Using X-ray Clusters as Cosmological Probes

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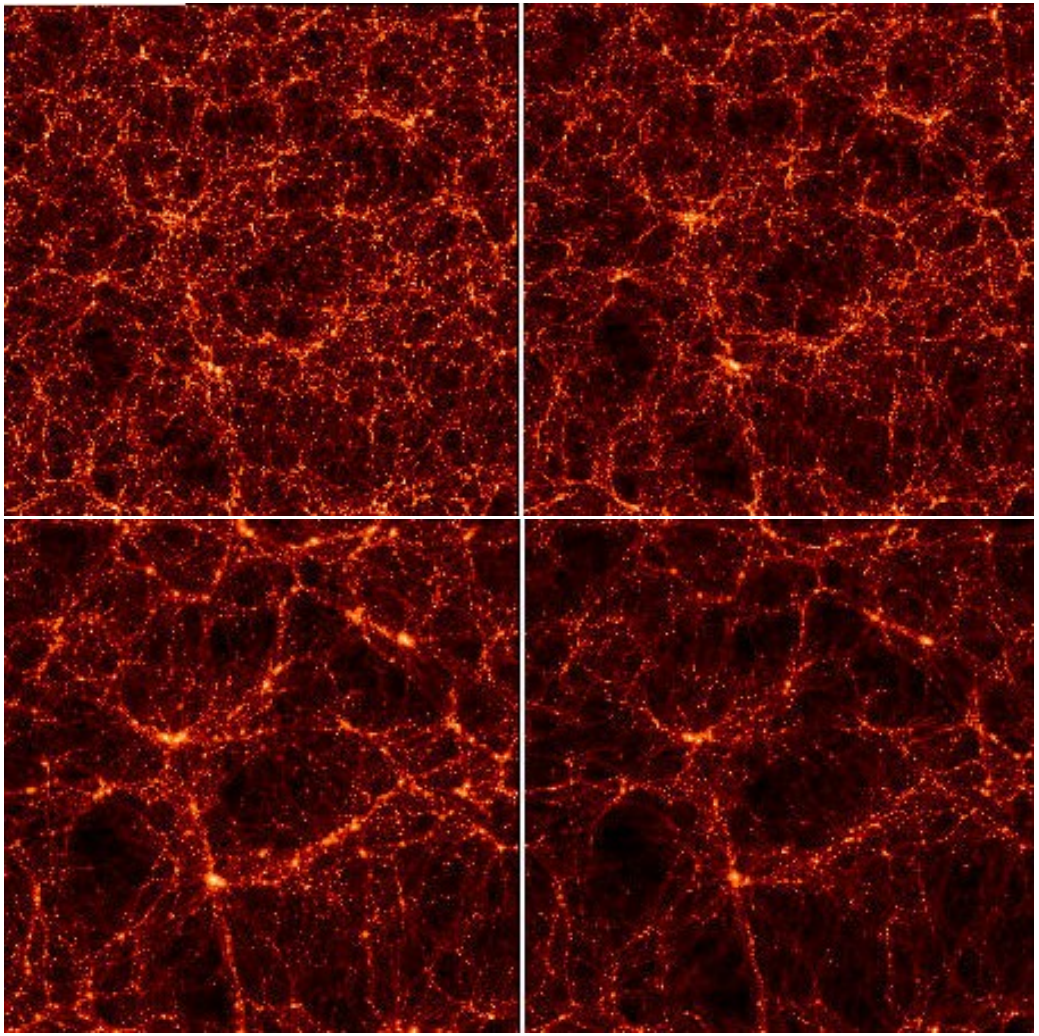
Testing cosmological models with the statistics of LSS

