Cosmology with cluster sizes: measuring the Hubble constant from Planck and XMM-Newton observations of galaxy clusters.

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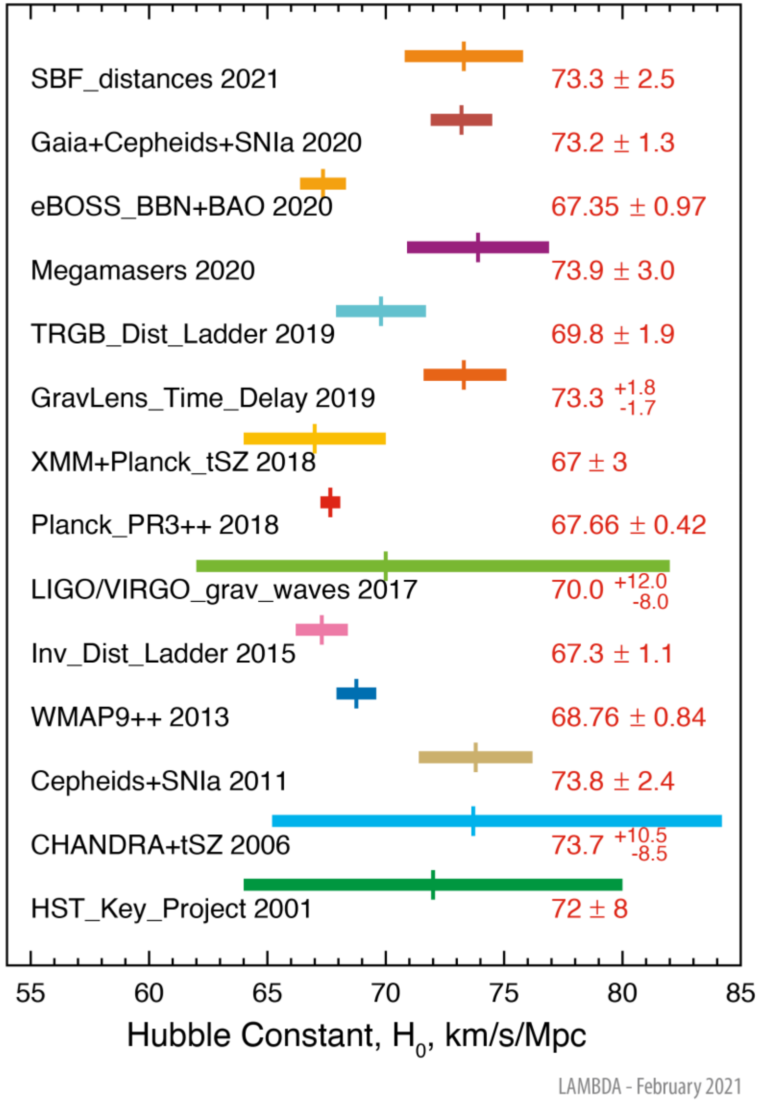
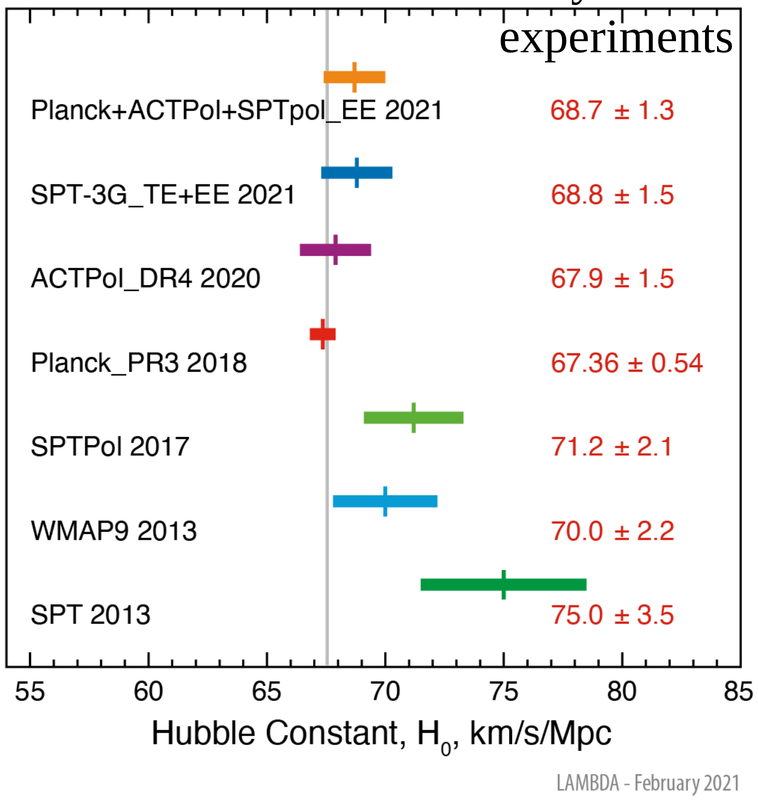
AN OPEN COSMOLOGICAL PROBLEM: THE H_0 TENSION



The most recent analysis of the expansion rate H_0 of the Universe have reached more precise results during the last two decades. However, early-Universe H_0 inferred from the Cosmic Microwave Background (CMB) and local estimation of H_0 from cosmic distance ladder (Cepheid plus SNIa) show significant bias.

