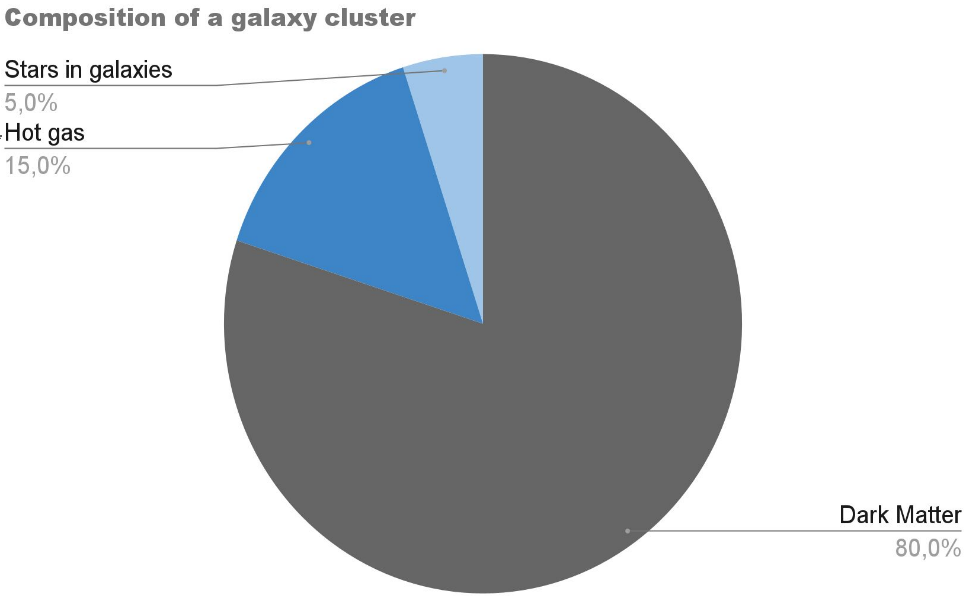


Galaxy clusters and their gas mass fraction

Instrumental effects

Cosmology

$$f_{gas}(z) = K \times \frac{\Upsilon(z)}{B(z)} \times A(z) \times \left(\frac{\Omega_b}{\Omega_m}\right) \times \left(\frac{D_A^{ref}(z)}{D_A(z)}\right)^{3/2}$$

Physical/Baryonic effects

Allen et al. 2008

Galaxy clusters and their gas mass fraction

- Gas mass : obtained using the density profile of the gas in the cluster

$$M_{gas}(< r) = \int_0^r 4\pi r'^2 \rho_{gas}(r')dr'$$

- Total mass :

can be obtained from HE equation :