Different LSS for different cosmological models

SCDM

Ω_m=1



τCDM

Ω_m=1

ΛCDM

Ω_m=0.3

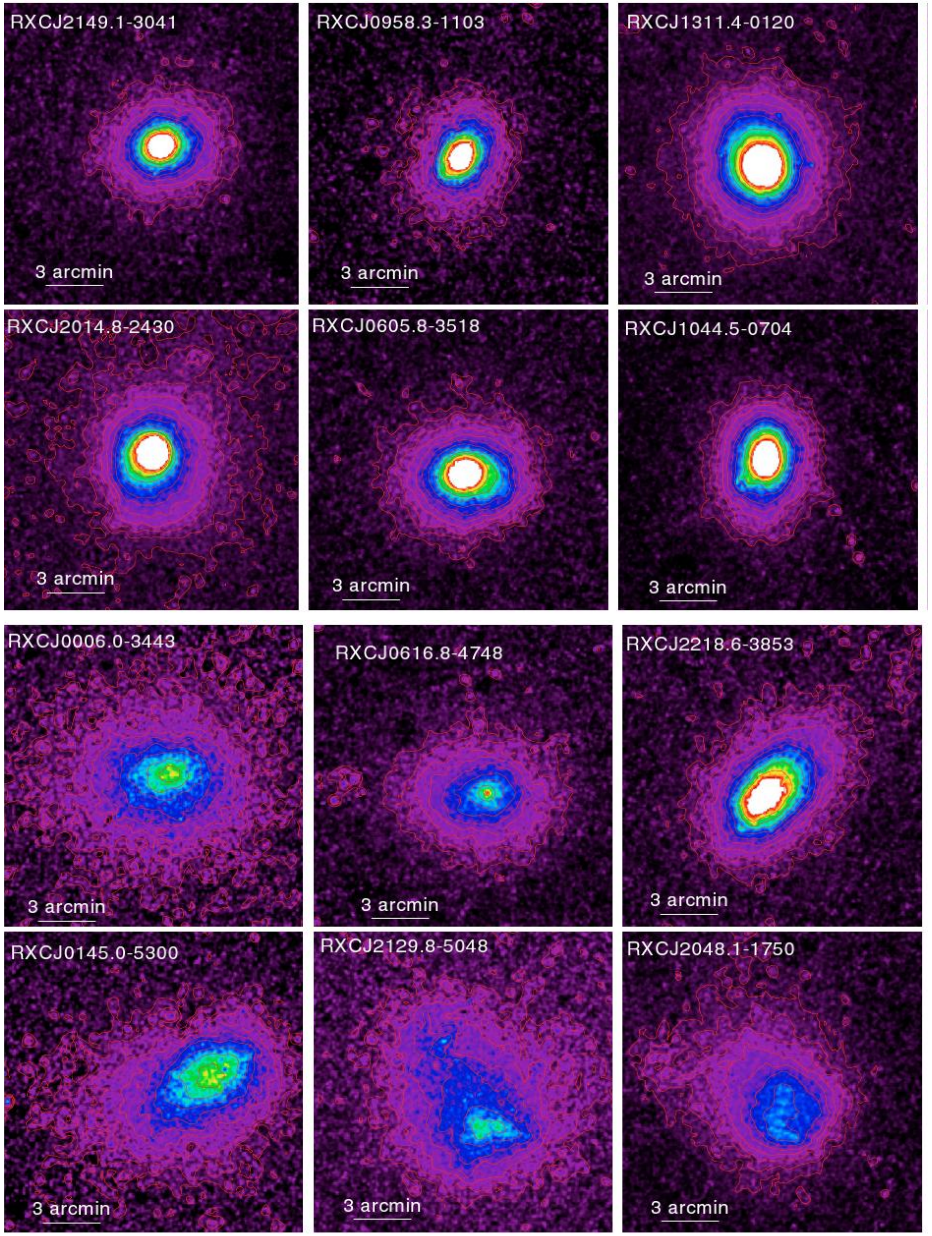
Ω_Λ=0.7

OCDM

Ω_m=0.3

MPA , Garching & Virgo Consortium

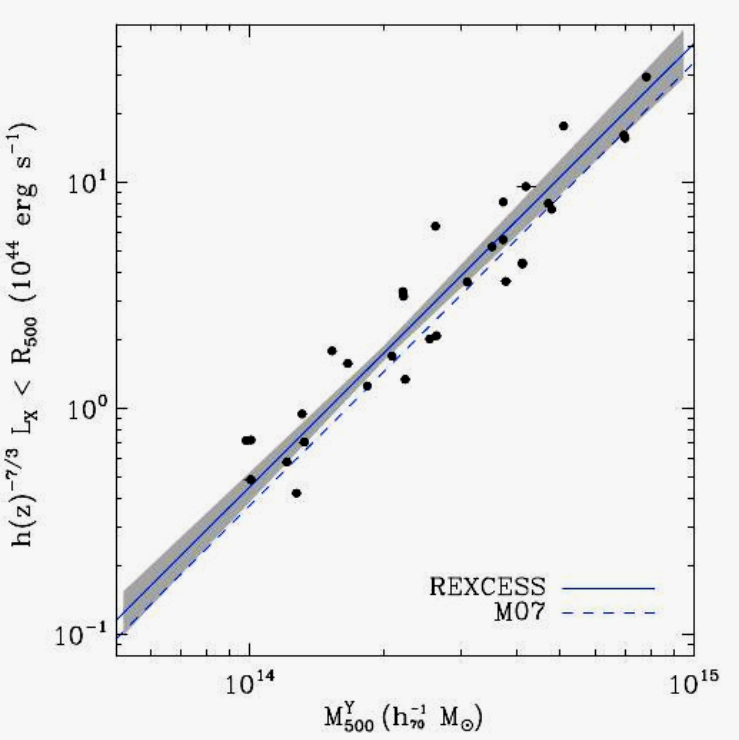
Morphological variation of clusters

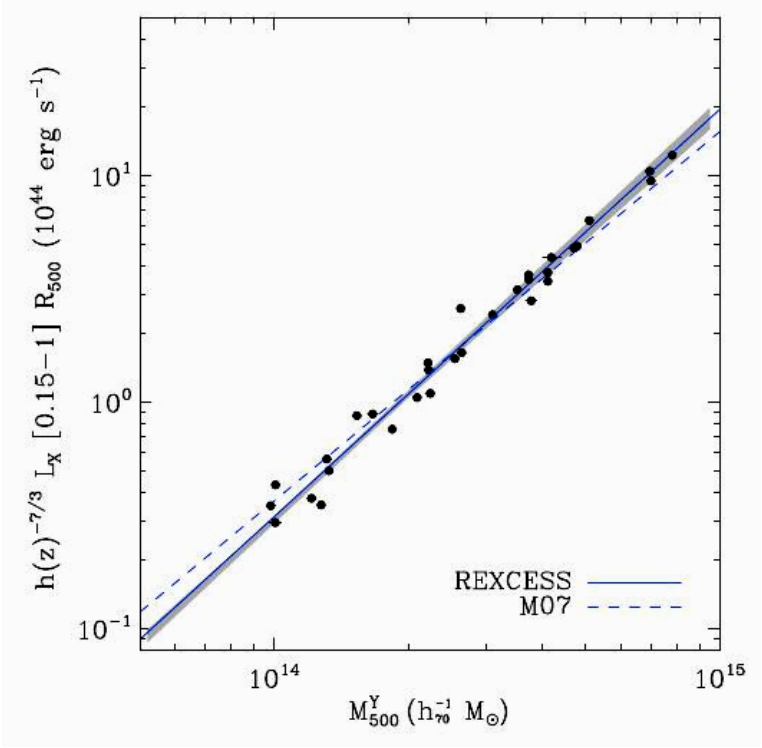


Some of the most regular and most structured galaxy clusters of the REXCESS sample
- a representative sample for X-ray surveys

Böhringer et al. 2007

L_X - M relation for REXCESS clusters





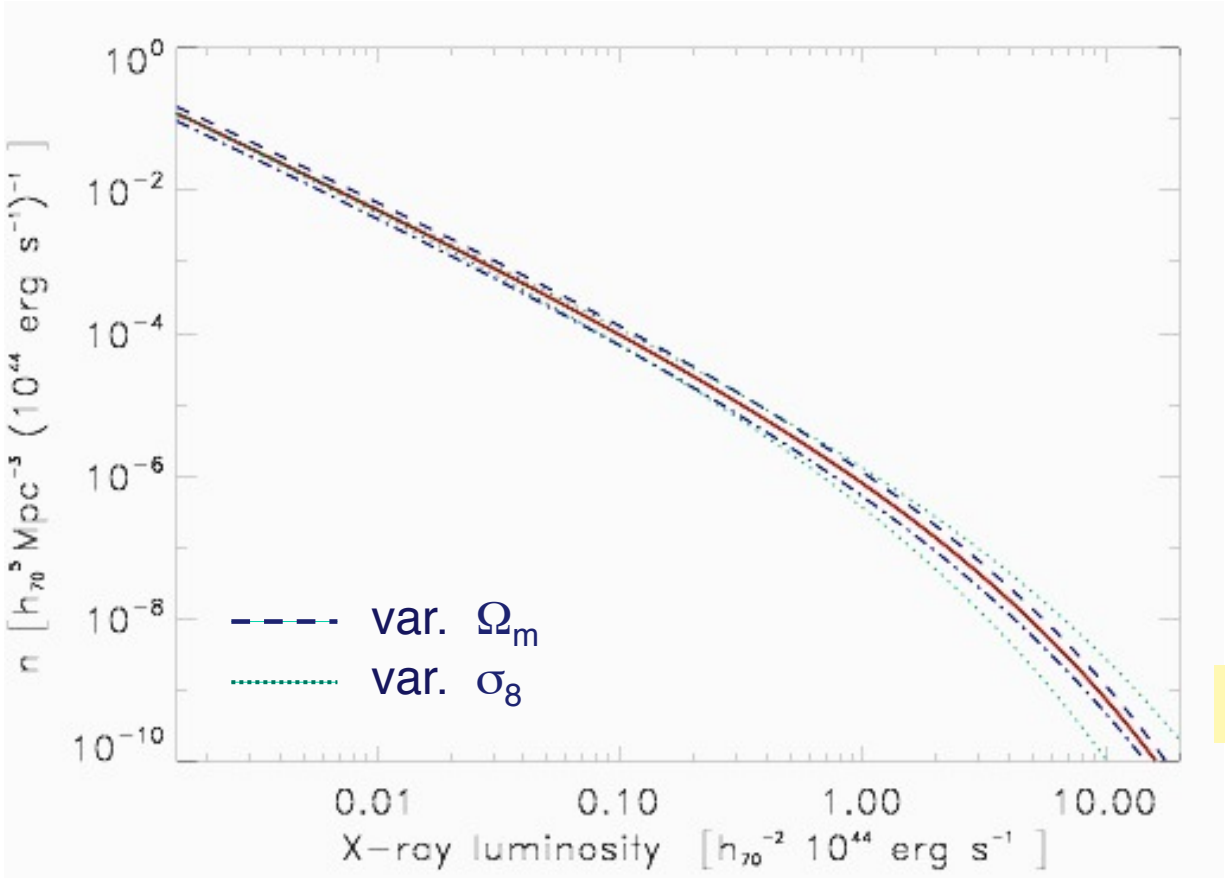
M estimated from Y_X

scatter ~ 40%

scatter ~ 18%

Pratt, H.B., et al. 2009

Predicted Cluster Luminosity Function
with parameter dependence



background cosmology

⇩

structure formation P(k)

