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

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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.
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):

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

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

$$\eta_T = \frac{P_x}{P_{SZ}}$$

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

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

Source of departure from unity:
- Emitting ICM distribution property ($\mathcal{B}$);
- Underlying cosmological framework ($\mathcal{C}$);

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

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

$$\mathcal{B} = b_n \frac{C_p^{1/2}}{e_{LOS}^{1/2}}$$
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).

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

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

\[
[n_p n_e](r) = \frac{n_0^2 (r/r_c)^{-\alpha'}}{[1 + (r/r_c)^2]^{3\beta_1 - \alpha'/2}} \frac{1}{[1 + (r/r_s)^{\epsilon}]} + \frac{n_0^2}{[1 + (r/r_{c_2})^2]^{3\beta_2}}
\]
This work is based on the CHEX-MATE sample. It is a large, unbiased, signal to noise limited sample of \( \sim 120 \) galaxy clusters detected by Planck (PSZ2 sample) via their SZ effect.

\[
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\]
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).
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.
From the joint fit of Planck and XMM-newton profiles of clusters coming from the DR1-SPT subsample, we retrieve the distribution of $\eta_T$.

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

Outlier at high $\eta_T$: Phoenix cluster. XMM X-ray data contaminated by AGN.

\[
P_x = n_e \cdot kT(r) = \eta_T \cdot P_{SZ}
\]
Once the morphological bias $\mathcal{B}$ is estimated, it is possible to estimate the cosmological parameter of 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:

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

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.
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. $\eta_T$ 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 $\eta_T$ distribution.
• Morphological analysis for $B$ bias:
  1. Estimation of priors taking advantage of simulations.
• Bayesian estimation of $H_0$ for the final sample.
THANKS FOR THE ATTENTION!