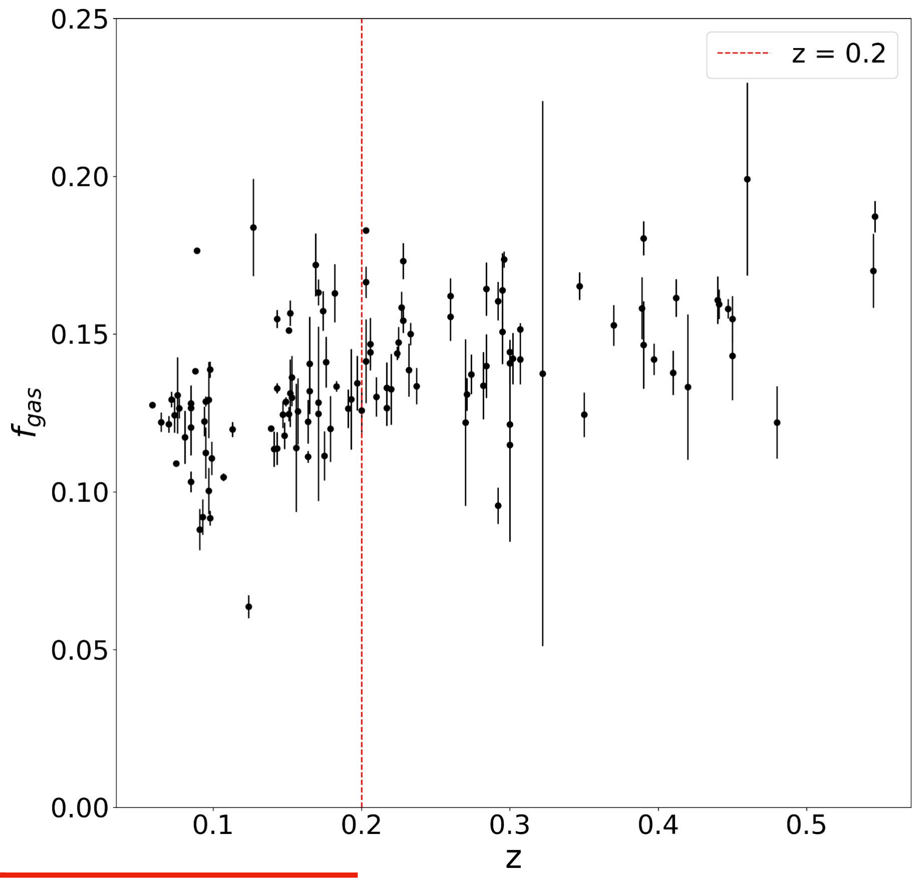
$$M_{tot}(< r) = -\frac{rk_B T(r)}{G\mu m_p}\left(\frac{d\ln\rho(r)}{d\ln r} + \frac{d\ln T(r)}{d\ln r}\right)$$

or from observable-to-mass scaling relations

$$f_{gas} = \frac{M_{gas}}{M_{tot}}$$

Galaxy clusters and their gas mass fraction

- Preliminary work carried out on the *Planck*-ESZ sample, as described in Lovisari et al. 2020.
- 120 clusters observed in X-ray with XMM-*Newton*, in the range **0.059<z<0.546**
- Total masses deduced from HE equation at R_{500}



Probing the redshift evolution of the mass bias

Instrumental effects

Cosmology

$$f_{gas}(z) = K \times \frac{\Upsilon(z)}{B(z)} \times A(z) \times \left(\frac{\Omega_b}{\Omega_m}\right) \times \left(\frac{D_A^{ref}(z)}{D_A(z)}\right)^{3/2}$$

PHYSICAL/BARYONIC EFFECTS

Allen et al. 2008

Probing the redshift evolution of the mass bias

- Hydrostatic equilibrium hypothesis biases the mass measurements :

$$M_{measured} = B(z) \times M_{true} \quad , B(z) = (1-b)(z)$$

- Hydrodynamical simulations based on Λ-CDM find no clear evolution of B with the redshift
- What we actually constrain is $\Upsilon(z)/B(z)$
- We assume a linear evolution of the bias:

$$B(z) = B_0 + B_1 \times (z - z_{pivot})\text{, where } z_{pivot} = \langle z \rangle$$

- We chose Υ constant in z : Υ_0 (Planelles et al. 2013)
- See Bora et al. 2021 for investigation on the variation of Υ