⇩

mass function (Tinker)

⇩

L_X-mass scaling relation

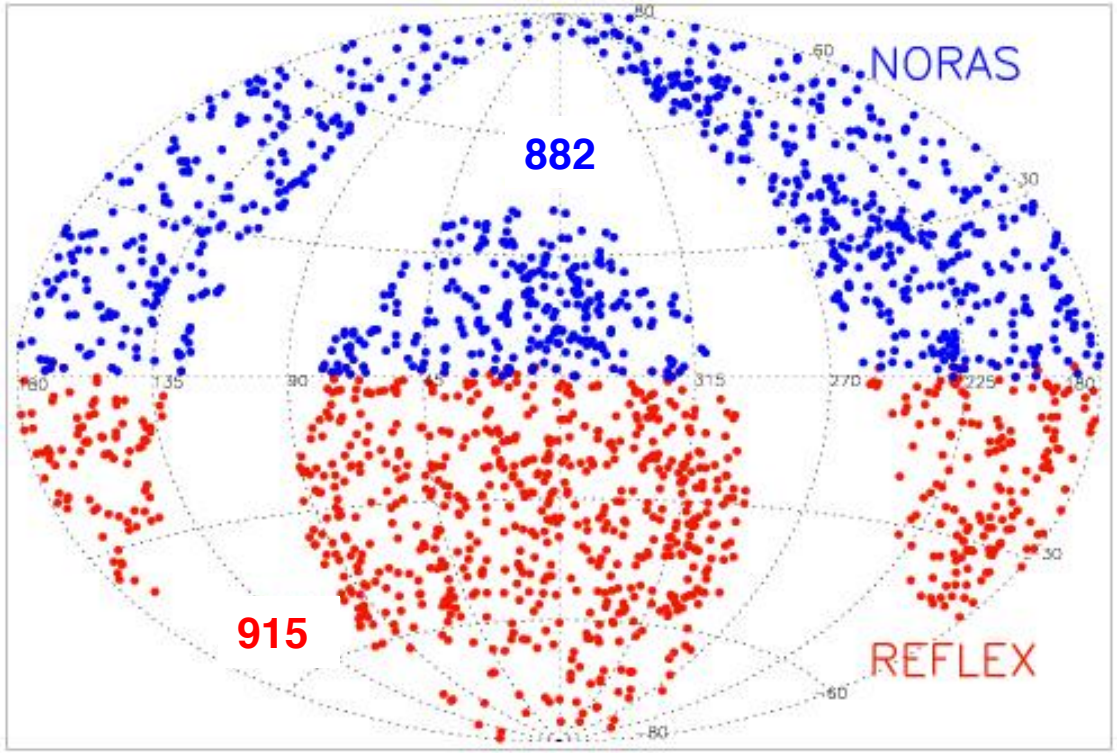
⇩

X-ray luminosity function

Sensitive dependence on σ_8 and Ω_m

Combined REFLEX & NORAS Survey

Extragal. ALL-SKY RASS Survey



REFLEX II 915 clusters

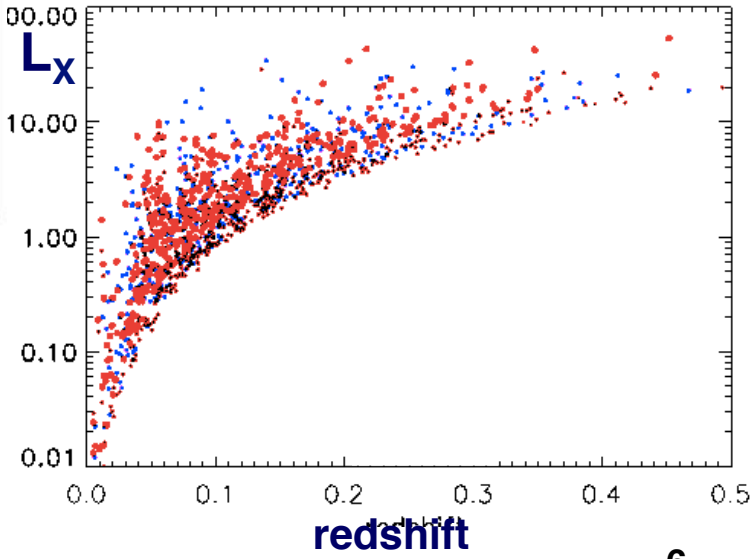
NORAS II 882 clusters

$F > 1.8\ 10^{-12}$ erg s^{-1} cm^{-2}

REFLEX I: 18 runs La Silla

REFLEX II: 9 runs ESO 3.6m/NTT

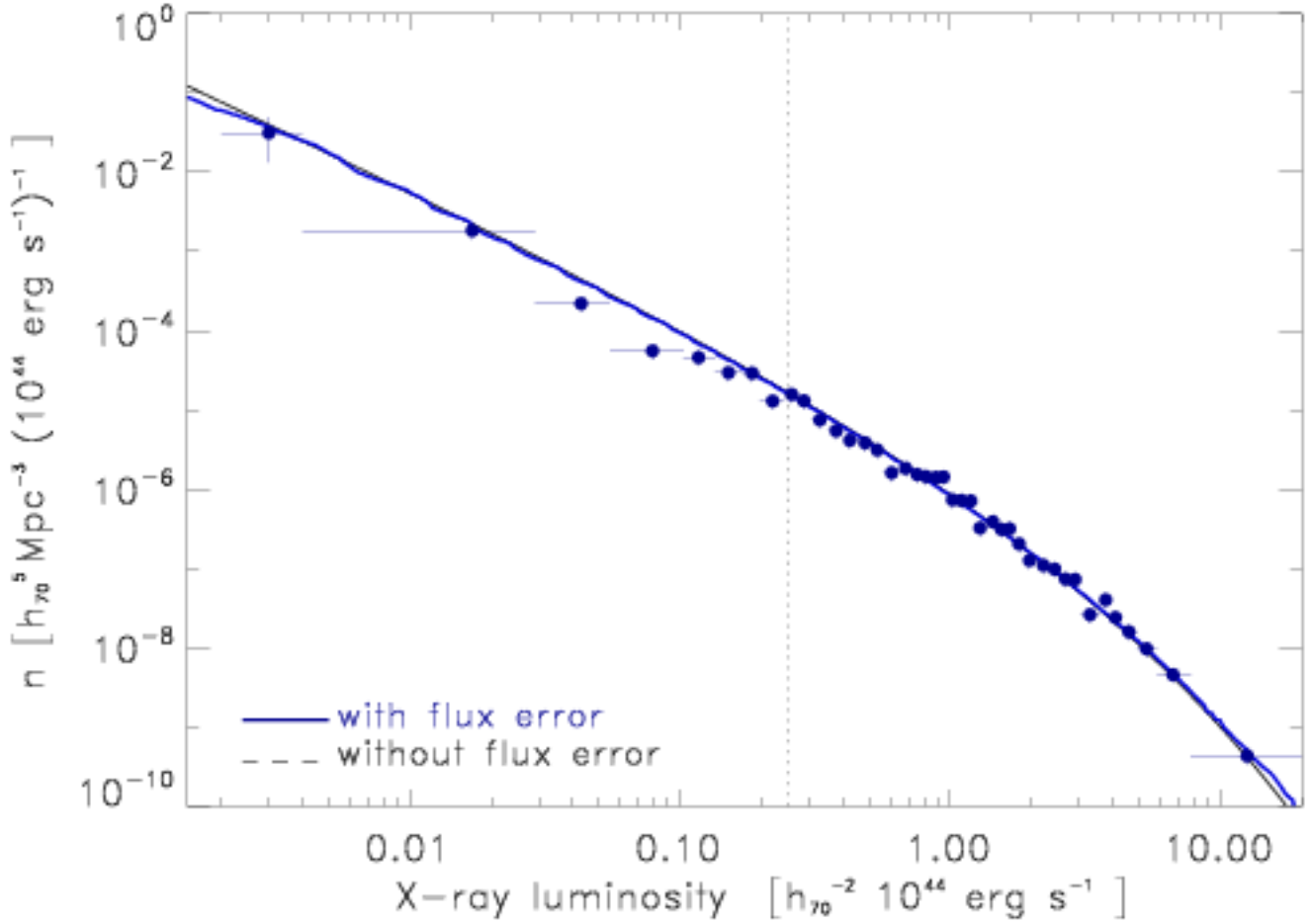
NORAS 11 runs C.A. 2 runs K.P.



