HICOSMO

Cosmology with a complete sample of galaxy clusters

Gerrit **Schellenberger**,[1,2] Thomas H. **Reiprich**[2]

[1]Harvard-Smithsonian Center for Astrophysics
[2]Argelander-Institut für Astronomie, Universität Bonn

NASA/CXC

Abstract:

Galaxy clusters are excellent cosmological probes, since they originate from collapsed overdensities in the early Universe and witness its history. The X-ray regime provides the unique possibility to measure in detail the most massive visible component, the intra cluster medium.
<u>**Using Chandra observations of a local sample of 64 bright clusters (HIFLUGCS) we provide total (hydrostatic) and gas mass estimates of each cluster individually.**</u> Making use of the completeness of the sample we quantify two interesting cosmological parameters by a Bayesian cosmological likelihood analysis.
We find $\Omega_M = 0.30 \pm 0.01$ and $\sigma_8 = 0.79 \pm 0.03$ (statistical uncertainties) using our default analysis strategy combining both, a mass function analysis and the gas mass fraction results. The main sources of biases that we discuss and correct here are
(1) the influence of galaxy groups (higher incompleteness in parent samples and a differing behavior of the L - M relation),
(2) the hydrostatic mass bias (as determined by recent hydrodynamical simulations),
(3) the extrapolation of the total mass (comparing various methods),
(4) the theoretical halo mass function and
(5) other cosmological (non-negligible neutrino mass), and instrumental (calibration) effects.

HICOSMO I:
https://arxiv.org/abs/1705.05842

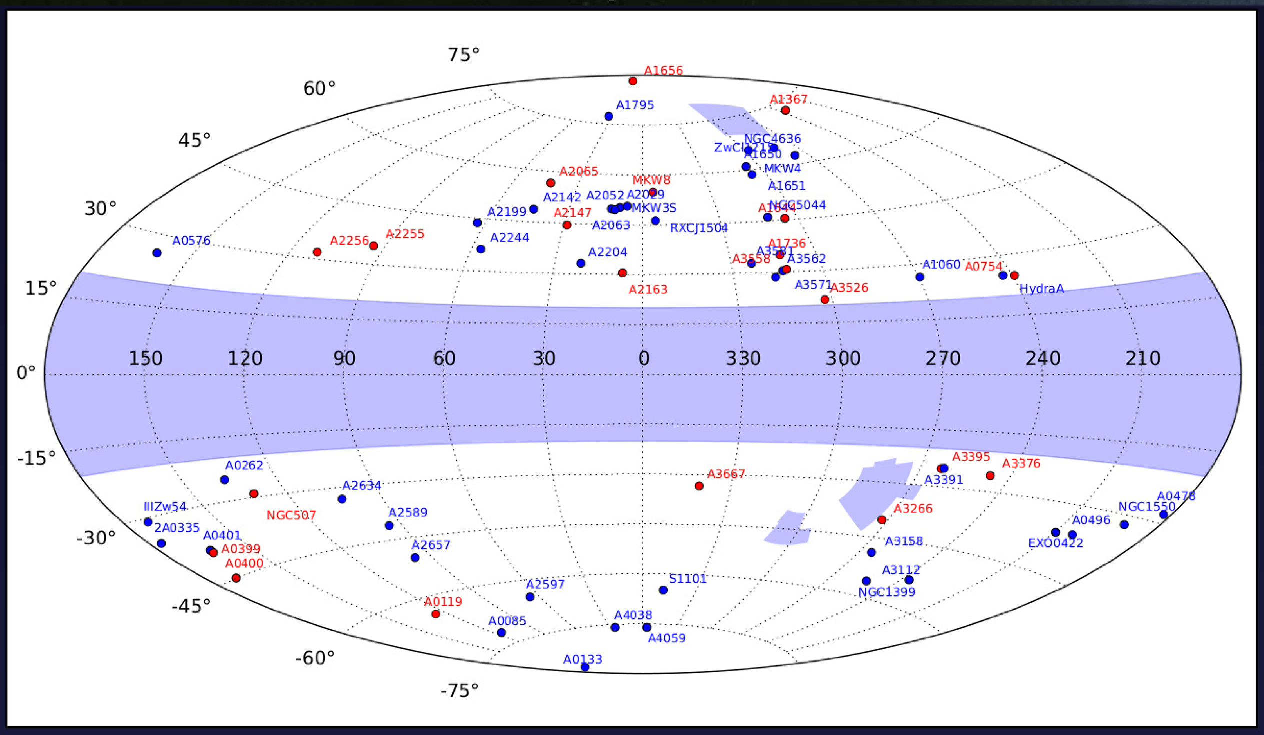
HICOSMO II:
https://arxiv.org/abs/1705.05843