Probing the redshift evolution of the mass bias

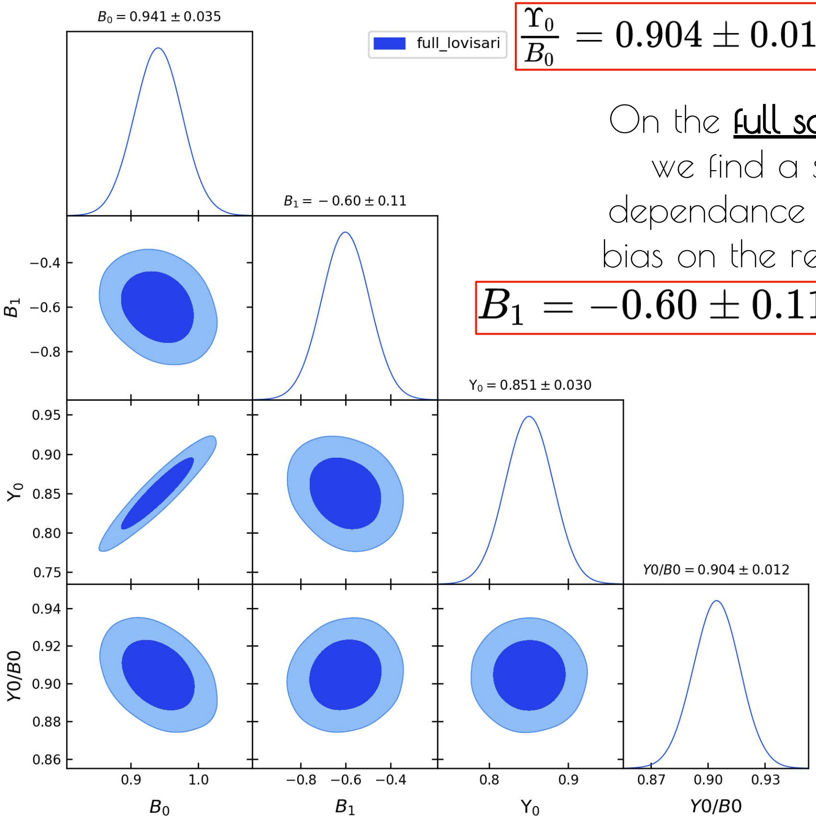
ByoPiC

To fit our data, we carry out a MCMC analysis.
Summary of the priors that have been used for this study :

$\mathbf{B_0}$	$\boldsymbol{U}$**(0.3, 1.7)**
$\mathbf{B_1}$	$\boldsymbol{U}$**(-1.5, 1.5)**
Υ_0	$\boldsymbol{N}$**(0.85, 0.03)** (Planelles et al. 2013)
σ_f (instrinsic scatter)	$\boldsymbol{U}$**(0, 1)**
Cosmological parameters	Planck Collaboration et al. 2018

$N(\mu, \sigma)$: normal prior of mean μ and of standard deviation σ
$U(l, u)$: uniform prior of lower bound l and upper bound u

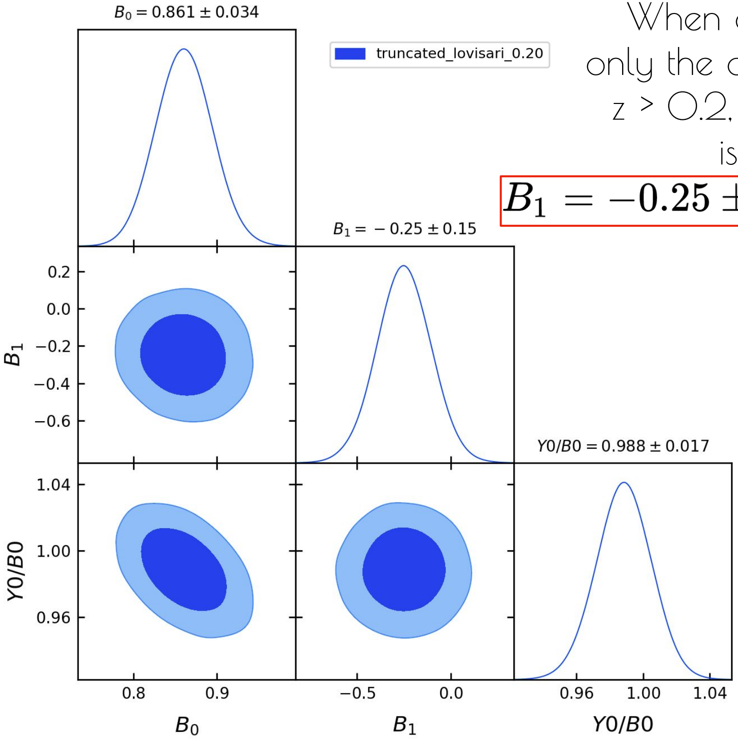
Probing the redshift evolution of the mass bias



