The role of Helium in the ICM emission

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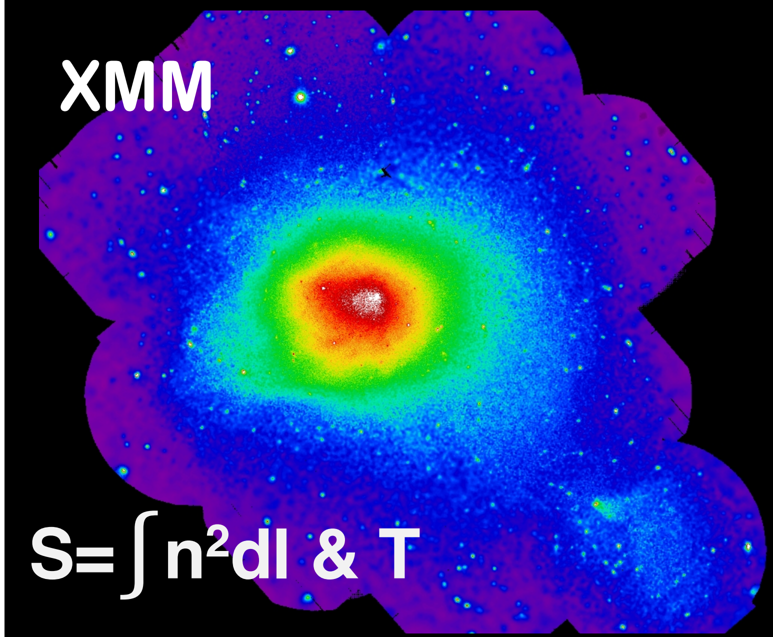
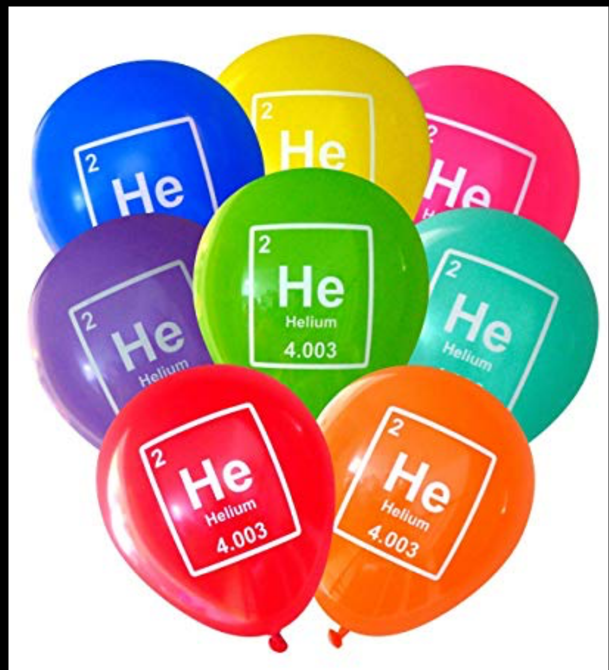
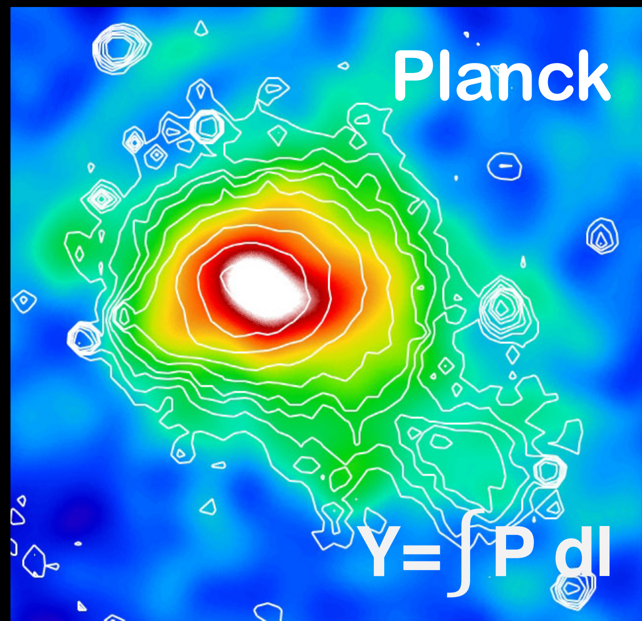






Helium in the ICM

ICM is primordial (H, He) & then enriched up to ~0.3 $Z_\odot$

BBN (& metal-poor HII regions) constrains $\mathbf{Y = \rho_{He}/\rho_b = 0.2471 \pm 0.0001}$

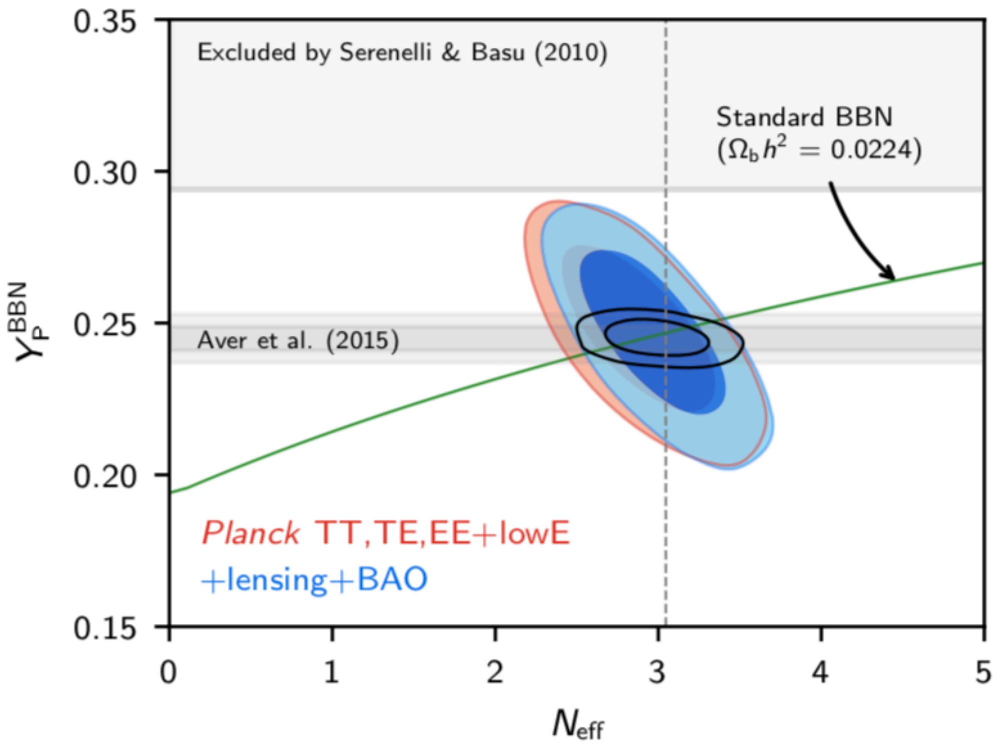
Helium in ICM is fully ionized and not directly observable, and can be different from primordial due to:

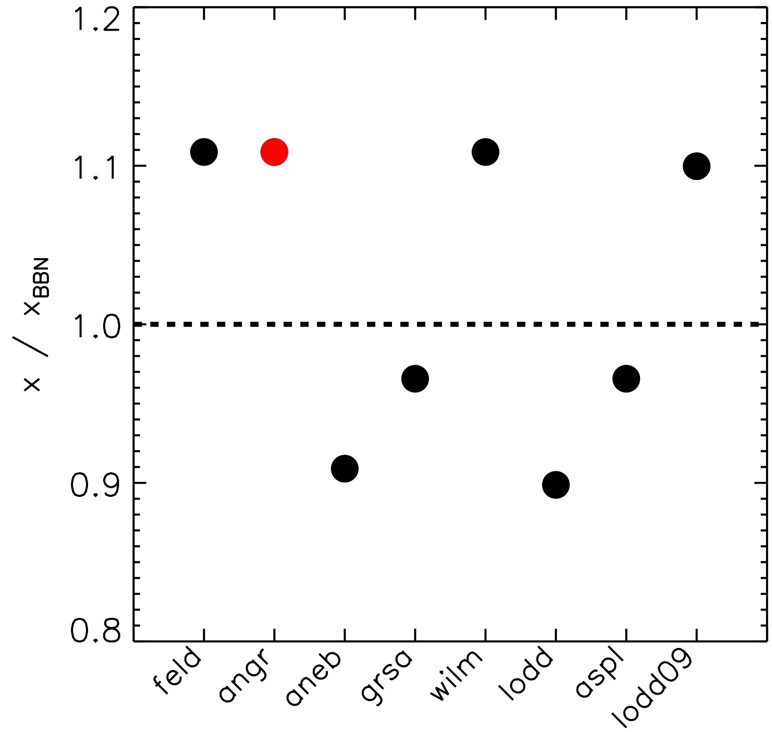
(i) release from stars

(ii) **sedimentation**, mostly in cluster cores under the action of the central gravitational acceleration ***g*** (Fabian & Pringle 77, Rephaeli 78, Abramopoulos etal 81, Gilfanov & Syunayaev 84, ***Qin & Wu 00***, Chuzhoy & Loeb 04, ***Ettori & Fabian 06, Markevitch 07***); *if the suppression due to B is modest, diffusion can occur & He can drift inwards* (but not heavier metals like Fe)

$$\mathbf{v_{sed}} = A_1\, A_2\, v_{th}^3\, \boldsymbol{g} \,/\, (Z_1^2\, Z_2^2\, n_1 \ln\Lambda) \approx 2 \text{ kpc / Gyr}$$

He: reference values, BBN & CMB





BBN (& metal-poor HII regions;

Pitrou+18; see Planck 2018.VI, sect.7.6.2) constrains

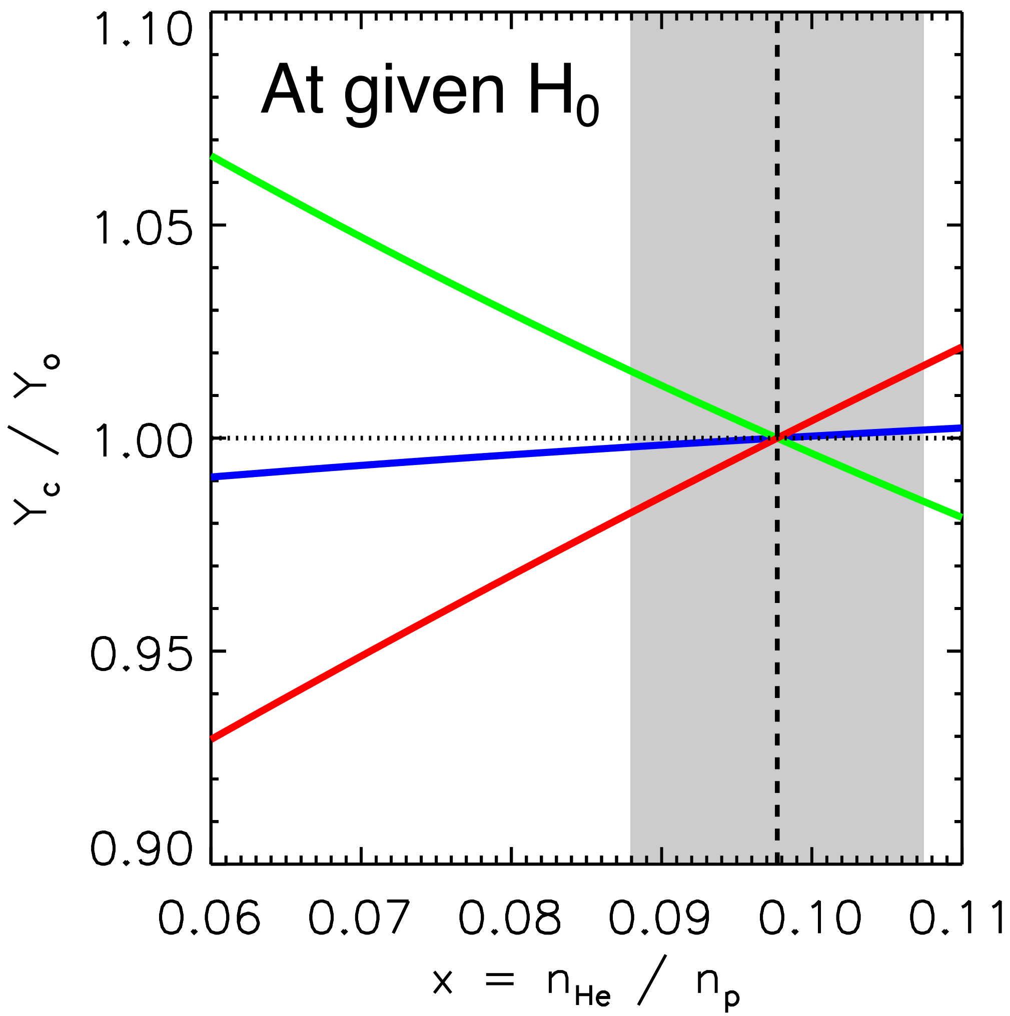
$Y = \rho_{He}/\rho_b$=0.2471±0.0001 i.e. **n_{He}/n_H = 0.088**

According to Anders & Grevesse 89, **n_{He}/n_H = 0.098** *He*
(but see Grevesse & Sauval 98 & Asplund+ 05: **0.085**)

He: effect on the ICM emission

$x = n_{He}/n_p$

(in XSPEC: **0.0977**/AG89;
0.0851/GS98; 0.0964/L09_proto)



$M_{gas} \sim \mu\, (n_p + n_e)$
$\sim h^{-2.5}$ **$(1+4x)^{0.5}/(2+3x) * (1+x)/(1+2x)^{0.5}$**

$M_{hyd} \sim h^{-1}\, \mu^{-1} \sim h^{-1}$ **$(2+3x) / (1+4x)$**

f_{gas}

Note: *Hitomi collaboration shows that, by enhancing the He abundance to 1.1 times its original value, the main effect is an enhancement of the abundances of all metals by 0.02–0.03)*