Aims

- Determine with high-precision the hydrostatic- and gas masses from X-ray observations
- Take systematic effects for mass estimates into account
- Determine local Lx-M scaling relation and cluster mass function
- Derive cosmological parameters for a local sample and combine with gas mass fraction analysis
- Quantify systematic influences in cosmological parameters

HIFLUGCS

The 64 X-ray brightest galaxy clusters statistically complete, local and flux limited sample



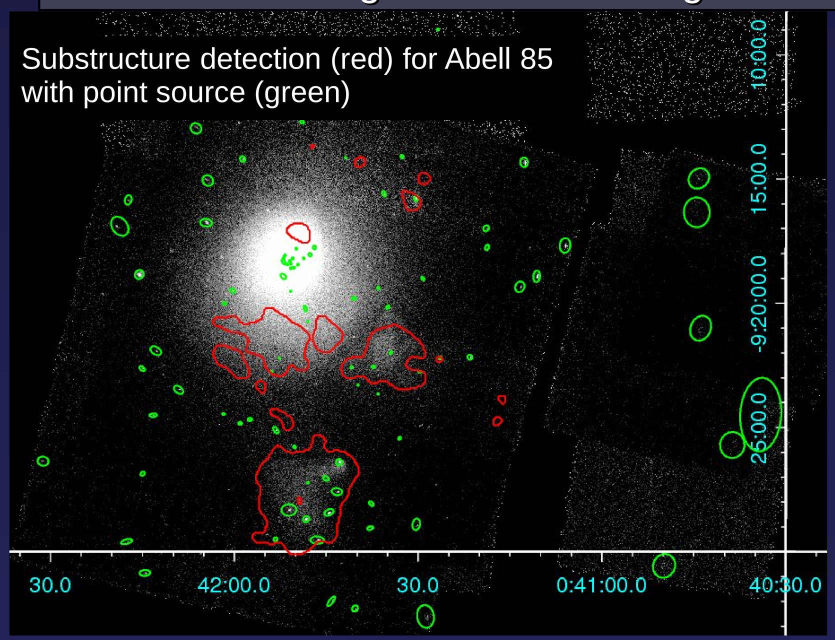
Mass determination

Starting from the assumption of hydrostatic equilibrium (see equation) we calculate for

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

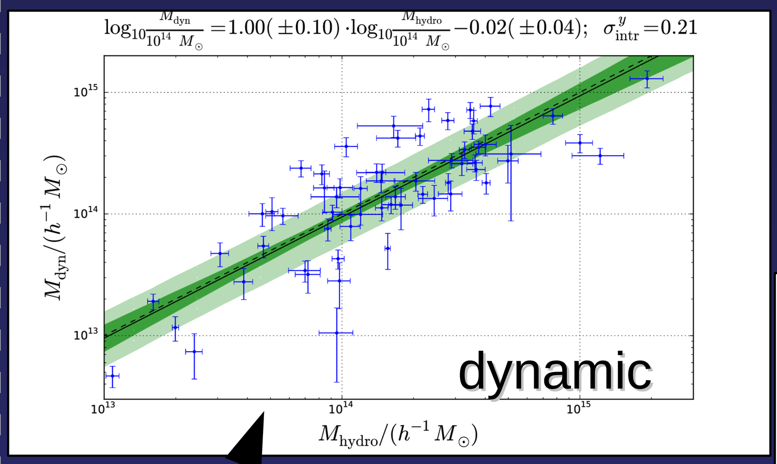
each galaxy cluster individual total and gas masses. This includes a parametrization of the temperature and density profiles determined from 196 Chandra observations (7.7 Ms). The sample contains a variety of merging systems, where we remove substructure using an automated algorithm to find overdensities.