Only CMB experiments



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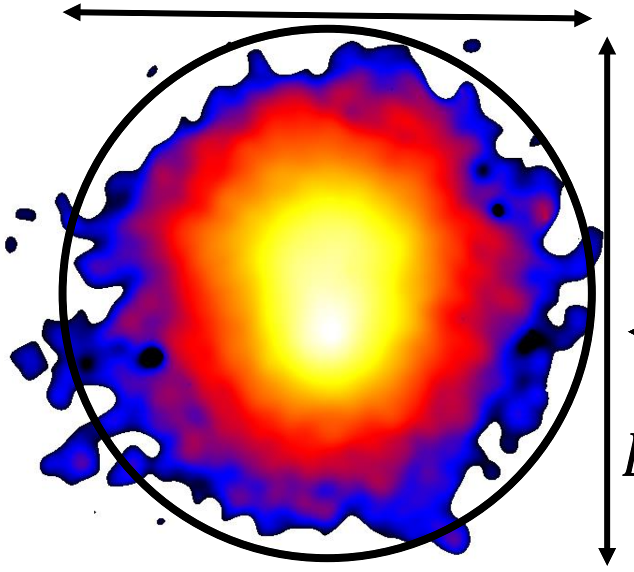
THEORETICAL FRAMEWORK

Combining the SZ effect and X-ray emission allow a direct estimation of the angular diameter distance and H_0, if the cluster redshift is known (Cavaliere et al. 1977):

$$\sim \frac{y^2}{\Sigma_X}$$



ϑ_c: characteristic scale of the cluster

$$\sim 2\vartheta_c$$

$$D_a(z, H_0) \sim \frac{y^2}{\Sigma_X \vartheta_c}$$

$$\Sigma_X = \frac{1}{4\pi(1+z)^3} \int [n_p n_e]\, \Lambda(T, Z) D_a d\vartheta$$

$$y = \frac{\Delta T}{T f_{(x,T_e)}} = \frac{\sigma_T}{m_e c^2} \int n_e k T_e D_a d\vartheta$$

THEORETICAL FRAMEWORK

In this work, we will use this technique, following Kozmanyan et al. (2019) approach. The cosmological information can be derived from the 3D thermo-dynamical profiles for P_e, n_e studing X-ray-SZ data:

$$\eta_T = {}^{P_X}/_{P_{SZ}}$$

η_T describe discrepancy between only X-ray or SZ pressure profiles. In the ideal case: $\eta_T = 1$

$$\boxed{\eta_T = \mathcal{C} \times \mathcal{B}}$$

Source of departure from unity:

- Emitting ICM distribution property ($\mathcal{B}$);
- Underlying cosmological framework ($\mathcal{C}$);

$$P_x = n_e\,(r) \cdot kT(r) = \eta_T \cdot P_{SZ}$$

$$\mathcal{C} = \left(\frac{\overline{D_a}}{D_a}\right)^{1/2} \cdot \left(\frac{n_p/n_e}{\overline{n_p}/\overline{n_e}}\right)^{1/2} \cdot \left(\frac{1 + 4\,{}^{n_{He}}/_{n_p}}{1 + 4\,{}^{\overline{n_{He}}}/_{\overline{n_p}}}\right)^{1/2}$$

$$\mathcal{B} = b_n \frac{C_\rho^{1/2}}{e_{LOS}^{1/2}}$$

THEORETICAL FRAMEWORK

The SZ and X-ray data are processed and analysed using, respectively, a gNFW pressure profile from Nagai et al. (2007) and the analytic profiles of temperature and density from Vikhlinin et al. (2006).