He: effect on the ICM emission

$\mathbf{P_{SZ}} \sim h\, n_e T_e$

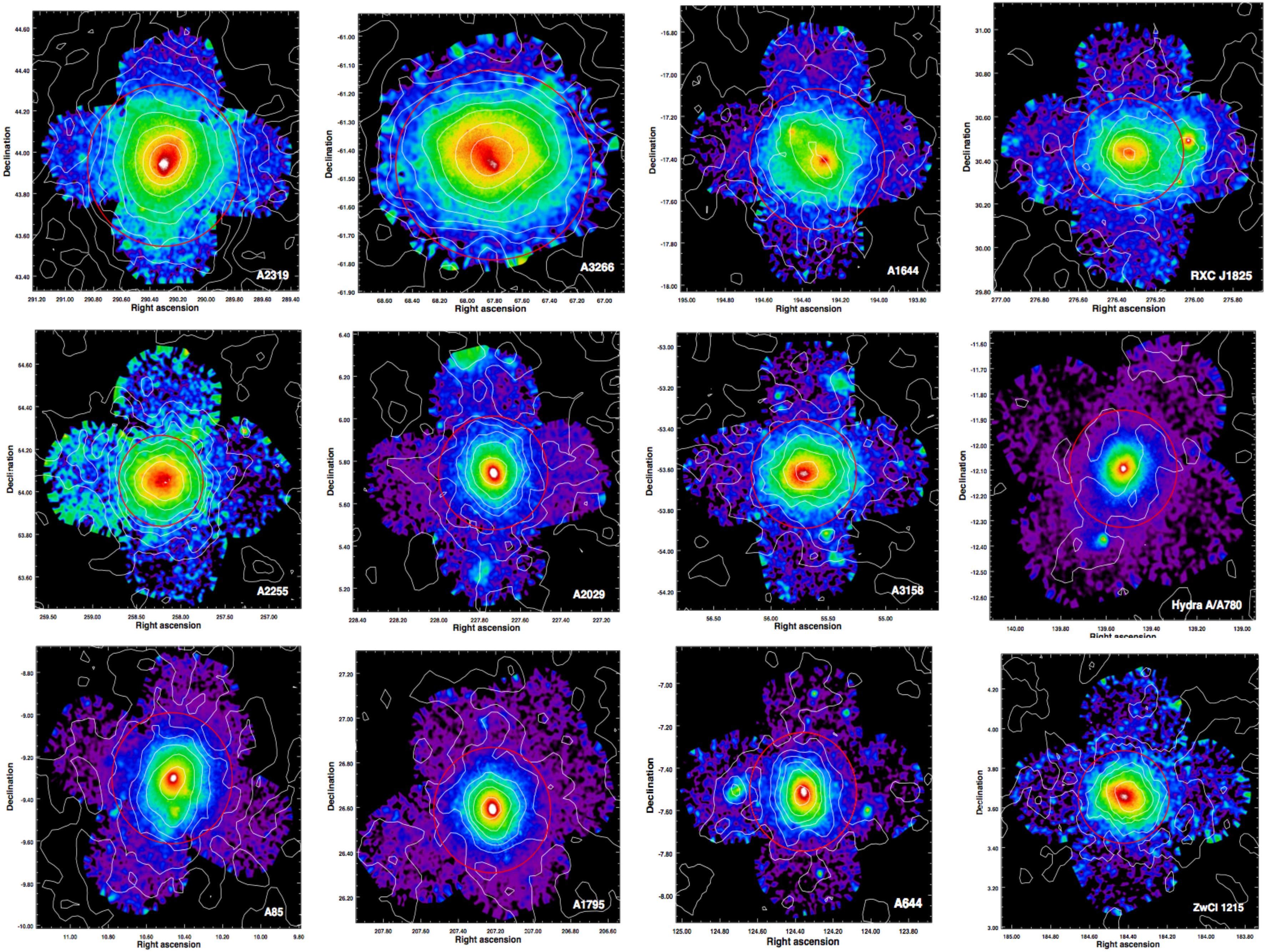
$\mathbf{P_X} = \text{deproj}(S_X)^{0.5}\, T_e \sim h^{0.5}\, [\, (1+2x) / (1+4x)\,]^{0.5}\, n_e T_e$

➔ $\mathbf{P_{SZ}} / \mathbf{P_X} = \eta = h^{0.5}\, y^{0.5}$ where $\mathbf{y} = (1+4x) / (1+2x)$

Assuming spherical symmetry & using a clumping-free n_e, & $h \equiv H/70$ km/s/Mpc from independent measurements (e.g. BBN, SNae), **$x = n_{He}/n_p$ can be measured** (Marketich 07)

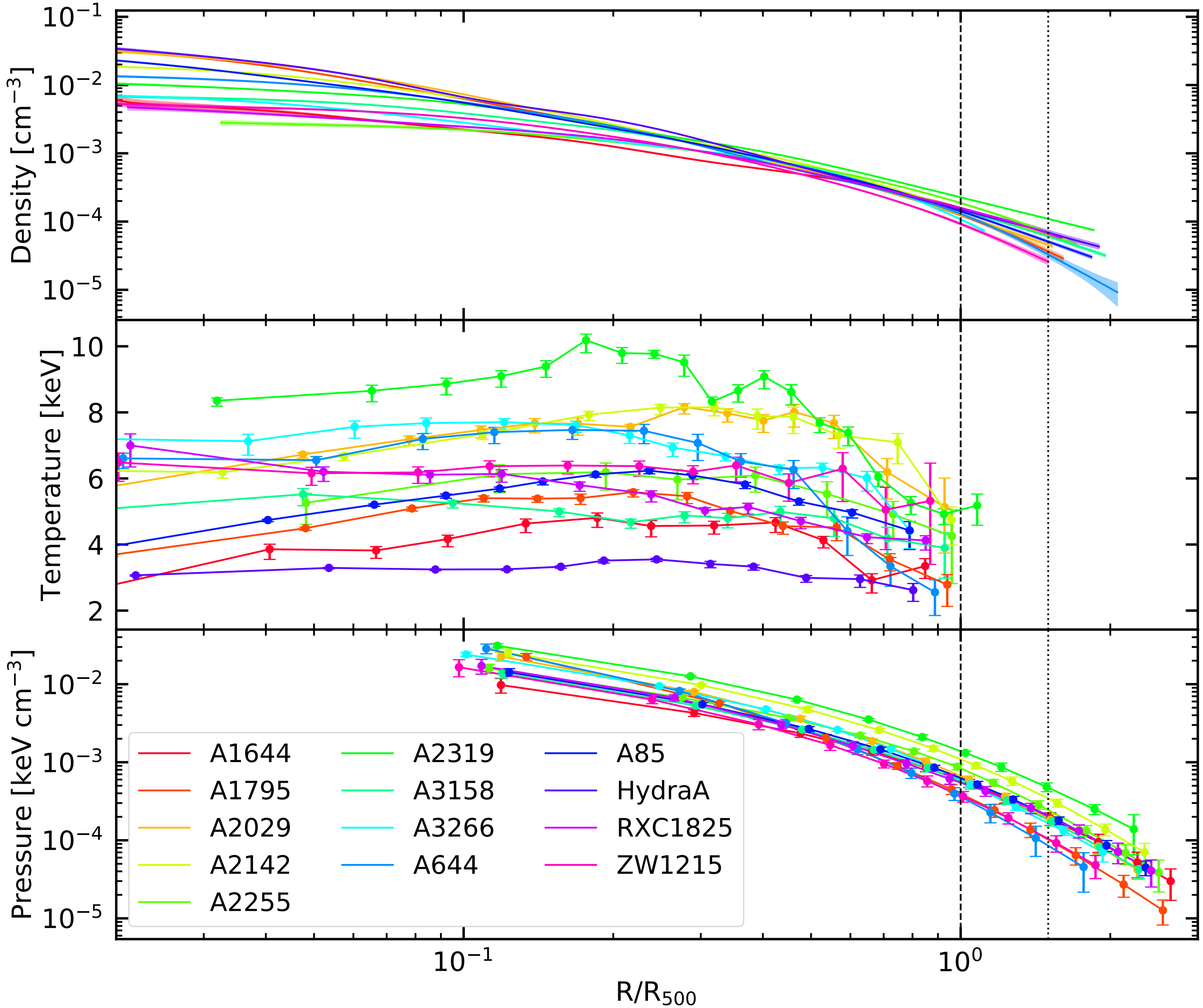
Reversely, the method can be used to constrain H_0
(e.g. Kozmanyan+19)

