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Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA
INAF

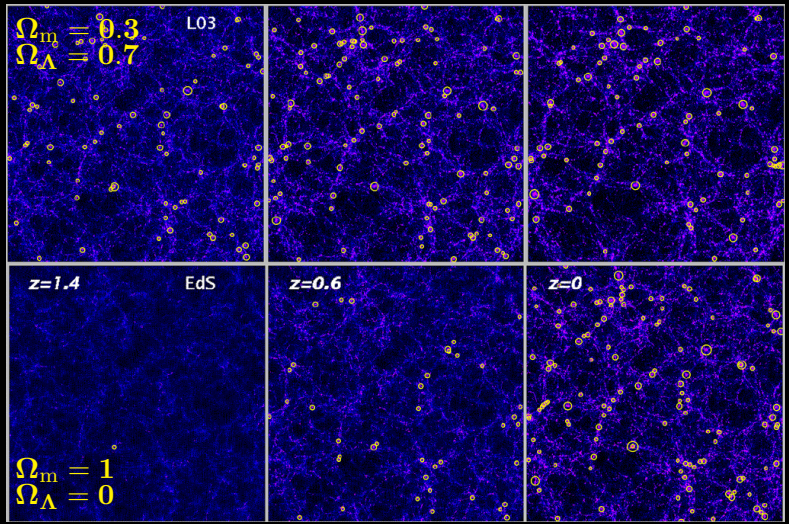
Cosmology from the gas distribution from CHEX-MATE and X-COP to SPT

Vittorio Ghirardini and Stefano Ettori

on behalf of CHEX-MATE collaboration

INAF ISTITUTO NAZIONALE DI ASTROFISICA
OAS BOLOGNA

Cluster number count



Borgani+ 2001

Cosmology from the gas distribution

- **Gas mass fraction** — Allen+ 2007, Ettori+ 2009, Mantz+ 2014,2022
- **Size temperature relation** — Mohr+ 2000
- **SZ vs X-ray pressure** — Bonamente+ 2006, Kozmanyan+ 2019
- **Emission measure profile** — Arnaud+ 2002, Morandi+ 2016

Cosmology from the gas distribution

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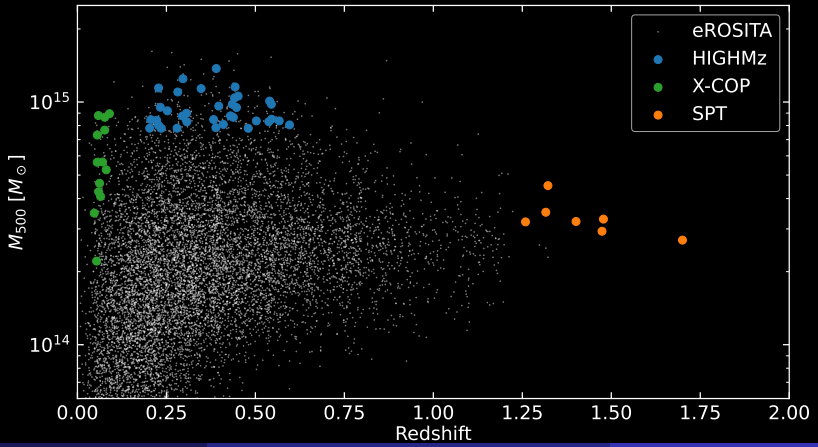
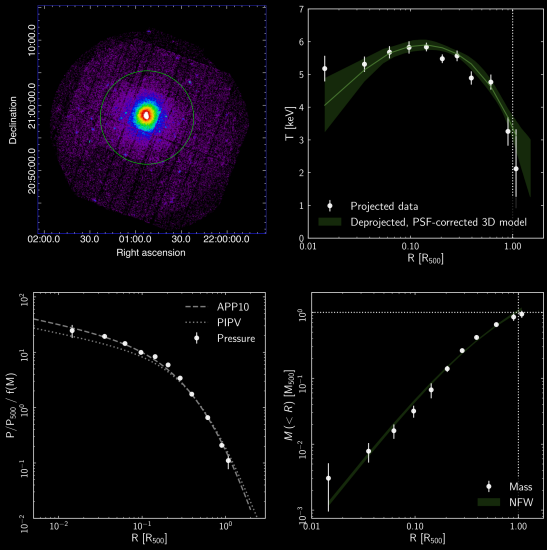
- **Redshift independent relation for self-similar scenario** — Mohr+ 2000
- **Angular diameter distance proxy** — Bonamente+ 2006, Kozmanyan+ 2019
- **Gravity is self-similar $\Rightarrow$ minimal scatter profiles** — Arnaud+ 2002, Morandi+ 2016