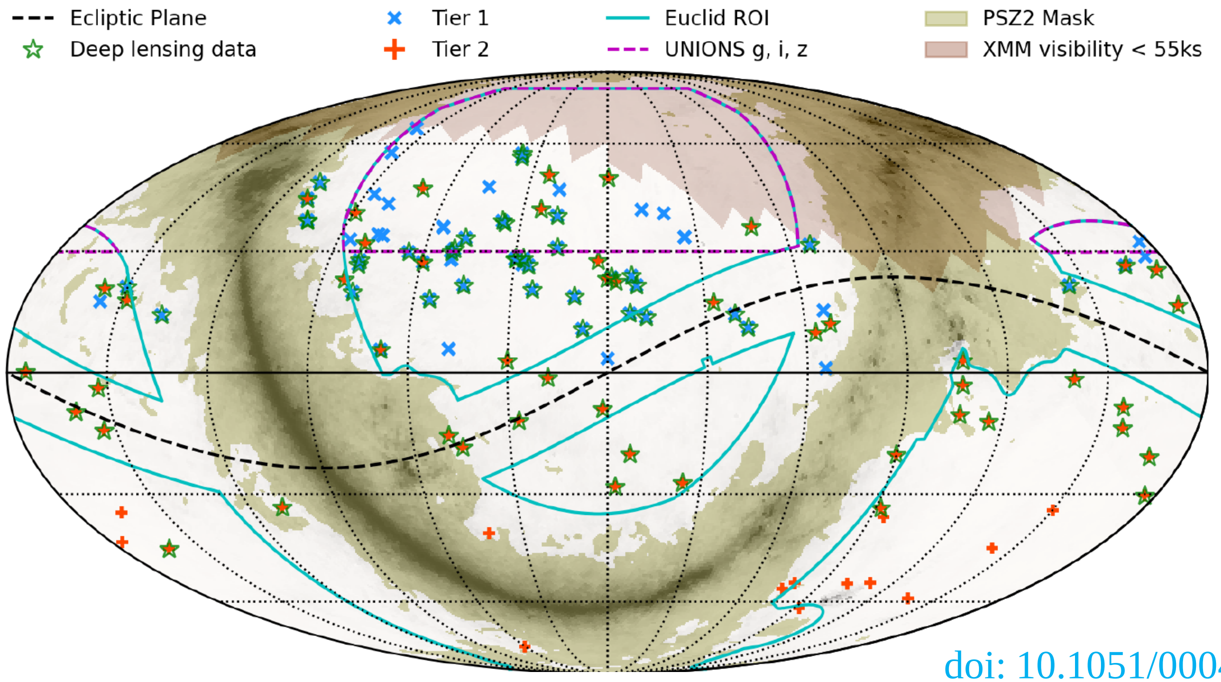
$$P_e(r) = \frac{P_0}{(c_{500}x)^{\gamma}[1+(c_{500}x)^{\alpha}]^{(\beta-\gamma)/\alpha}}$$

$$kT(r) = T_0 \frac{x + T_{min}/T_0}{x+1} \frac{(r/r_t)^{-a}}{[1+(r/r_t)^{-b}]^{c/b}}$$

$$[n_p n_e](r) = \frac{n_0^2 (r/r_c)^{-\alpha'}}{[1+(r/r_c)^2]^{3\beta_1-\alpha'/2}} \frac{1}{[1+(r/r_s)^{\gamma}]^{\epsilon/\gamma}} + \frac{n_0^2}{[1+(r/r_{c2})^2]^{3\beta_2}}$$

THE SAMPLE

This work is based on the CHEX-MATE sample. It is a large, unbiased, signal to noise limited sample of ~ 120 galaxy clusters detected by Planck (PSZ2 sample) via their SZ effect.