X-COP: *XMM +Planck*



X-COP: "universal" profiles

(& scatter; Ghirardini+19 arXiv:1805.00042)



T = P/n

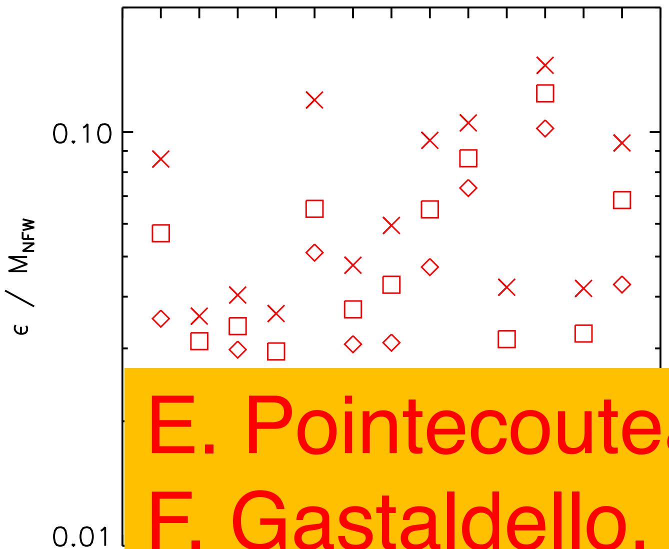
K = P/n$^{5/3}$

M ~ -r^2/**n** d**P**/dr

(see also
- Eckert+19 on ***P$_{NT}$***
- Ettori+19 on ***M$_{hyd}$***
- Ghirardini+19b on ***effective polytropic index***)

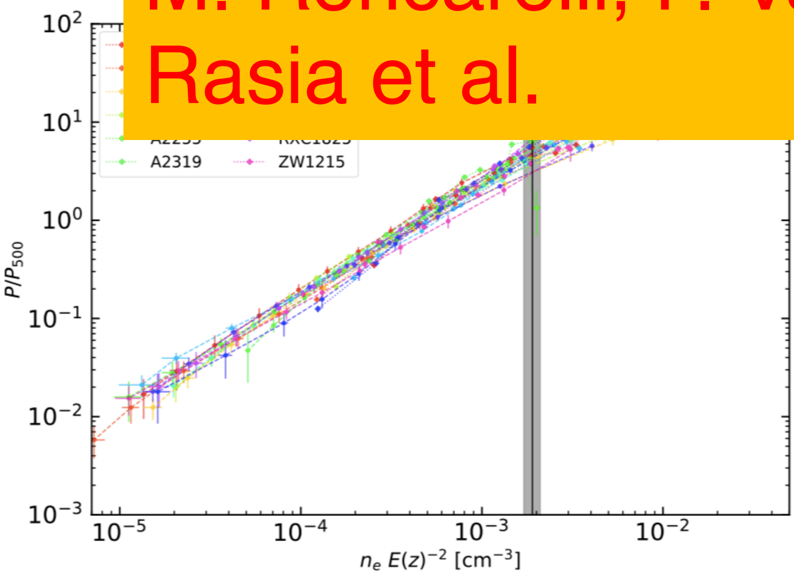
X-COP: main results

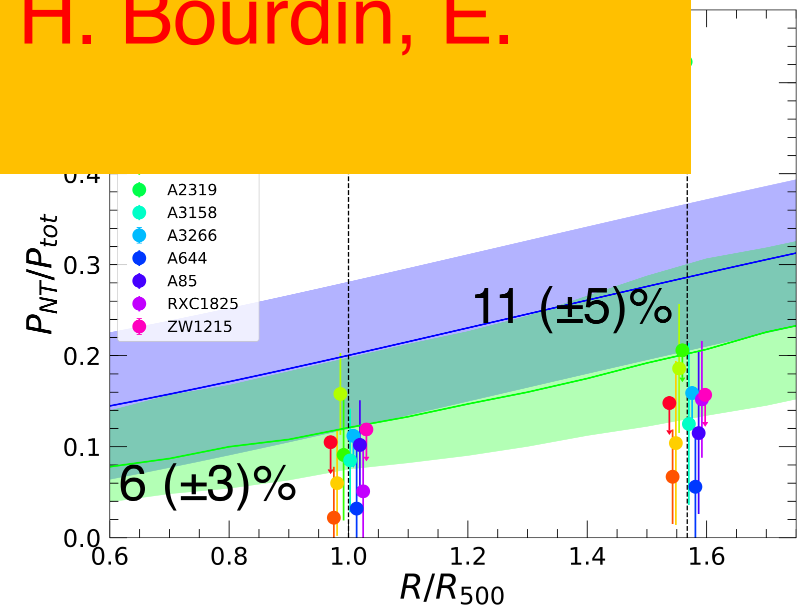
(Ghirardini+19a & b; Eckert+19; Ettori+19)



$$\frac{d}{dr}(P_T(r) + P_{NT}(r)) = -\rho_{\rm gas}\frac{GM_{\rm tot}(<r)}{r^2}$$

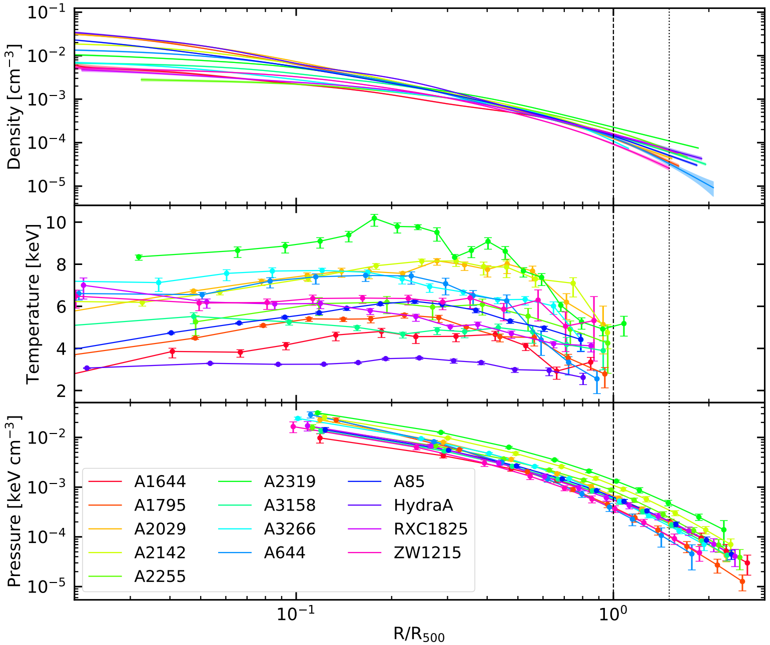
E. Pointecouteau, S. Molendi, M. Gaspari, F. Gastaldello, M. Rossetti, S. De Grandi, M. Roncarelli, F. Vazza, H. Bourdin, E. Rasia et al.