Sample descriptions:
Böhringer et al. 2000, 2001, 2004, 2013, 2014, 2015 in prep
Chon & Böhringer 2012

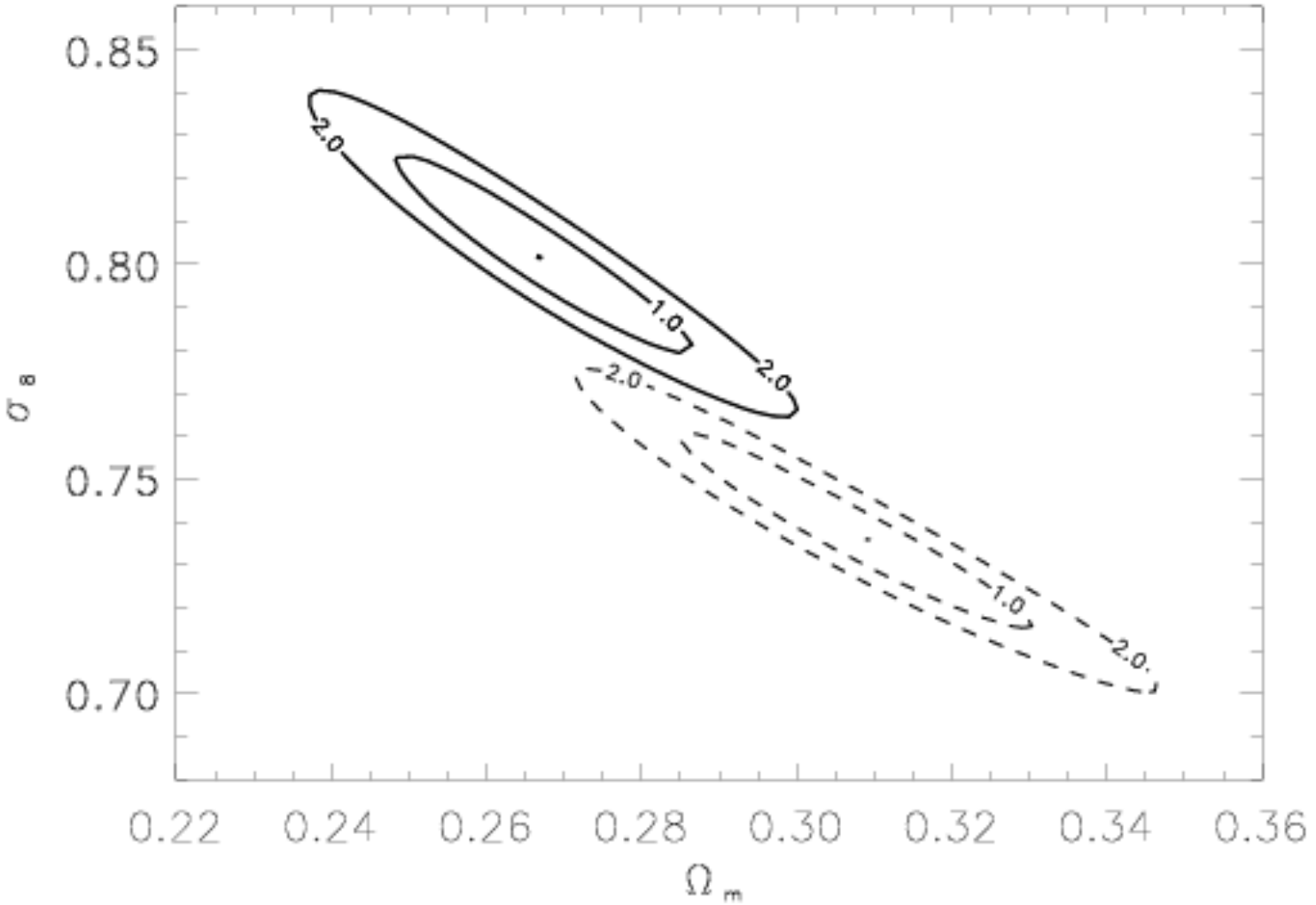
Observed and predicted X-ray luminosity function

Prediction from a flat ΛCMD model $\Omega_m = 0.27$, $\sigma_8 = 0.80$ and REFLEX II XLF