XMM-Heritage observational map

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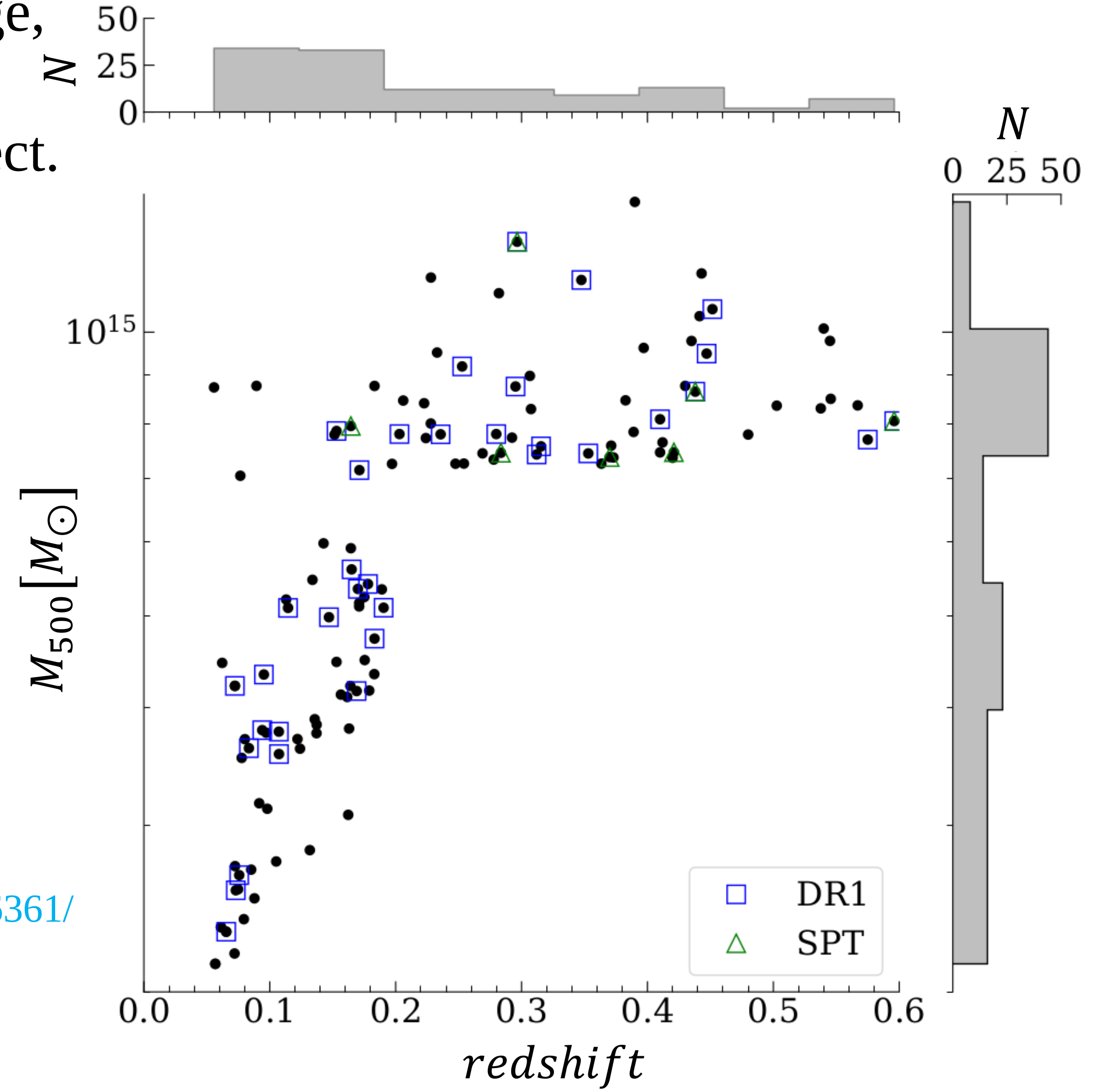
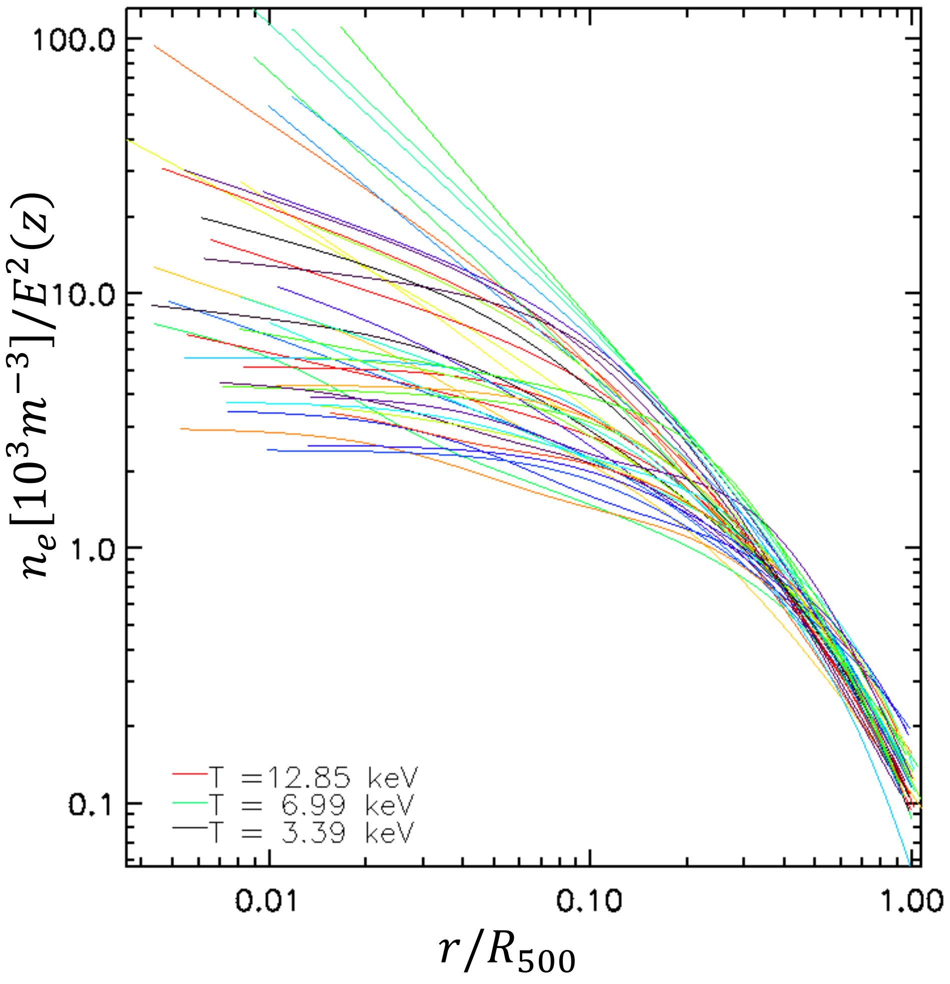