Substructure detection (red) for Abell 85 with point source (green)

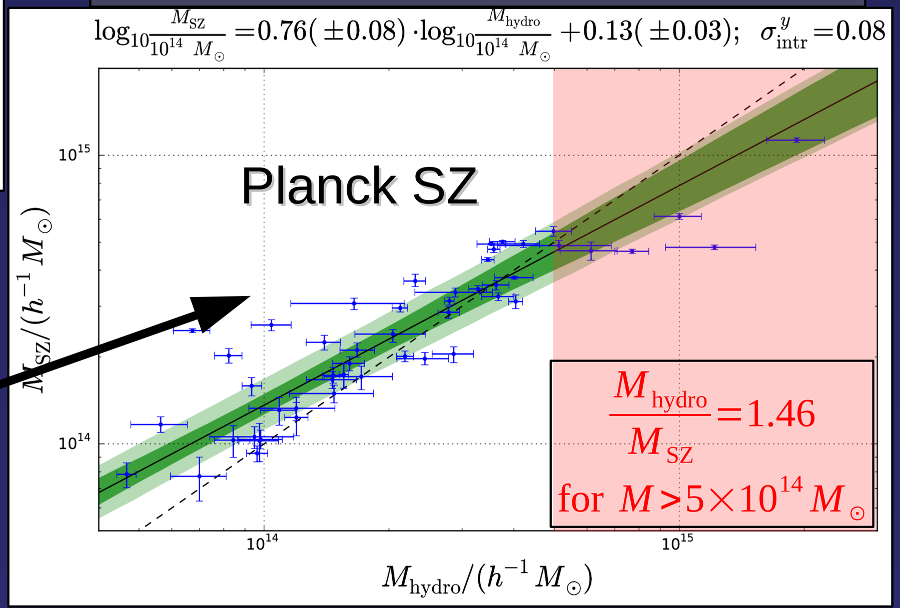


On average the Chandra FOV allows to extract spectra (and determine temperatures) out to 66% of R500, which means we have to extrapolate the profiles for most clusters. We compare several methods and conclude that fitting a NFW profile to our mass profile around the maximum extraction region is most reliable.

We find good agreement with mass estimates for HIFLUGCS from galaxy velocity dispersion measurements, while comparing a subset of HIFLUGCS with Planck reveals a mass dependent trend: Using random samples we were able to reproduce the trend above by taking into account the Planck SZ selection function.