Dataset

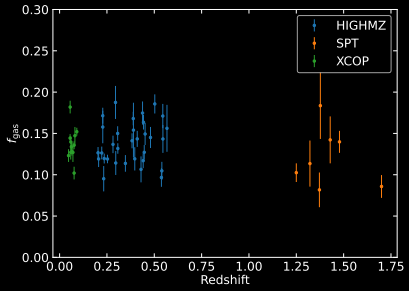
- X-COP: 12 massive clusters ($M_{500} > 4 \times 10^{14}\, M_\odot$) at $0.05 < z < 0.1$
- HIGHMz: 32 massive clusters ($M_{500} > 7.75 \times 10^{14}\, M_\odot$) at $0.2 < z < 0.6$
- SPT: 7 massive clusters ($M_{500} > 3 \times 10^{14}\, M_\odot$) at $z > 1.2$

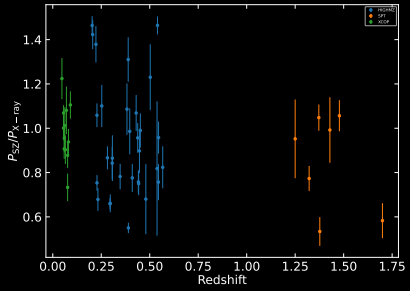


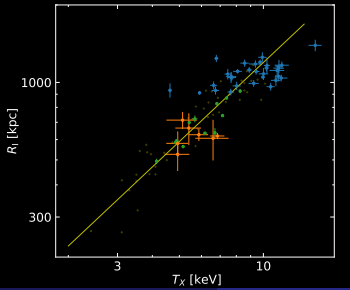
Data

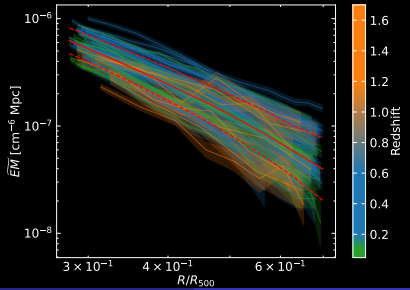

Declination
10:00.0
21:00:00.0
20:50:00.0
02:00.0
30.0
01:00.0
30.0
22:00:00.0
Right ascension
T [keV]
Projected data
Deprojected, PSF-corrected 3D model
R [R500]
APP10
PIPV
Pressure
P/P500 / f(M)
R [R500]
M (< R) [M500]
Mass
NFW
R [R500]