GALAXY CLUSTER PROFILES FOR DR1+SPT SUBSAMPLE

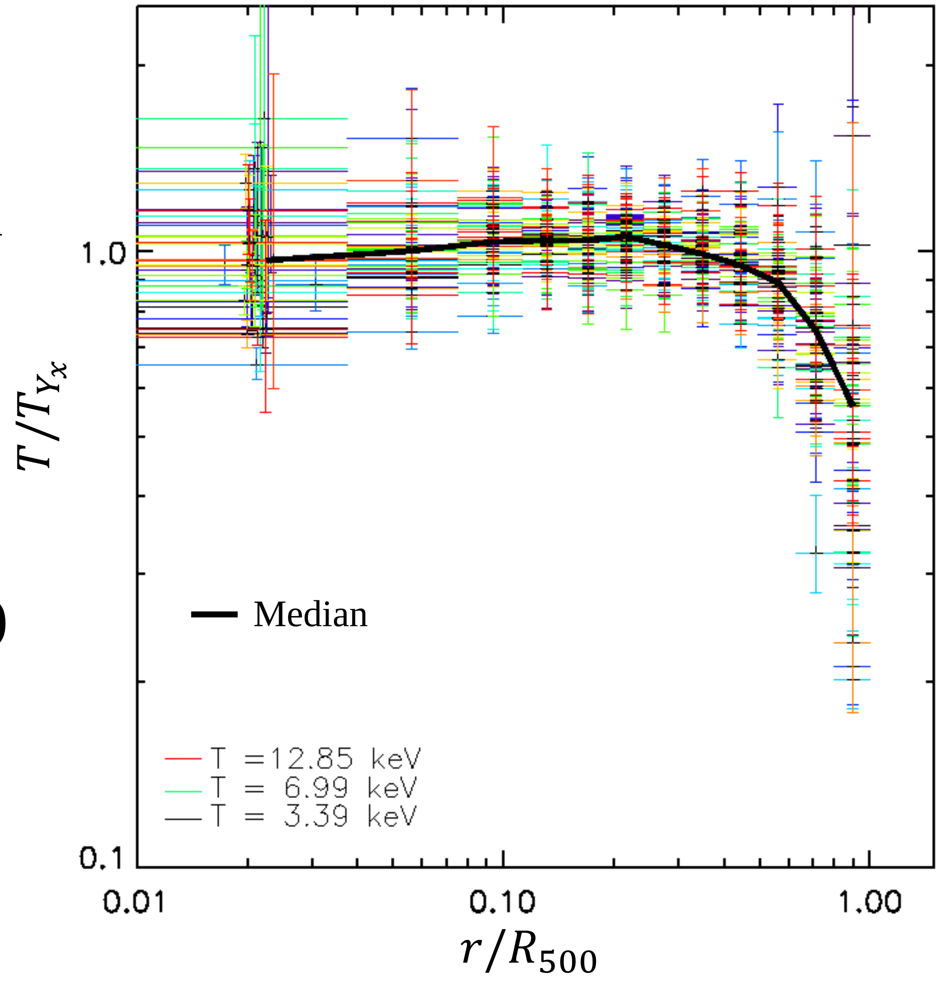


DR1: 35 objects.
It is a technical and representative (mass and redshift) subsample.

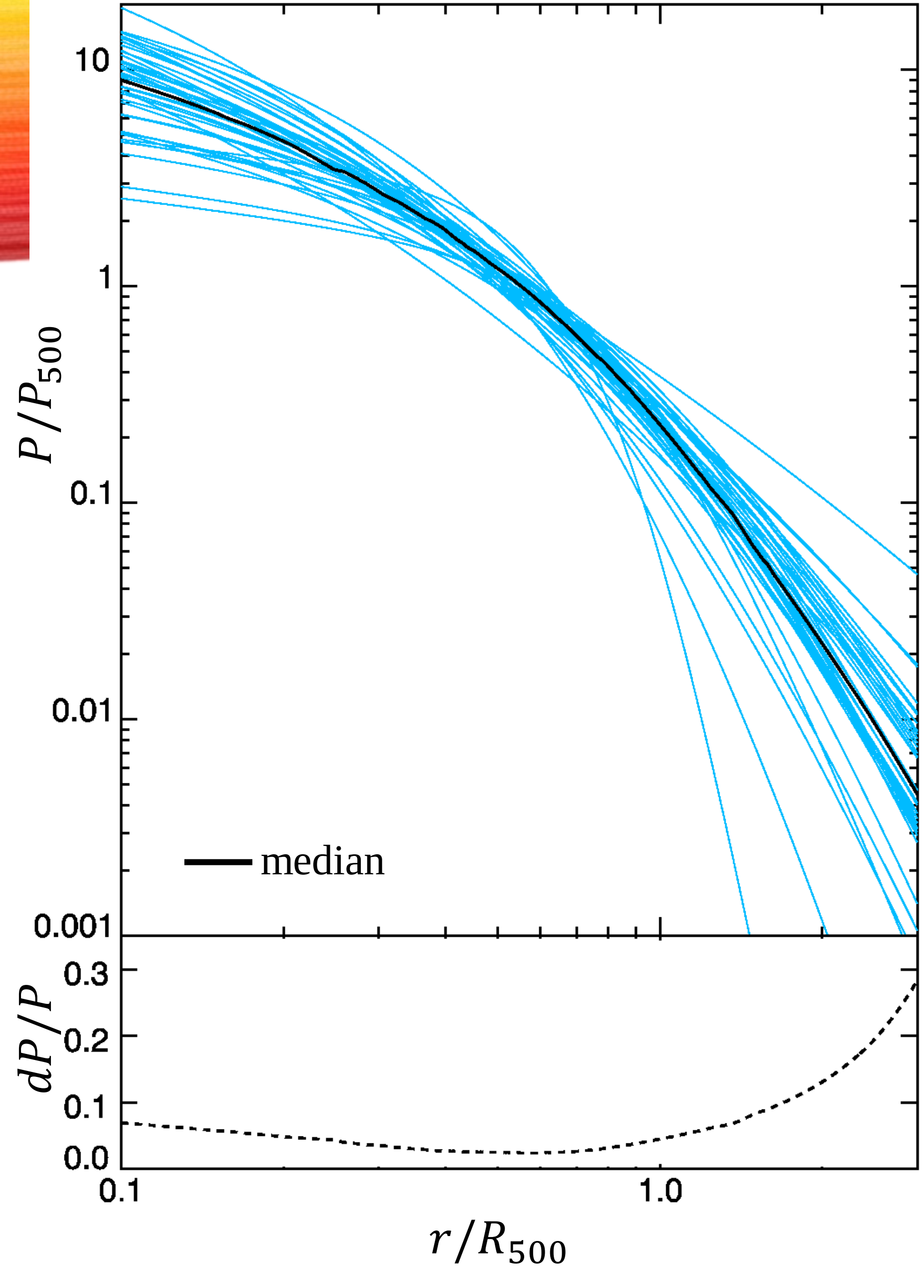
SPT: 6 cluster (4 in common).