$\frac{M_{hydro}}{M_{dyn}} = 0.97$



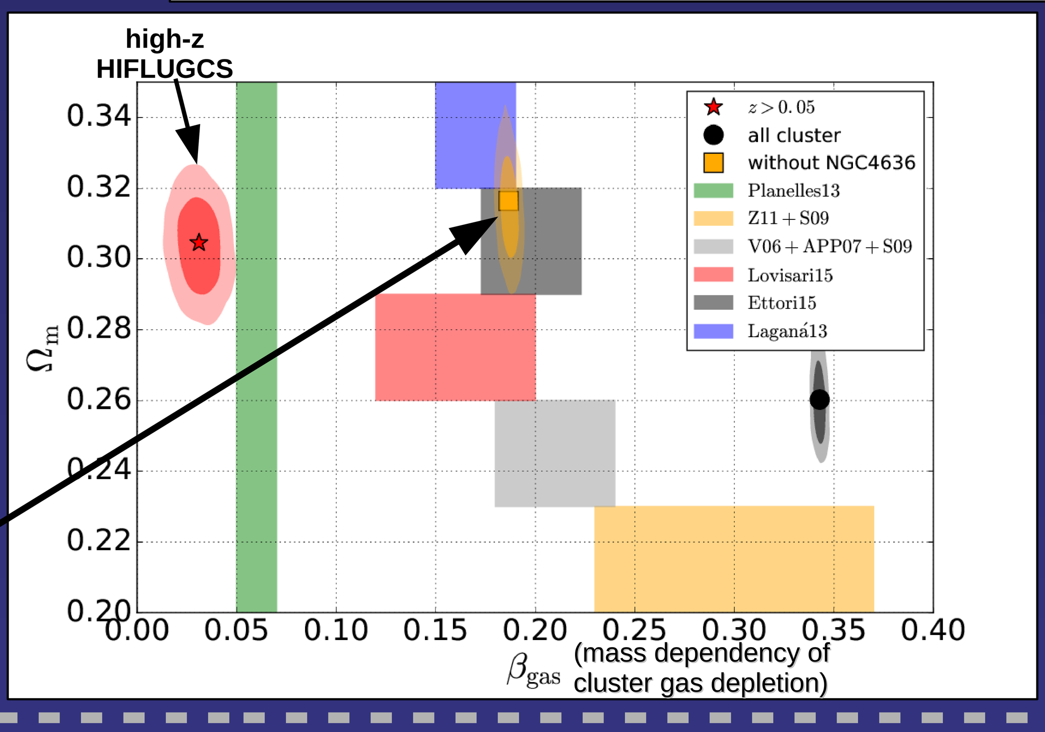
$\frac{M_{hydro}}{M_{SZ}} = 0.86$

$\frac{M_{hydro}}{M_{SZ}} = 1.46$ for $M > 5\times10^{14} M_\odot$

Gas mass fraction

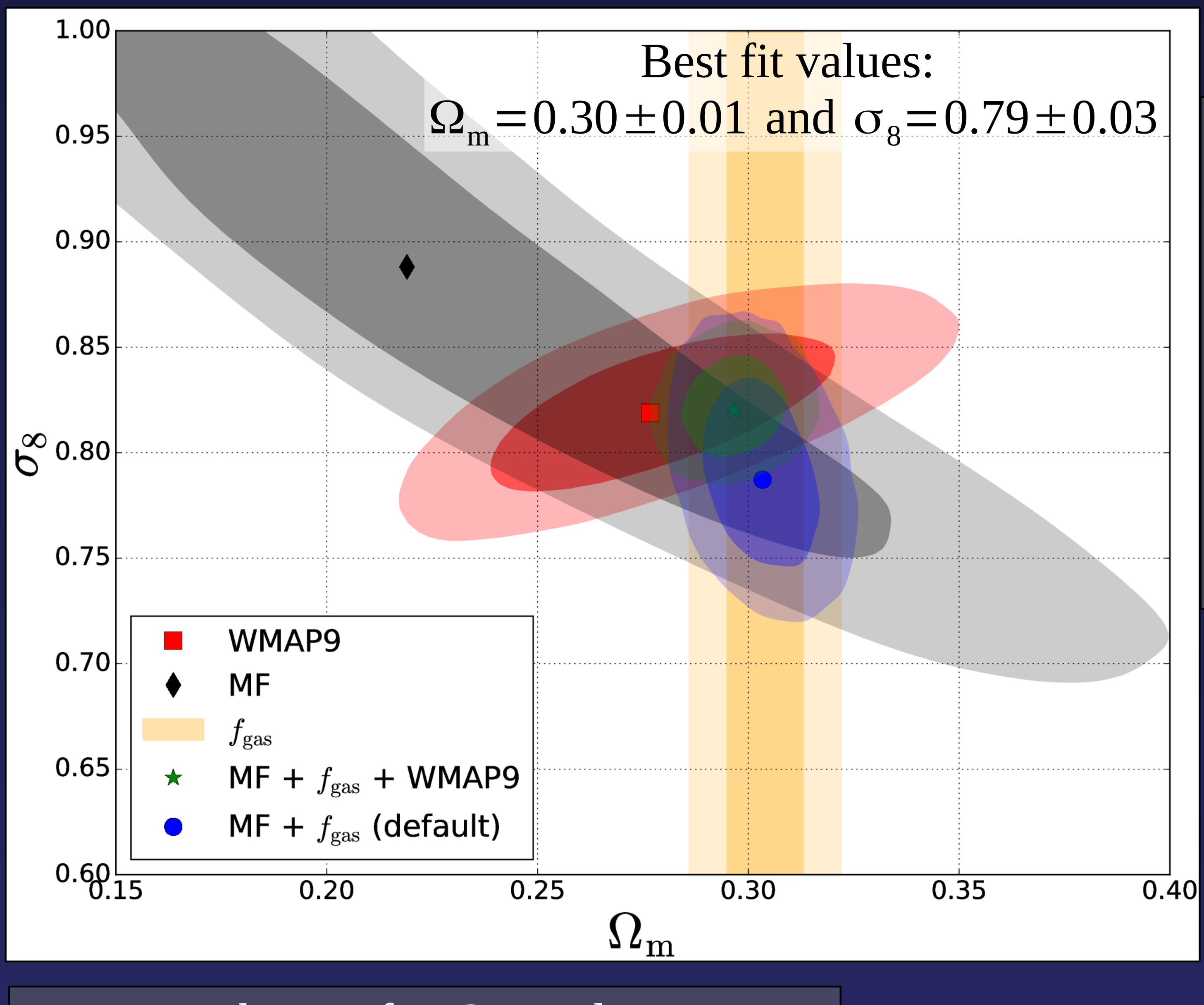
We measure the cluster gas mass fraction at R2500 and compare our results with recent simulations (Planelles+2013), to conclude $\Omega_M = 0.31 \pm 0.01$.

We also find a higher gas depletion for galaxy groups, than predicted from simulations. This is in agreement with earlier studies.