Data


HIGHMZ
SPT
XCOP
$f_{\rm gas}$
Redshift


$P_{SZ}/P_{X-{\rm ray}}$
Redshift

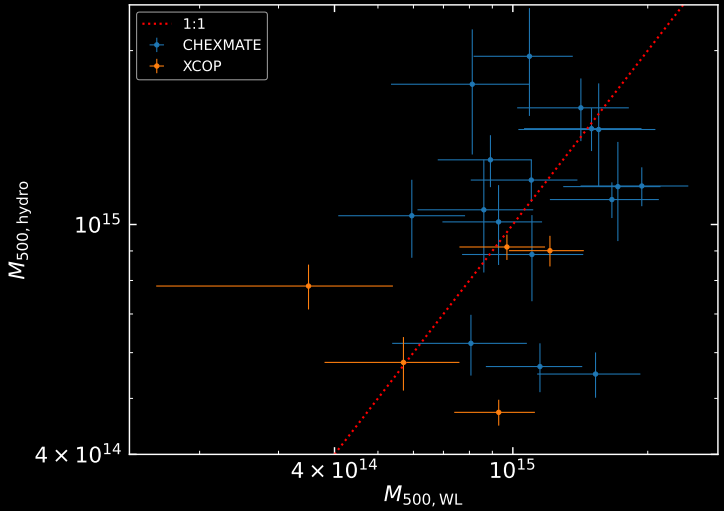

$R_{\rm l}$ [kpc]
T_X [keV]
Redshift


EM [cm^{-6} Mpc]
R/R_{500}
Redshift

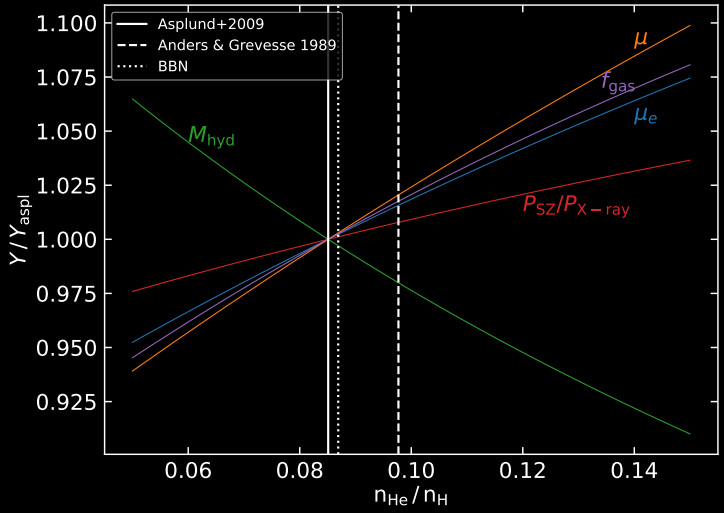
Modeling of systematics

- Mass bias
  - the adopted hydrostatic mass has to be calibrated
- Helium abundance
  - strongly connected with X-ray emissivity
    $\epsilon \approx \int n_e n_{\rm H} \Lambda(T_e) \left(1 + 4\frac{n_{\rm He}}{n_{\rm H}}\right) dl$
- Size temperature evolution
- Emission measure scaling