Total: 39 objects
(1/3 of the final sample)

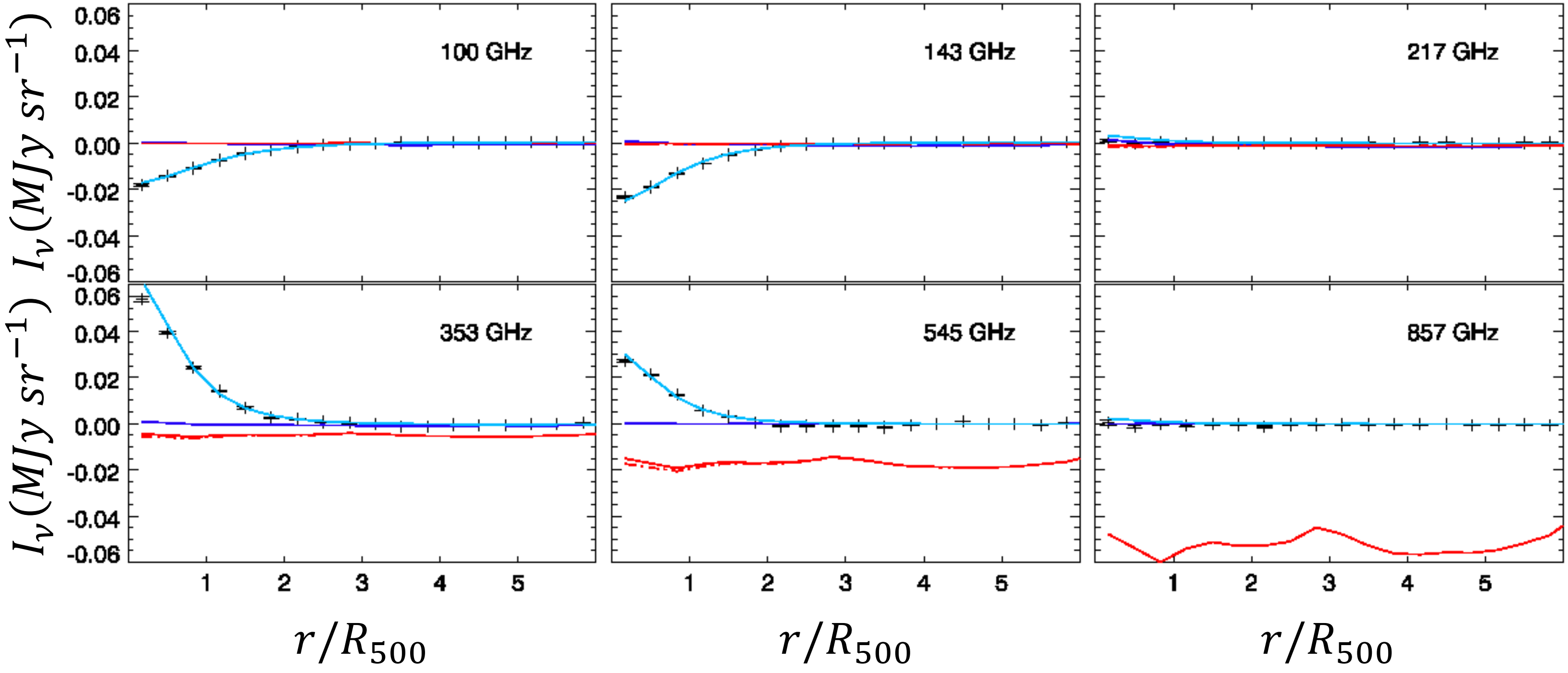
T_{Y_X}: temperature inside $[0.15 - 1]\ R_{500}$ (for Y_X relation).