$$\frac{\Upsilon_0}{B_0} = 0.904 \pm 0.012(1\sigma)$$

On the <u>full sample</u>, we find a strong dependance of the bias on the redshift:

$$B_1 = -0.60 \pm 0.11(1\sigma)$$



$$\frac{\Upsilon_0}{B_0} = 0.988 \pm 0.017(1\sigma)$$

When considering only the clusters with z > 0.2, the tension is alleviated:

$$B_1 = -0.25 \pm 0.15(1\sigma)$$

Probing the redshift evolution of the mass bias

- $B_1 < 0$: higher bias with redshift
- In contradiction with hydrodynamical simulations
- In contradiction with the trends found in Salvati et al. 2019 from *Planck* tSZ number counts ***for low z clusters***
- In agreement with Salvati et al. 2019, ***for high z clusters***
- Consistent with the trends from CoMaLit (Sereno & Ettori 2017) and LoCuSS (Smith et al. 2016) from weak lensing to SZ/X mass ratios, ***on high z clusters***

The gas mass fraction as a cosmological probe

ByoPiC

Instrumental effects

COSMOLOGY

$$f_{gas}(z) = K \times \frac{\Upsilon(z)}{B(z)} \times A(z) \times \left(\frac{\Omega_b}{\Omega_m}\right) \times \left(\frac{D_A^{ref}(z)}{D_A(z)}\right)^{3/2}$$

Physical/baryonic effects

Allen et al. 2008

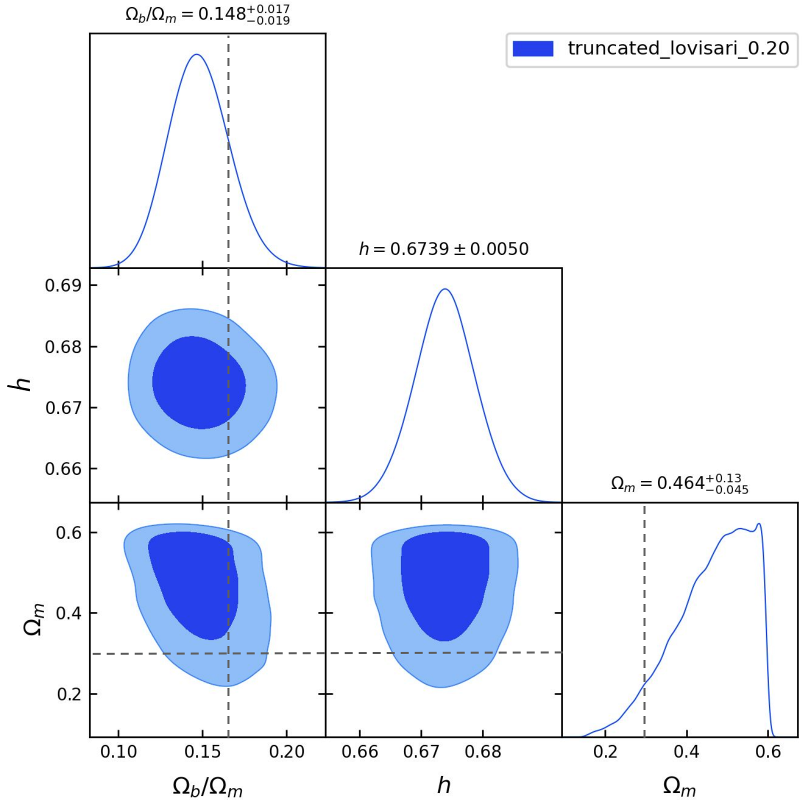
The gas mass fraction as as cosmological probe