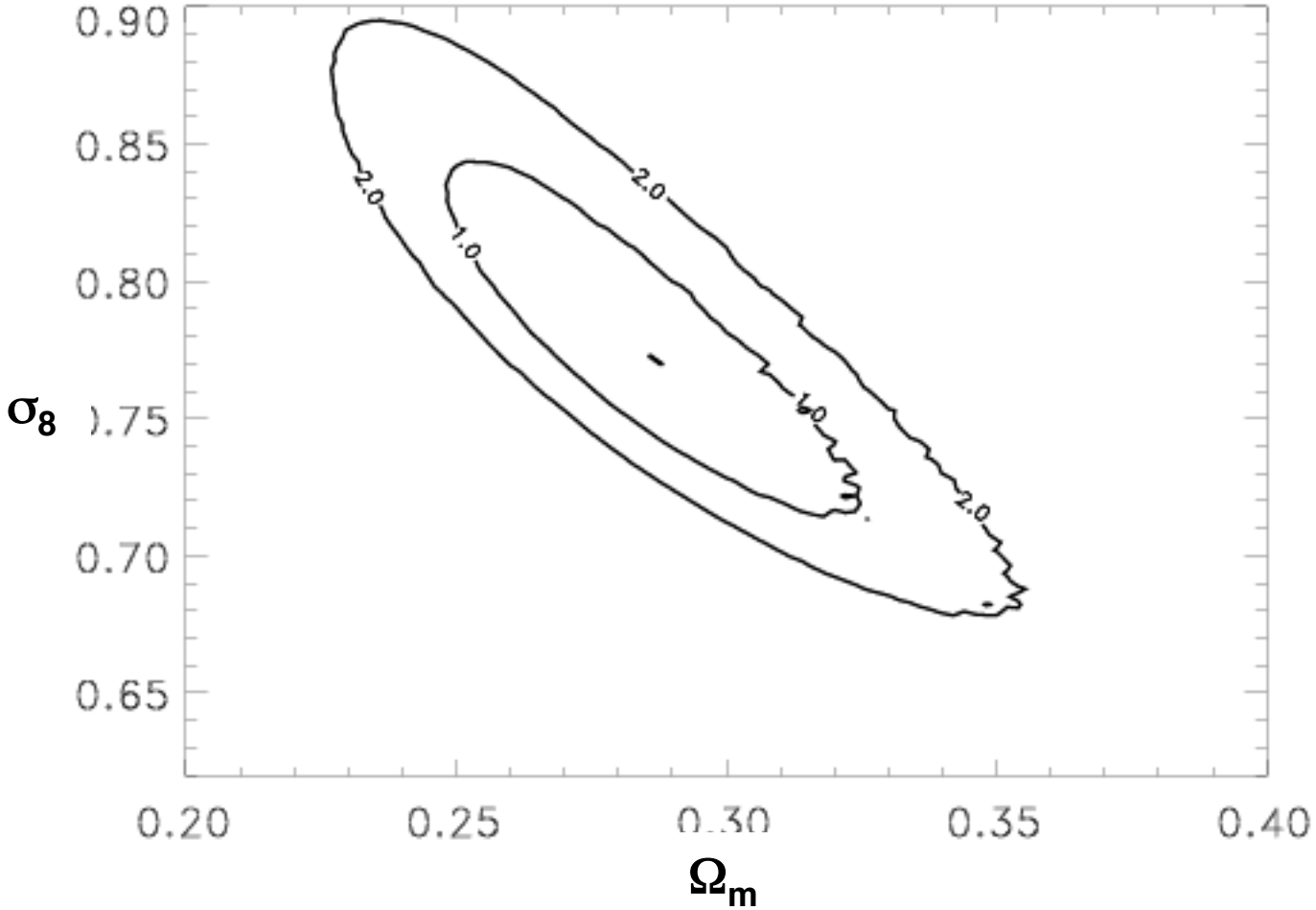
Böhringer et al. 2014

Cosmological constraints for two versions of the scaling relation: slope = 1.51 (solid line) 1.61 (dashed line)



Böhringer et al. 2014

Marginalized Constraints



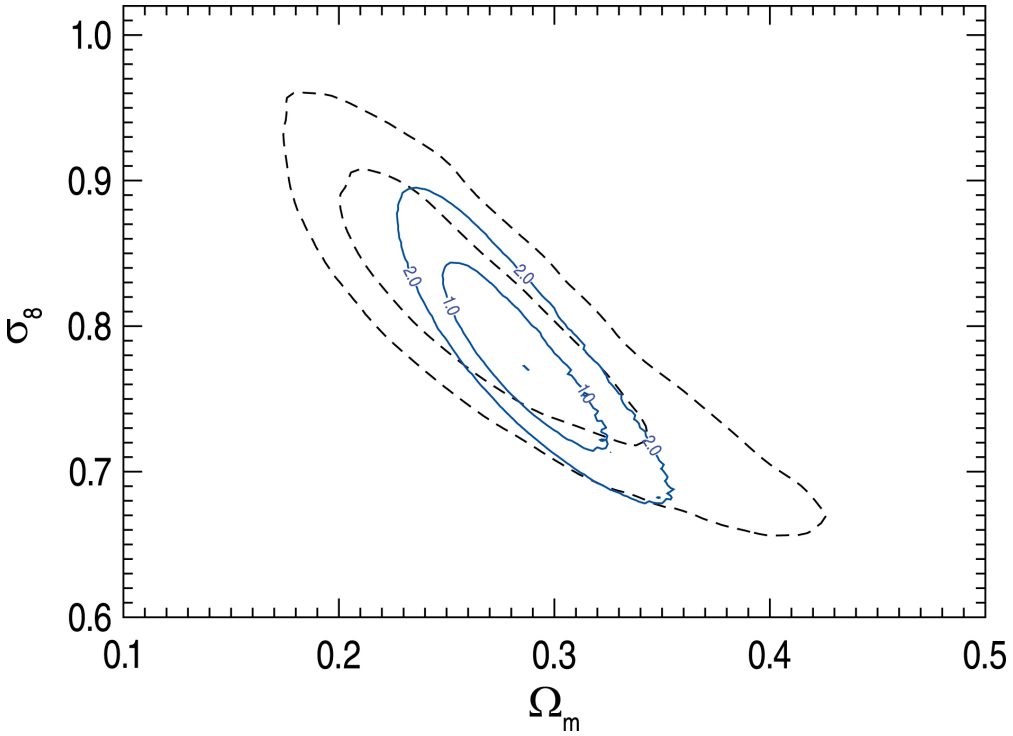
slope = 1.51 +- 7% normalisation = 0.1175 +- 14%

Böhringer et al. 2014

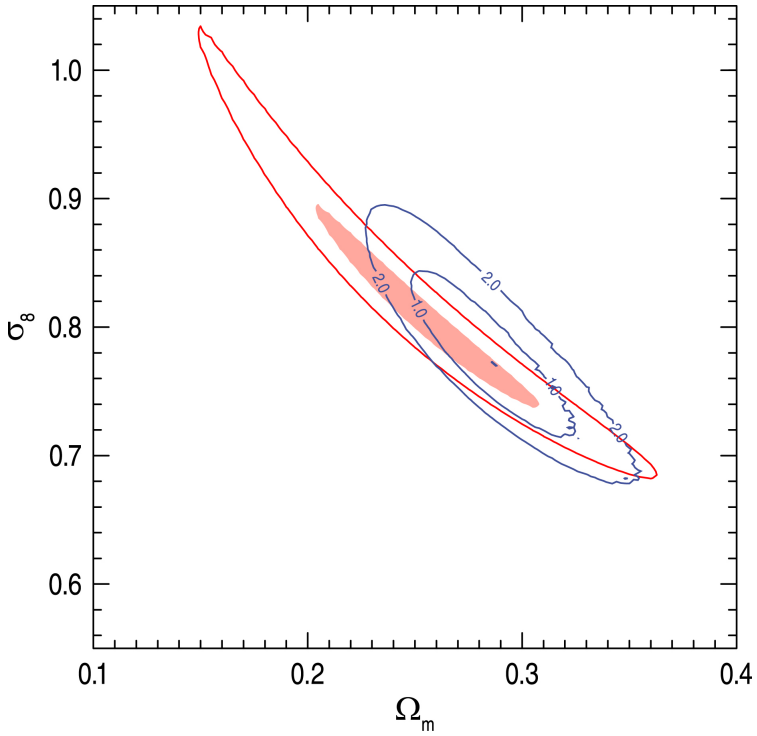
Results from REFLEX II, the SDSS MaxBCG sample and from the 400 deg² survey