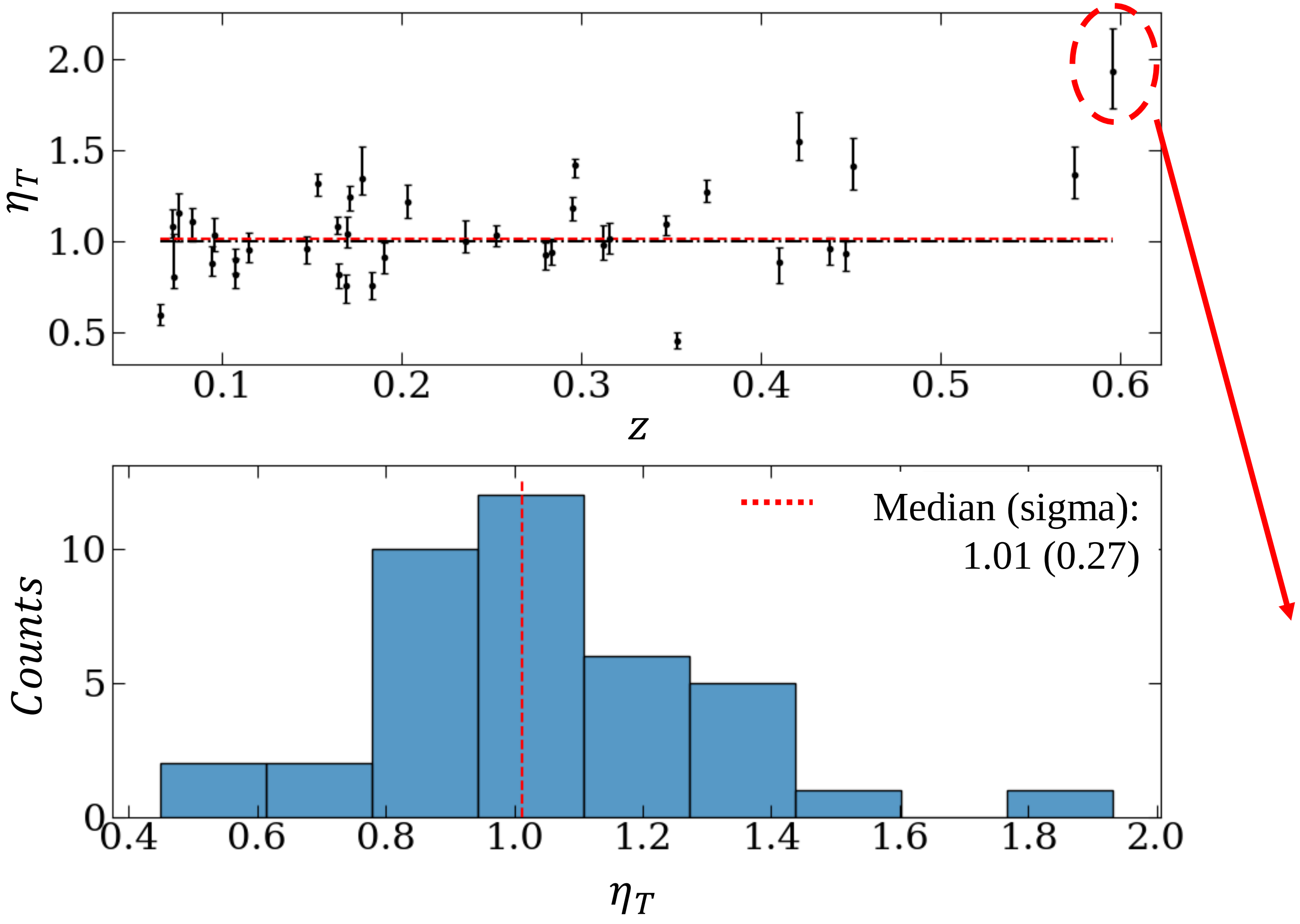
PLANCK-XMM JOINT FIT



For this subsample, the SZ signal of clusters are extracted with the method illustrated in Bourdin et al. (2017), based on wavelet denoising and component separation discussed also this morning in the talk by Oppizzi for SPT-Planck data.



η_T DISTRIBUTION



From the joint fit of Planck and XMM-newton profiles of clusters coming from the DR1-SPT subsample, we retrieve the distribution of η_T.

The median is compatible with previous works present in the literature.