ByoPiC

Summary of the priors that have been used at different steps of the study

	Full sample	z > 0.2
B_0	N(0.780, 0.092) (CCCP, Hoekstra et al. 2015)	N(0.780, 0.092) (CCCP, Hoekstra et al. 2015)
B_1	Fixed at 0, then N(-0.60, 0.11)	Fixed at 0, then N(-0.25, 0.15)
Ω_b/Ω_m	U(0.05, 0.3)	U(0.05, 0.3)
Ω_m	N(0.315, 0.007) (Planck Collab. et al. 2018) then U(0.01, 1.0)	N(0.315, 0.007) (Planck Collab. et al. 2018) then U(0.01, 1.0)
h	N(0.674, 0.005) (Planck Collab. et al. 2018)	N(0.674, 0.005) (Planck Collab. et al. 2018)

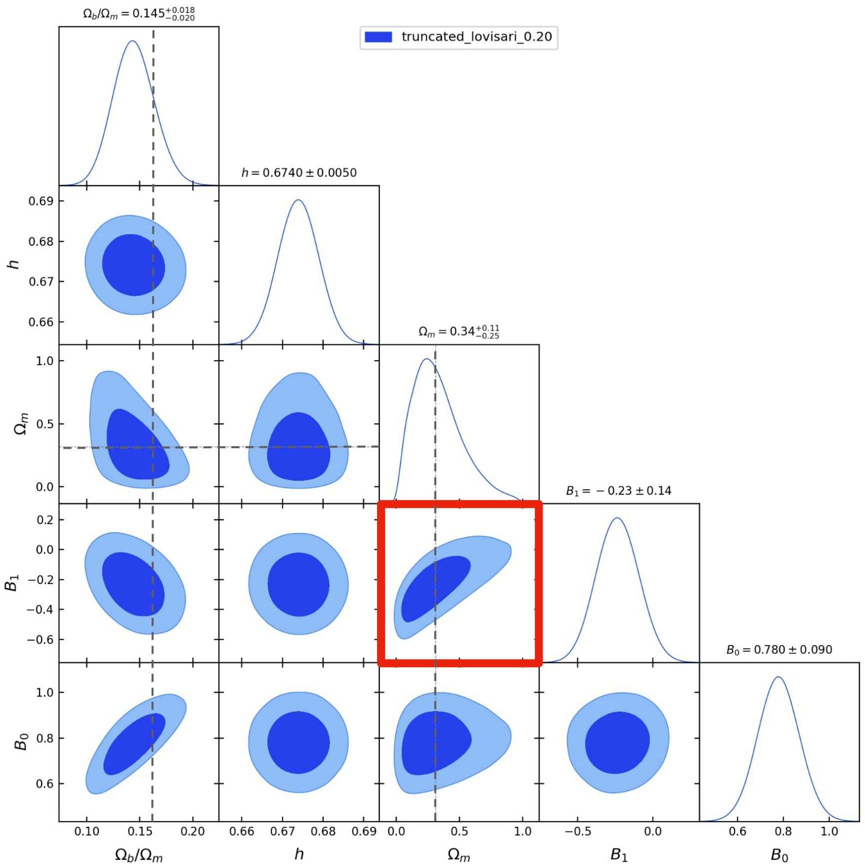
The gas mass fraction as as cosmological probe



Planck prior on h , Ω_m is free, $B_1 = 0$

If we consider no evolution of ***B(z)*** with z, the cosmological constraints are consistent with *Planck* for Ω_b/Ω_m , but are totally off for Ω_m

The gas mass fraction as a cosmological probe



This time we consider $B_1 = -0.25 \pm 0.15$

Ω_b/Ω_m is compatible with the *Planck* value, although slightly below.

Ω_m peaks below the *Planck* value, and has a strong degeneracy with B_1

CONCLUSION

- Results on the redshift evolution of the mass bias are strongly dependant on the sample.
- A mass dependence study will also be carried out using the same sample
- Need to be very careful about these effects when trying to use the gas mass fraction as a cosmological probe
- For investigations at R_{2500}, NIKA2 + X-ray data will be of great help

Thank you !