He: effect on the ICM emission

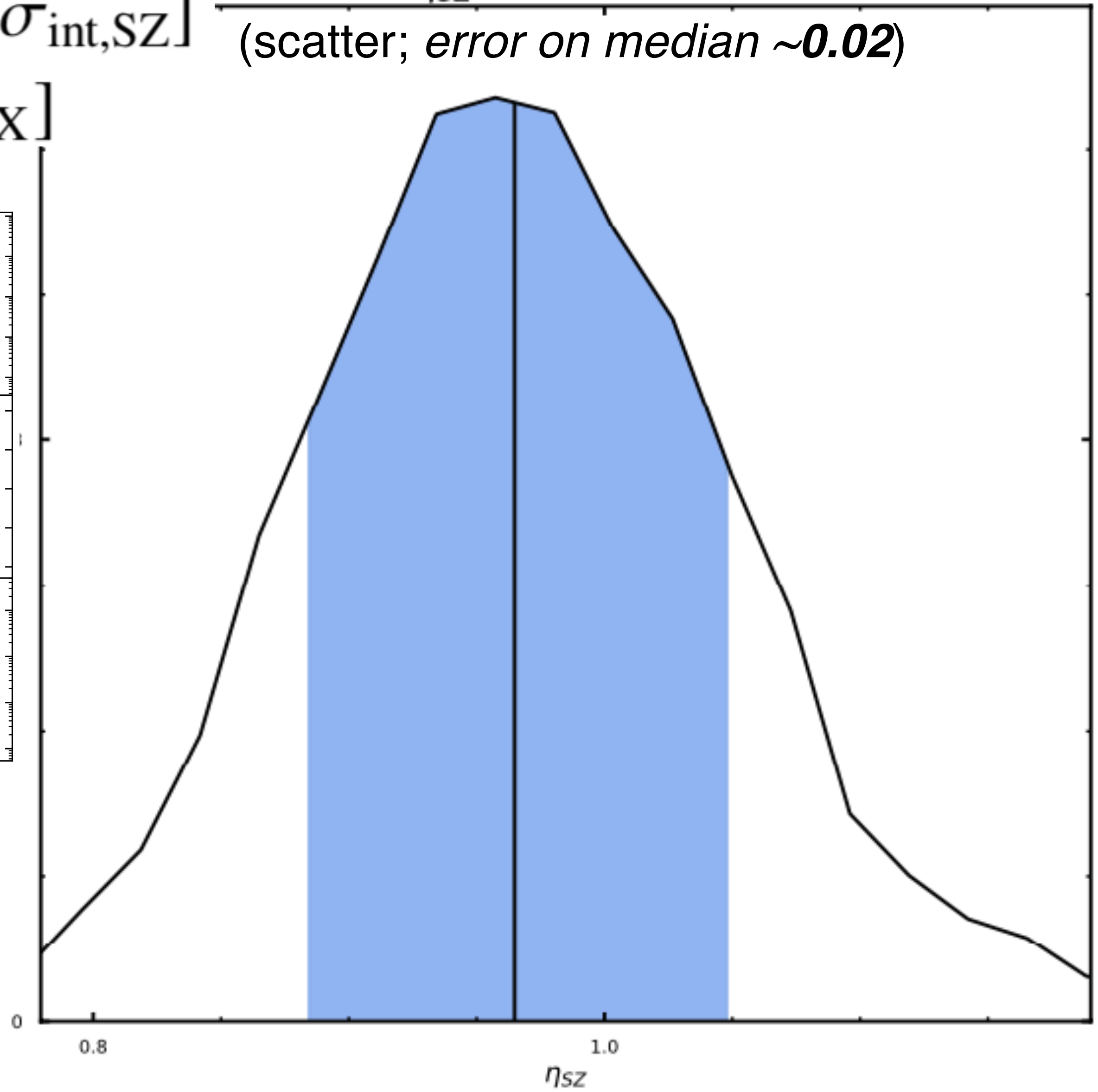
$$\begin{cases} P_{\mathrm{SZ}} = \eta_{\mathrm{SZ}} P_{\mathrm{model}} \cdot \exp[\pm\sigma_{\mathrm{int,SZ}}] \\ P_{\mathrm{X}} = P_{\mathrm{model}} \cdot \exp[\pm\sigma_{\mathrm{int,X}}] \end{cases}$$



Ghirardini+ 19

η_{SZ}=0.96 ± 0.08

(scatter; *error on median ~**0.02***)