Outlier at high η_T: Phoenix cluster.
XMM X-ray data contaminated by AGN.

$$P_x = n_e\ (r) \cdot kT(r) = \eta_T \cdot P_{SZ}$$

DERIVATION OF H_0

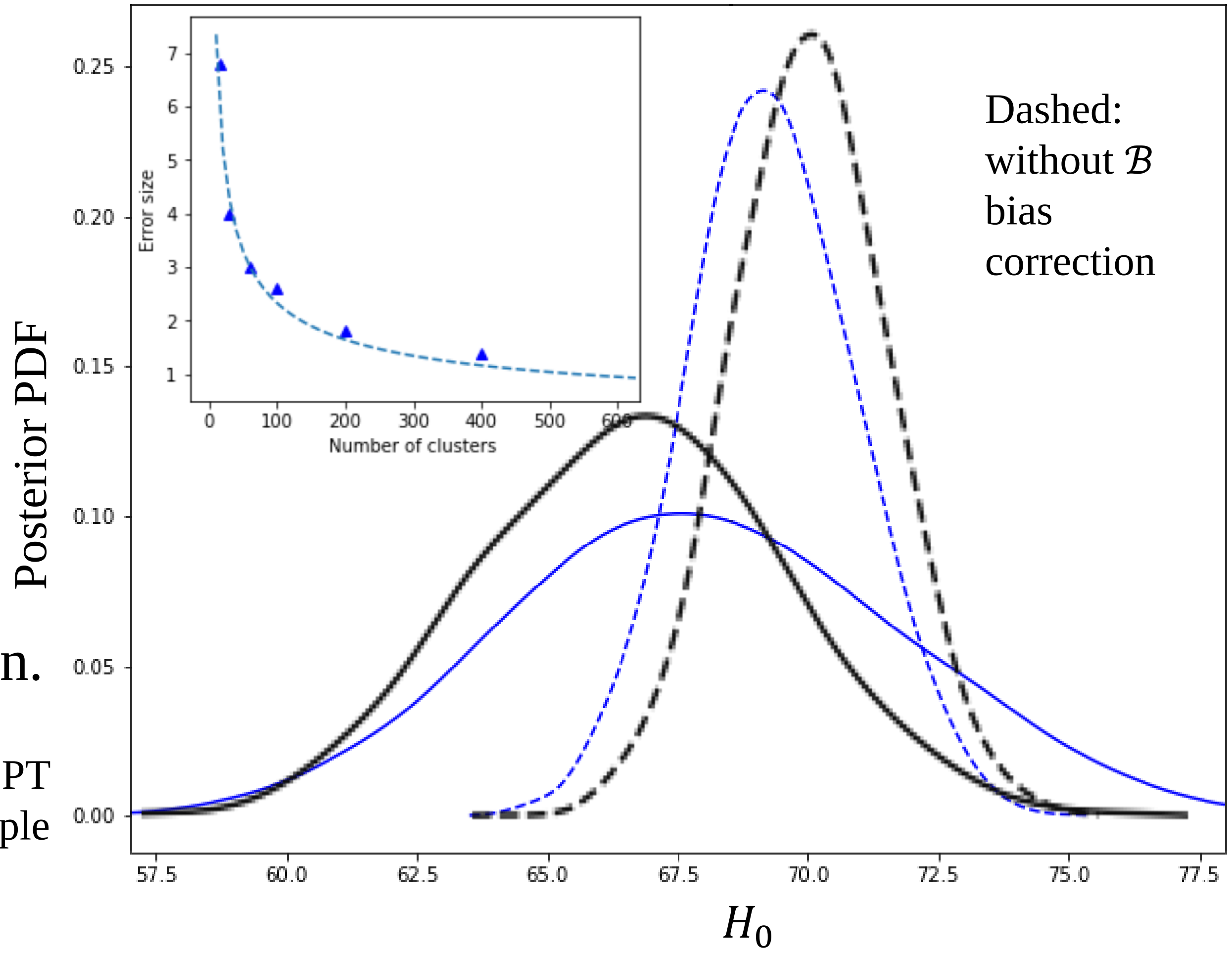
Once the morphological bias $\mathcal{B}$ is estimated, it is possible to estimate the cosmological parameter in interest using a Bayesian approach.

Considering, for the moment, the morphological prior from Kozmanyan et al. (2019), based on a subsample (61 objects) of Planck ESZ, we retrieve:

$$H_0 = (68 \pm 4)\ km\ s^{-1}\ Mpc^{-1}$$

Respect to Kozmanyan et al. (2019), the final CHEX-MATE sample is double in size and with a more accurate control on the mass selection function.

Black: Posterior distribution from Kozmanyan et al. (2019) $H_0 = (67 \pm 3) km\ s^{-1}\ Mpc^{-1}$



Blue: Posterior distribution for DR1-SPT clusters of CHEX-MATE sample

SUMMARY AND STATUS

Results already achieved
(For 1/3 of the sample):

1. X-ray analysis: derivation of the principal cluster profiles: P_e, T_e, n_e;
2. SZ analysis: XMM-Planck joint fit;
3. η_T distribution: first comparison of projected temperature profiles.

Next steps:

- Expansion of the analysis to the final CHEX-MATE sample:
    1. Final X-ray and SZ analysis;
    2. Final η_T distribution.
- Morphological analysis for $\mathcal{B}$ bias:
    1. Estimation of priors taking advantage of simulations.
- Bayesian estimation of H_0 for the final sample.

THANKS FOR THE ATTENTION!