Rozo et al. 2010

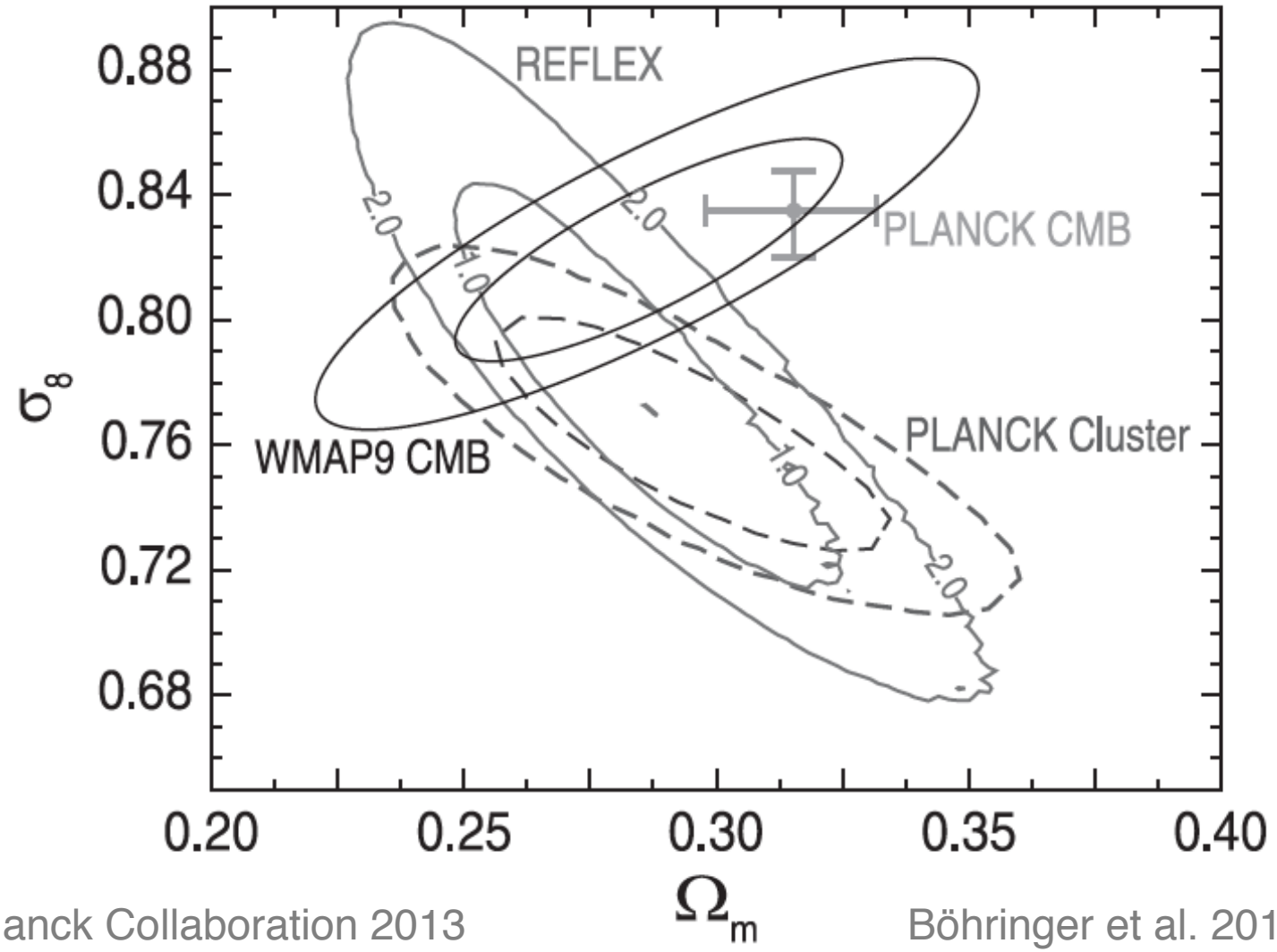
REFLEX II



Vikhlinin et al. 2009
local sample: 49 clusters
at <z> = 0.05



REFLEX and PLANCK cluster and PLANCK and WMAP CMB constraints

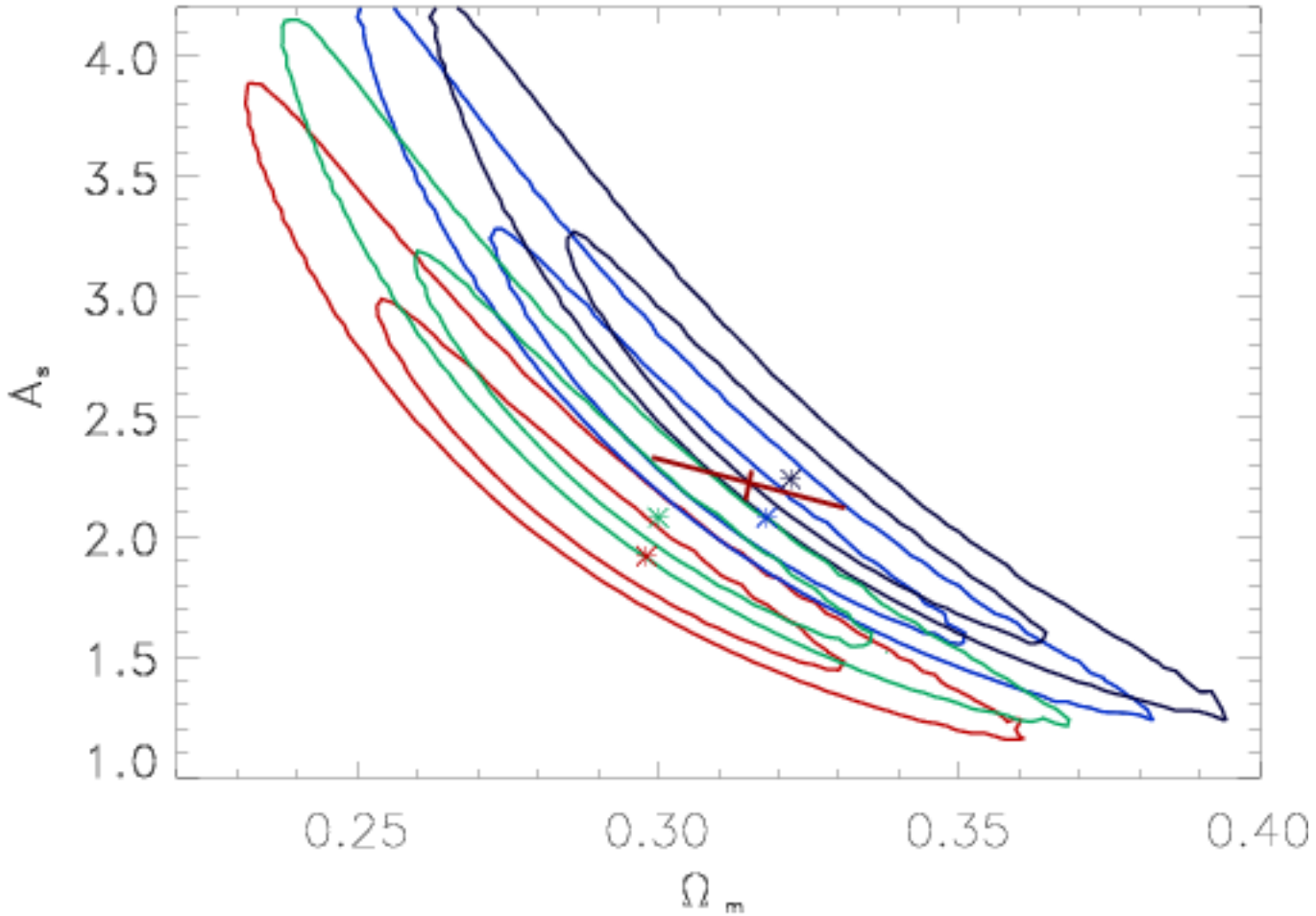


Planck Collaboration 2013
Hinshaw et al. 2013

Böhringer et al. 2014

Effect of massive neutrinos

Constraints on A_s and Ω_m for M_ν = 0, 0.17, 0.4, 0.6 eV