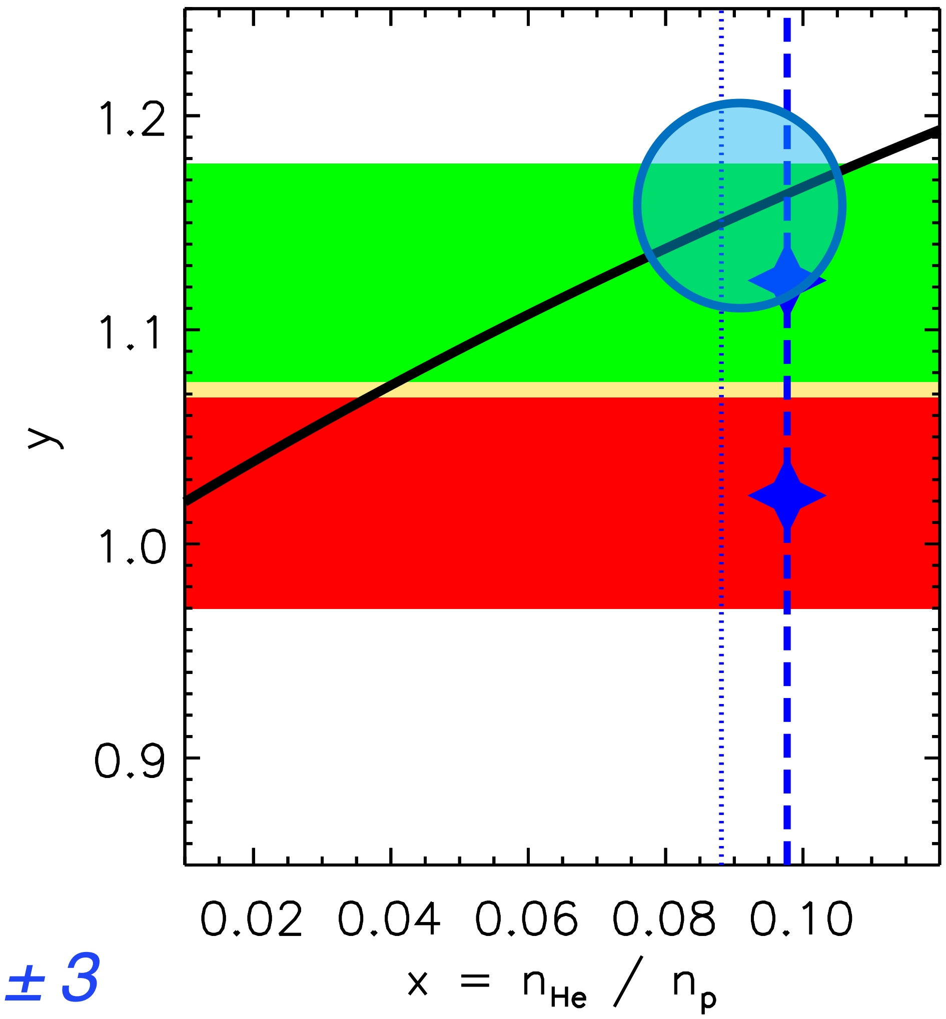
He: effect on the ICM emission

x = n_{He}/n_p (in XSPEC: **0.0977**/AG89; 0.0881/BBN)
y = (1+4x) / (1+2x)

➔ **P_{SZ}/ P_X** = η_{SZ} **=** $h^{0.5}$ $y^{0.5}$

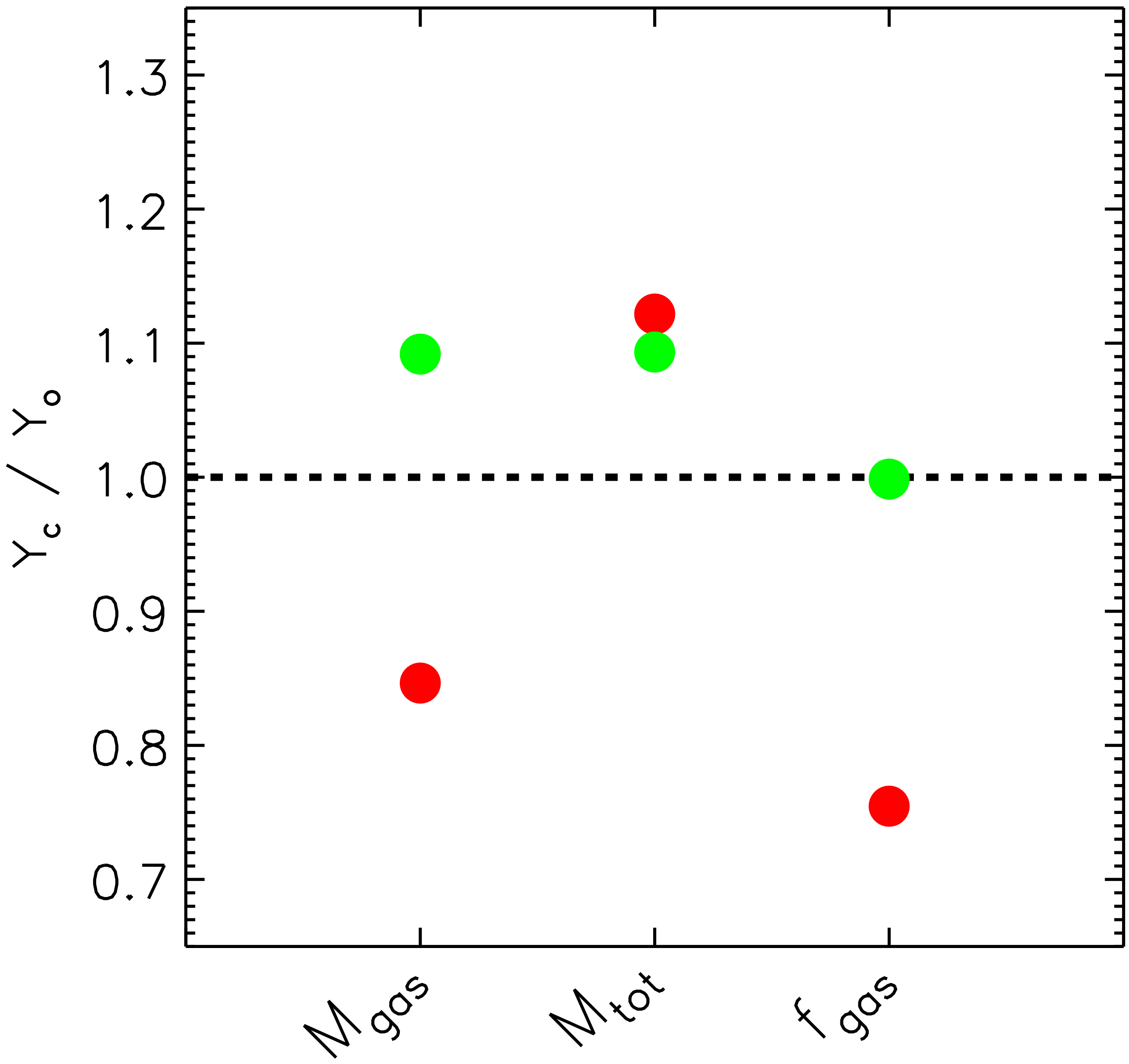
Using $h \equiv h_{70}$ from
Planck18.VI (67.4±0.5 km/s/Mpc)
Riess+19 (74.03±1.42 km/s/Mpc)
and **η_{SZ} from X-COP profiles**, we estimate