Mass calibration



Helium abundance

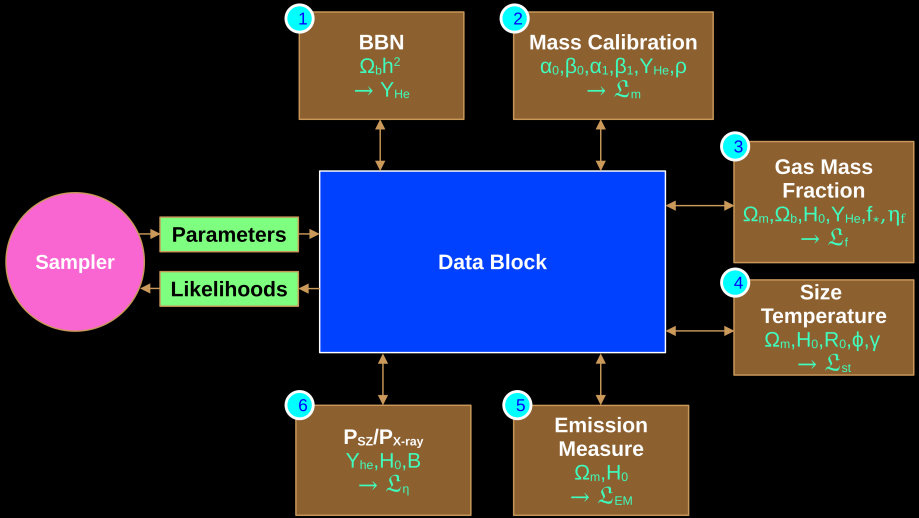


Parameter priors

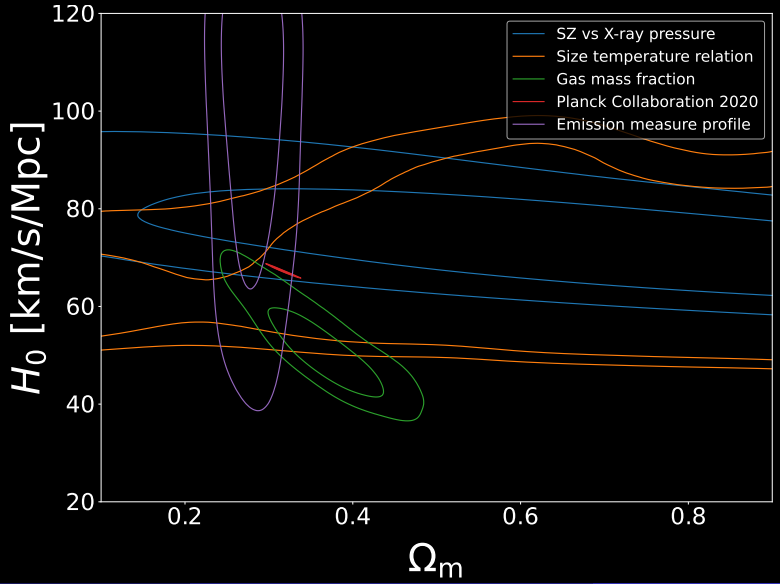
Parameter	Prior
• Cosmology	
$\Omega_{\rm m}h^2$	$\mathcal{U}(0.033, 1.5)$
h	$\mathcal{U}(0.1, 1.3)$
$\Omega_{\rm b}h^2$	$\mathcal{U}(0.013, 0.033)$
$\log 10^{10} A_s$	$\mathcal{U}(0, 6)$
n_s	$\mathcal{U}(0.9, 1.05)$
τ	$\mathcal{N}(0.0544, 0.0073^2)$
$\Omega_\nu h^2$	$\mathcal{U}(0, 0.01)$
w	$\mathcal{U}(-3, 1)$
• Mass calibration	
α_0	$\mathcal{U}(-2, 2)$
σ_0	$\mathcal{U}(0.01, 1)$
α_1	from HSC
β_1	from HSC
σ_1	$\mathcal{U}(0.01, 1)$
$\rho_{\rm hydro-WL}$	$\mathcal{U}(-0.99, 0.99)$

Parameter	Prior
• Gas mass fraction	
η_f	from measured slopes
$f_\star$	$\mathcal{N}(0.015, 0.005^2)$
$\sigma_{\rm gas}$	$\mathcal{U}(0.001, 0.2)$
a, b, c, d	from Rasia+2025
• Size - temperature relation	
R_0	$\mathcal{U}(300, 2000)$
ϕ	$\mathcal{U}(0, 2)$
$\sigma_{\rm size}$	$\mathcal{U}(0.001, 1)$
γ	$\mathcal{U}(-5, 5)$
• SZ vs X-ray pressure	
σ_η	$\mathcal{U}(0.001, 1)$
$\mathcal{B}$	from Kozmanyan+19
• Emission measure profiles	
$\alpha_{\rm EM}$	$\mathcal{N}(0, 1)$