Result

Final results for the two cosmological parameters combine the halo mass function and gas mass fraction analyses, which both include a Bayesian likelihood approach (eg, Mantz+10).



MF
Mass function excluding the low redshift objects (galaxy groups)

fgas
Gas mass fraction analysis constraining only OmegaM

MF+fgas
our default choice for the cosmological result

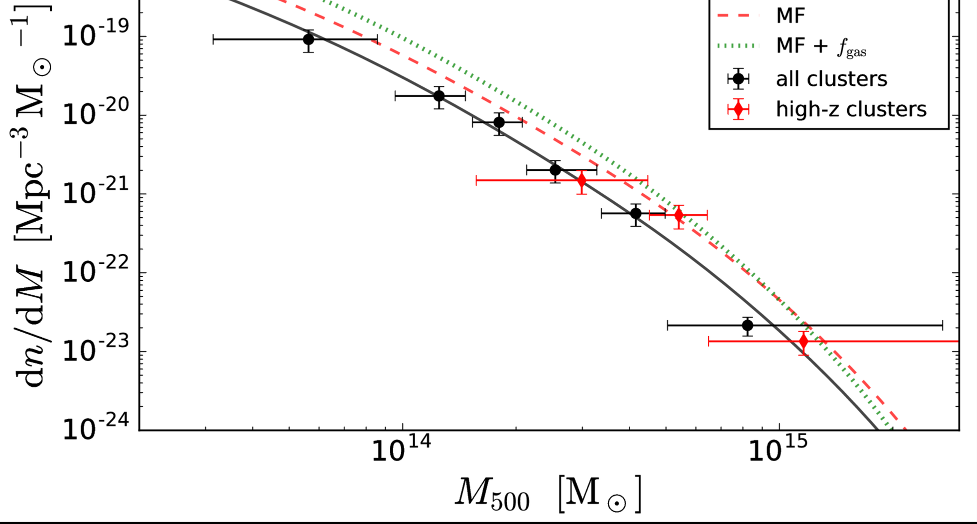
combining for Ω_M and σ_8:

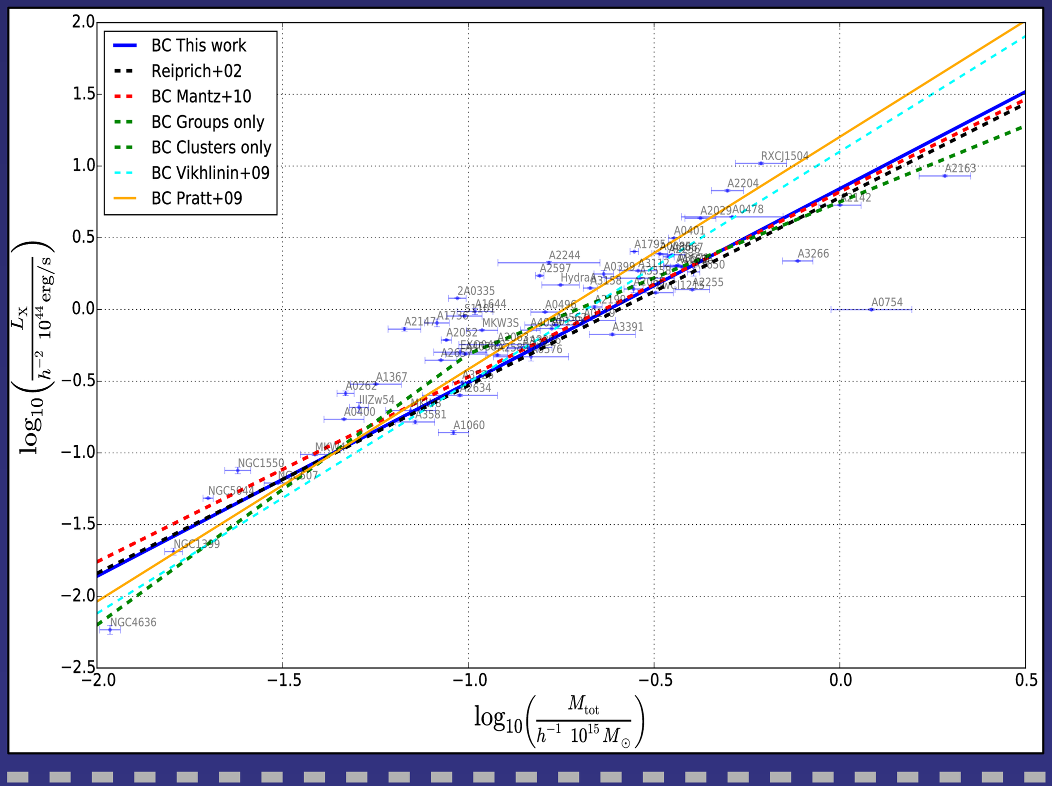
$S8 = \sigma_8\sqrt{\Omega_m/0.3} = 0.79 \pm 0.025$

$\Delta_{Statistical} \sim 3\%$ $\Delta_{Systematical} \sim 30\%$

Mostly driven by groups and extrapolation

We show the observed cluster mass function (binned) and theoretical models (not a fit!), which also include the constraints from the gas mass fraction analysis.





$L_x - M$ scaling relation

We find a (bias corrected) slope of the mass-luminosity relation of 1.34 +- 0.13, this is consistent with several references.
We find a clear steepening of the LM relation at the galaxy group scale:
Slope of groups: 1.88, while 1.06 for clusters only