$$y = \eta_{SZ}^2/h$$



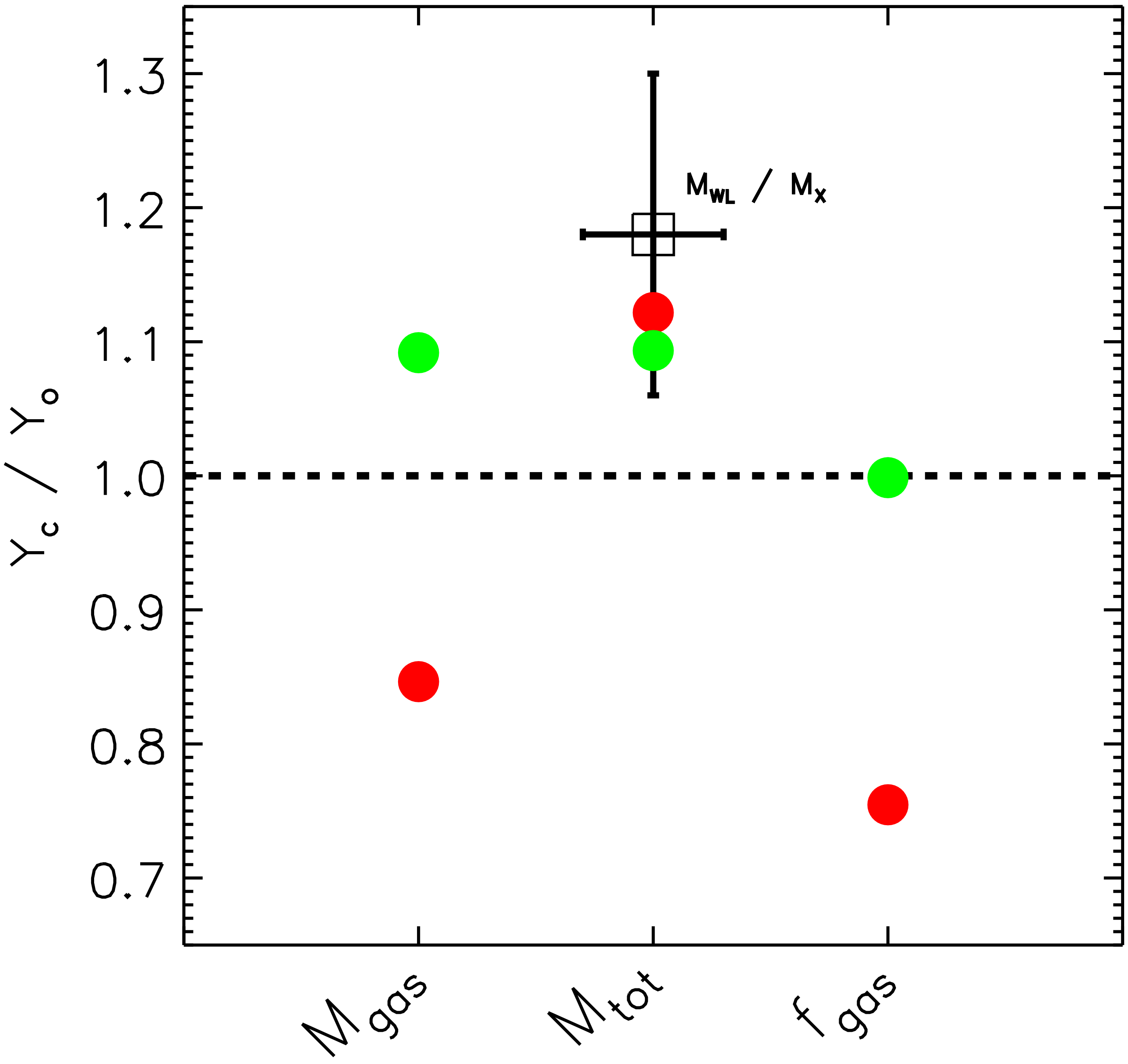
Fixing ***x*** to AG89/BBN ➔ *H_0 = 66 ± 3*

He: effect on the ICM emission



Using h≡h_{70}
from **Riess+19**
& **Planck18.VI**,
and **η_{SZ} from**
X-COP profiles

He: effect on the ICM emission



Using $h \equiv h_{70}$
from **Riess+19**
& **Planck18.VI**,
and **η_{SZ} from**
X-COP profiles