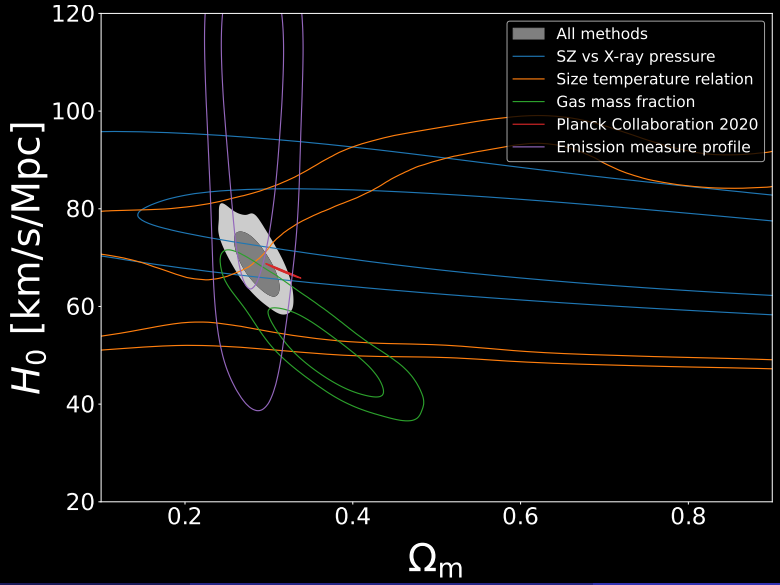
Fitting


1
BBN
$\Omega_b h^2$
$\rightarrow Y_{He}$
2
Mass Calibration
$\alpha_0,\beta_0,\alpha_1,\beta_1,Y_{He},\rho$
$\rightarrow \mathfrak{L}_m$
3
Gas Mass Fraction
$\Omega_m,\Omega_b,H_0,Y_{He},f_*,\eta_f$
$\rightarrow \mathfrak{L}_f$
4
Size Temperature
$\Omega_m,H_0,R_0,\phi,\gamma$
$\rightarrow \mathfrak{L}_{st}$
5
Emission Measure
Ω_m,H_0
$\rightarrow \mathfrak{L}_{EM}$
6
$P_{SZ}/P_{X\text{-ray}}$
Y_{he},H_0,B
$\rightarrow \mathfrak{L}_\eta$
Data Block
Sampler
Parameters
Likelihoods