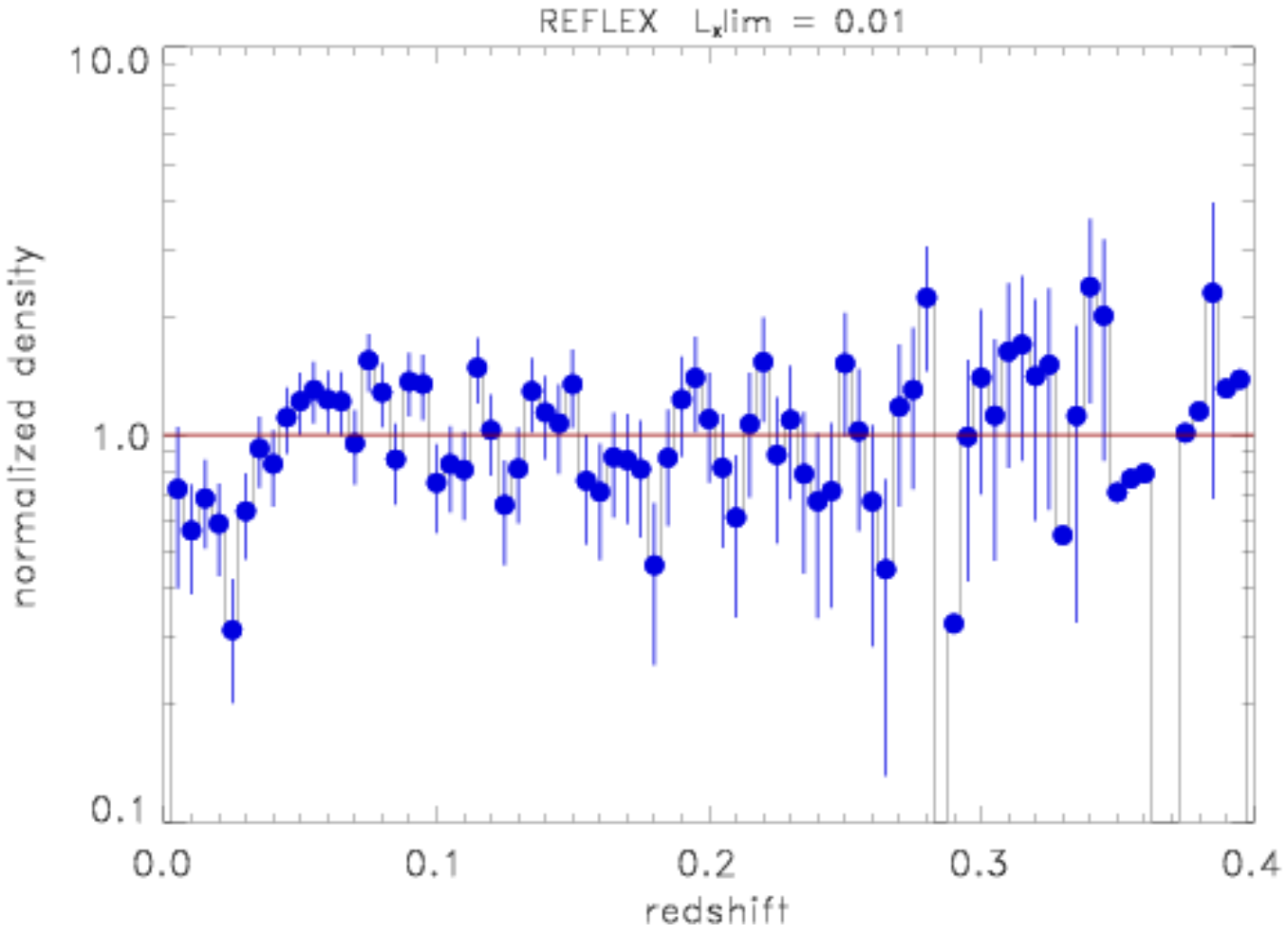


Formal consistency for M_ν = 0.45 +- 0.28 eV

Böhringer & Chon 2015

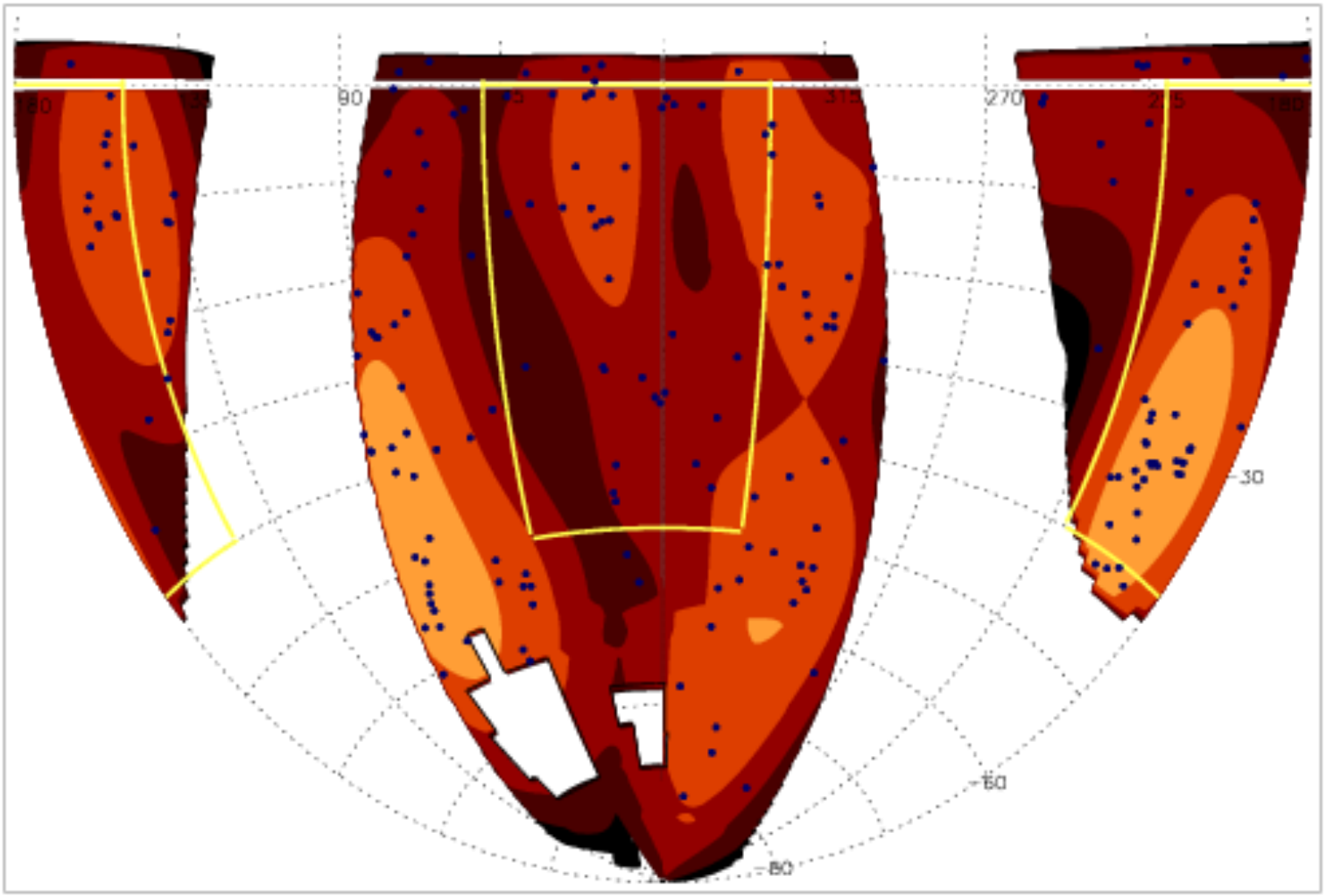
Local Cosmography

REFLEX Cluster Density Distribution as Function of Redshift



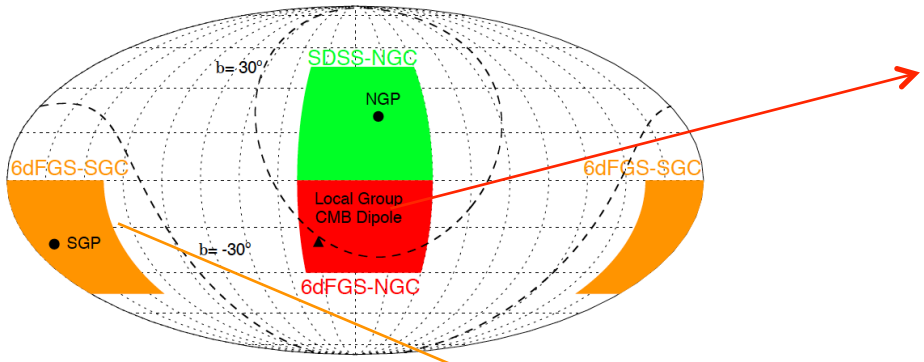
Böhringer et al. 2014

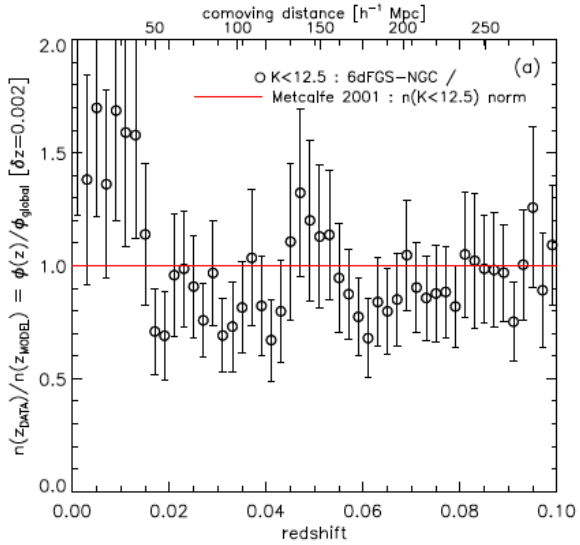
REFLEX Cluster Density Distribution at $z < 0.06$

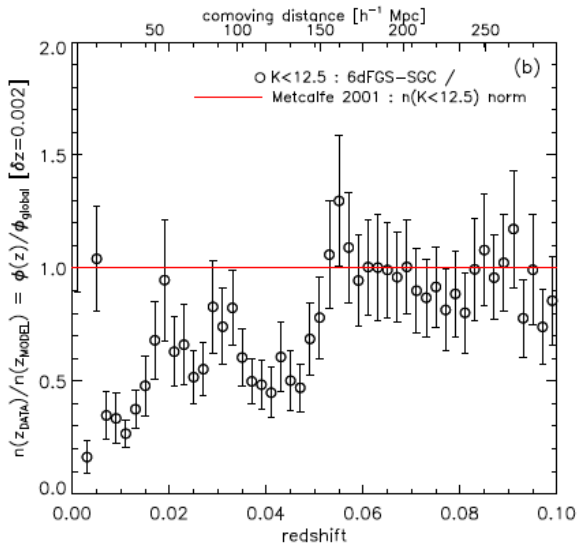