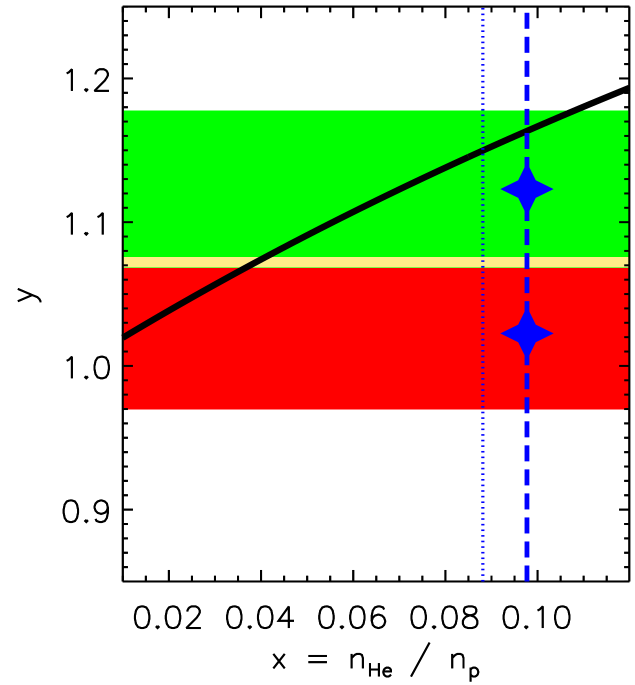
He: effect on the ICM emission

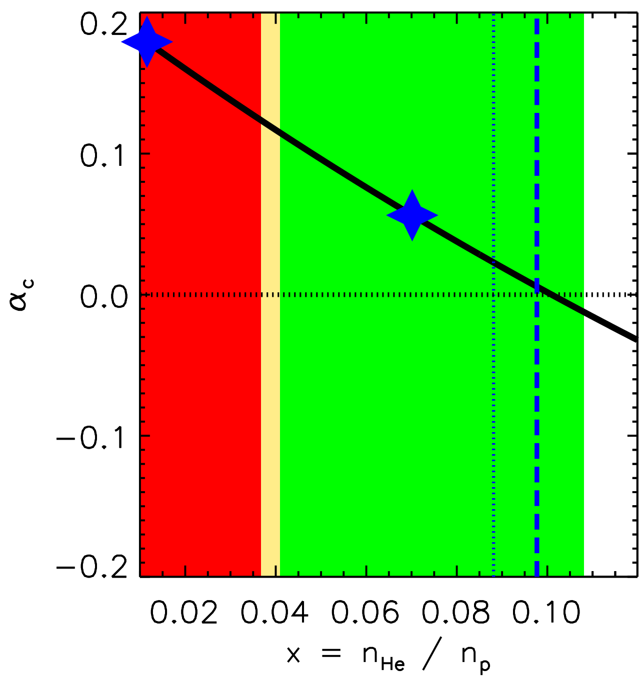
x = n_{He}/n_p **y =** $(1+4x)/(1+2x)$

➔ $P_{SZ}/P_X = \eta_{SZ} = h^{0.5}\, y^{0.5}$

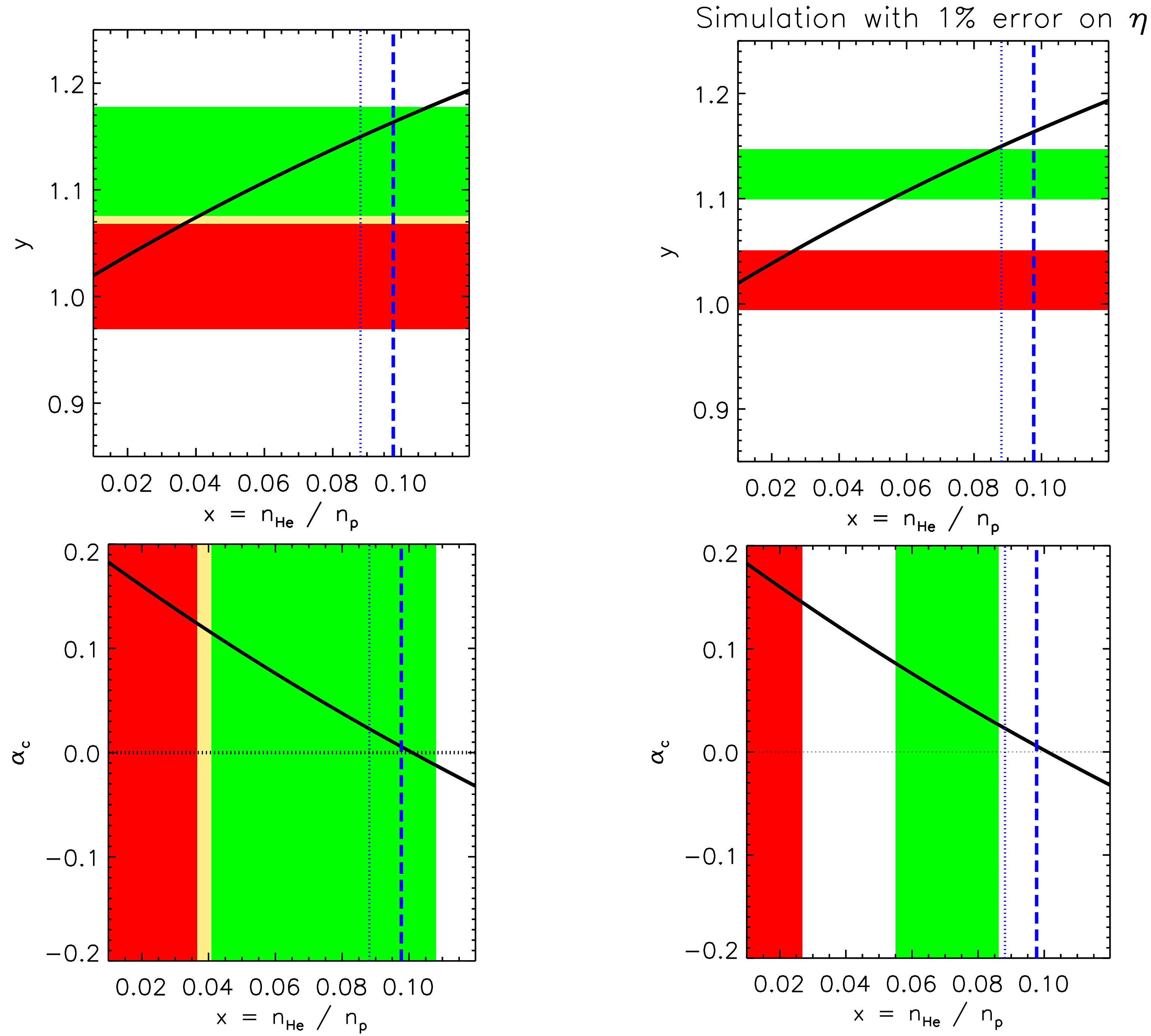
Using $h \equiv h_{70}$ from
Planck18.VI & **Riess+19**,
and **η_{SZ} from X-COP profiles,**
we estimate ***$y = \eta_{SZ}^2/h$***

- $f_{gas,\,true}/f_{gas,\,obs}$ =
  = $f_{gas,\,true}/f_{gas,\,c}$ $*\mathbf{f_{gas,\,c}/f_{gas,\,obs}}$
  = $(1-\alpha_T)\,(1-\boldsymbol{\alpha_c})$





He: effect on the ICM emission



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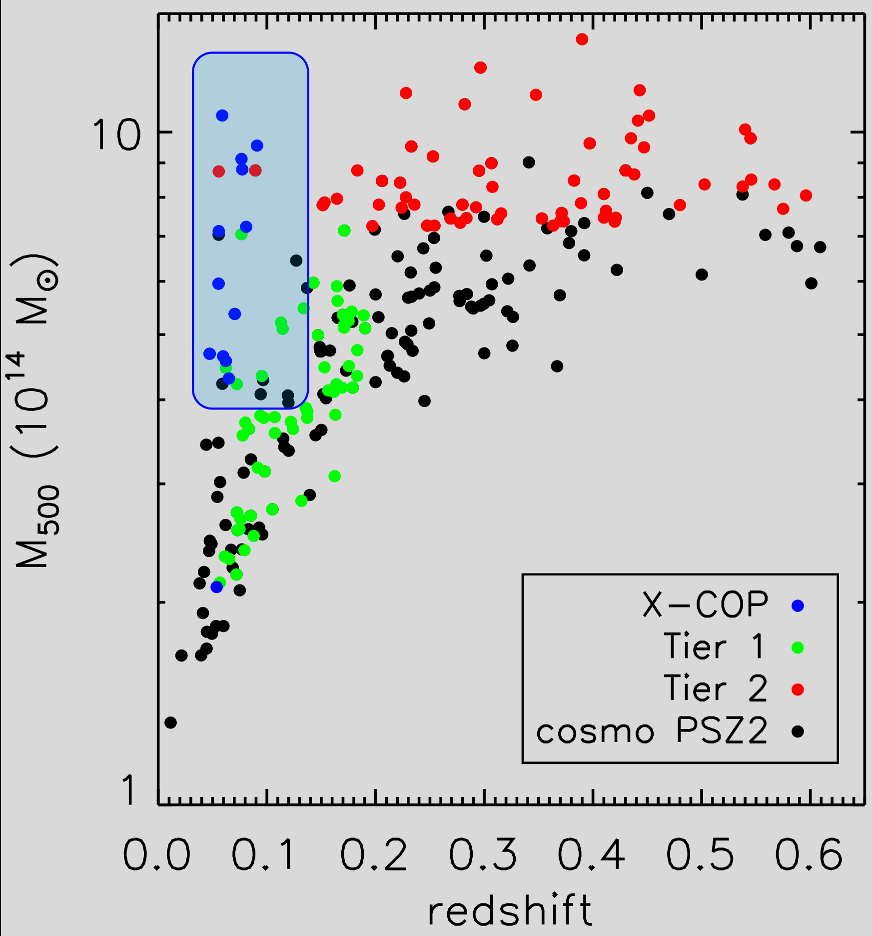
10x X-COP

➔ **3 Msec** over the next *3 years* to survey 118 Planck-SZ selected objects comprising an unbiased census of:

- *the population of clusters at the most recent time (z < 0.2),*
- *the most massive objects to have formed thus far in the history of the Universe*



Steering Committee: **M. Arnaud (PI), S. Ettori (PI),** D. Eckert, F. Gastaldello, R. Gavazzi, S. Kay, L. Lovisari, B. Maughan, E. Pointecouteau, G. Pratt, M. Rossetti, M. Sereno

Conclusions

The assumption of a spatially uniform distribution of **He** is applied when interpreting X-ray observations of the ICM.

- Sedimentation of **He** can take place during the formation history of galaxy clusters & can not be excluded *(He sedimentation can significantly enhance the UV signal observed in BCGs – Peng & Nagai 09; but it has a negligible impact on quantities integrated over large volume & SL –Bulbul+ 11)*

- We use estimates on $\mathbf{P_{SZ}/P_{X}}$ from 12 X-COP objects to constrain **He** abundance ***in combination with independent measures of H_0***: **data tend to prefer low values of $\mathbf{H_0}$** (or He abundance lower than reference values)