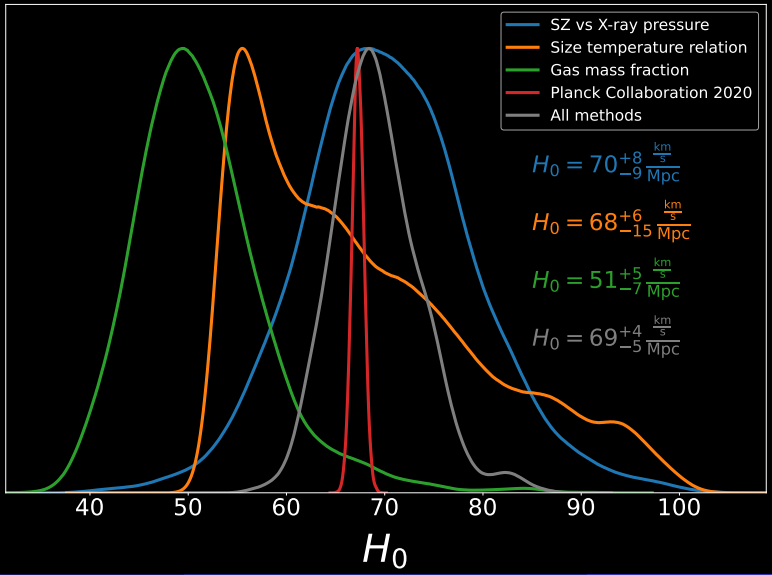
Preliminary results: flat ΛCDM



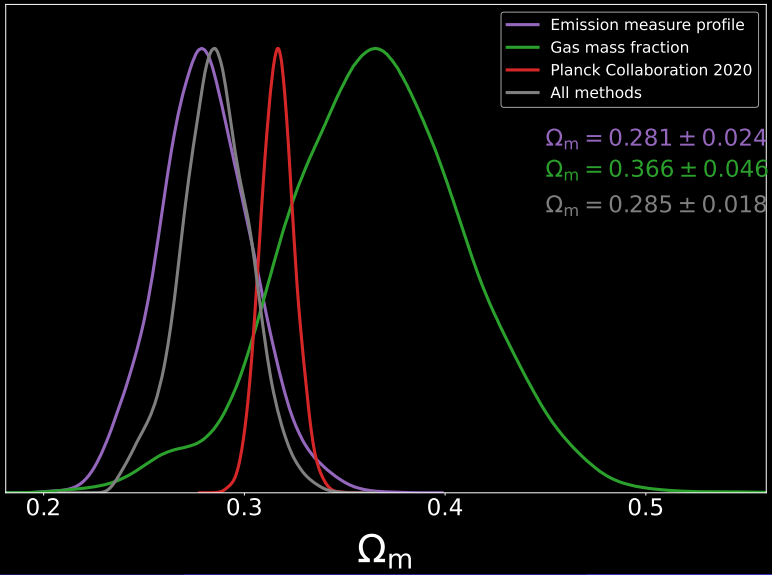
Preliminary results: flat ΛCDM



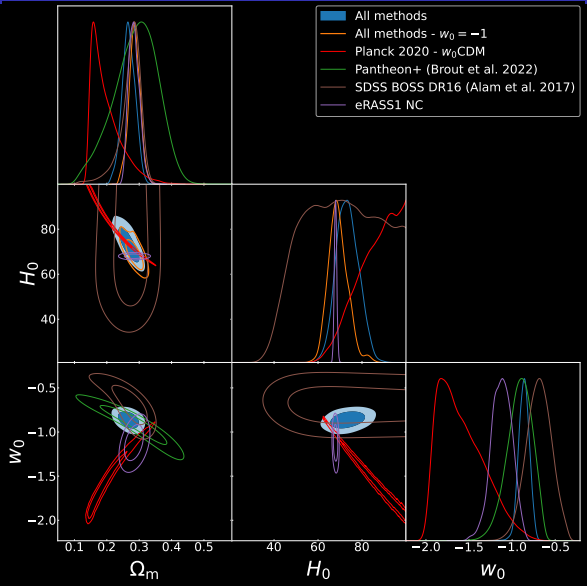
Preliminary results: flat ΛCDM - H_0



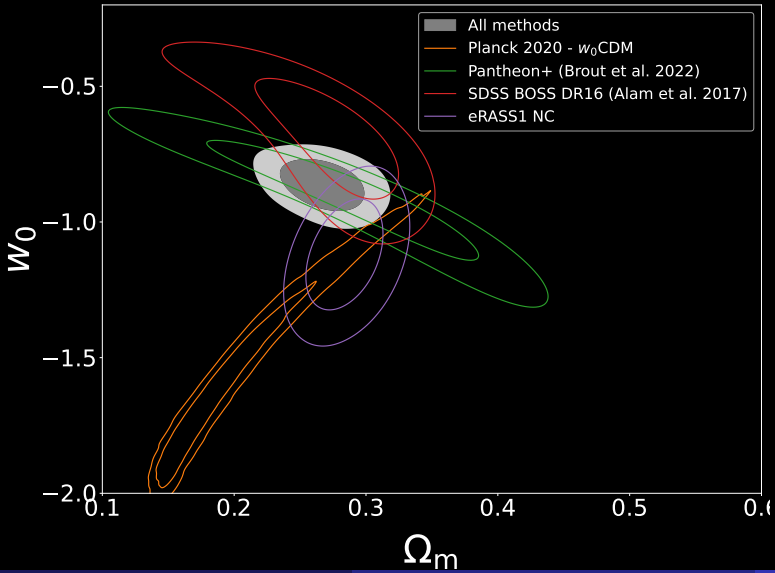
Preliminary results: flat ΛCDM - Ω_m



Preliminary results - w



Preliminary results - w



$$w = -0.863 \pm 0.062$$

Conclusion

- Gas distribution can provide excellent constraints with just few clusters (32+12+7)
- Systematics are accounted for and marginalized in the analysis

To do list:

$\Rightarrow$ Selection to be taken into account

$\Rightarrow$ Relax some priors from simulations