Böhringer et al 2014

Local Underdensity in the Galaxy Distribution in the South Galactic Cap







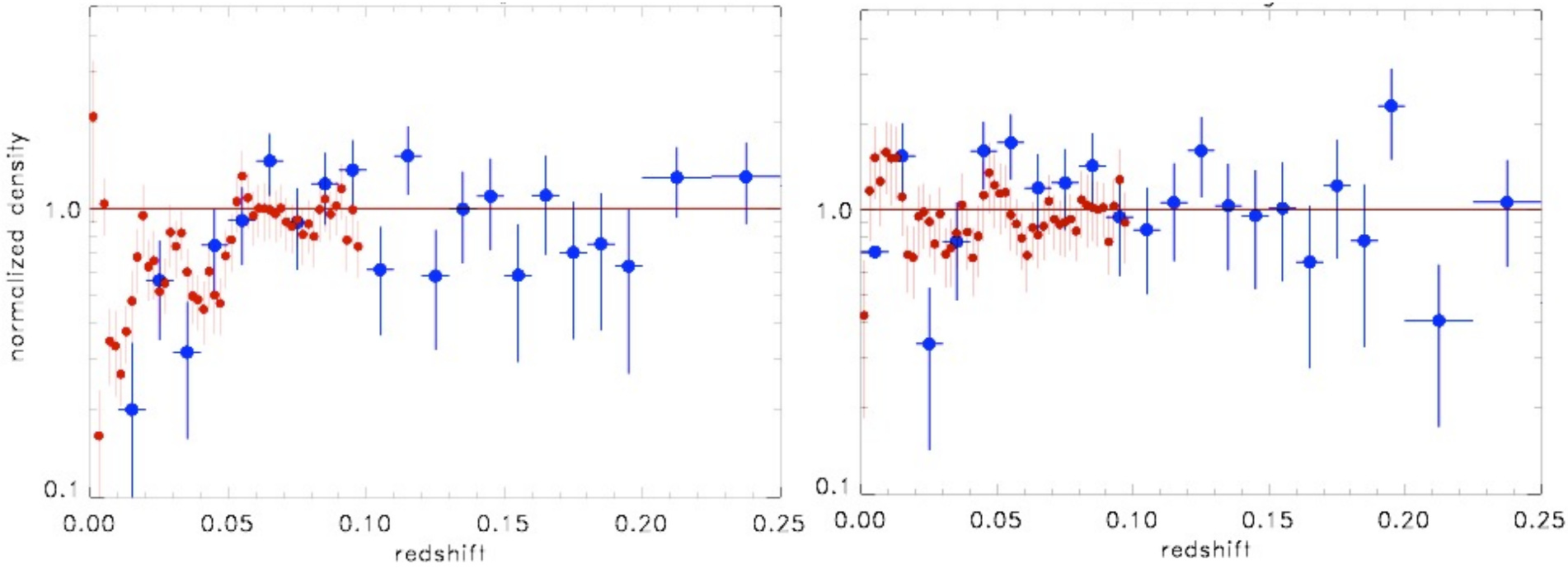
Whitbourn & Shanks 2014

(see also Keenan et l. 2012)

REFLEX Cluster Density Distribution in the North and South Galactic Cap (in the Southern Sky)

South galactic cap region

North galactic cap region in South

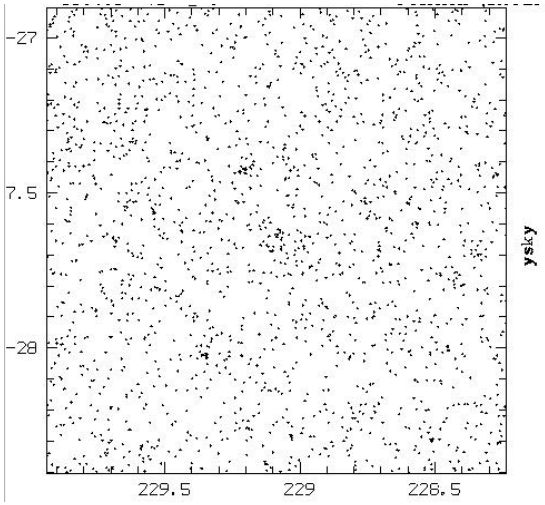


Böhringer et al. 2014

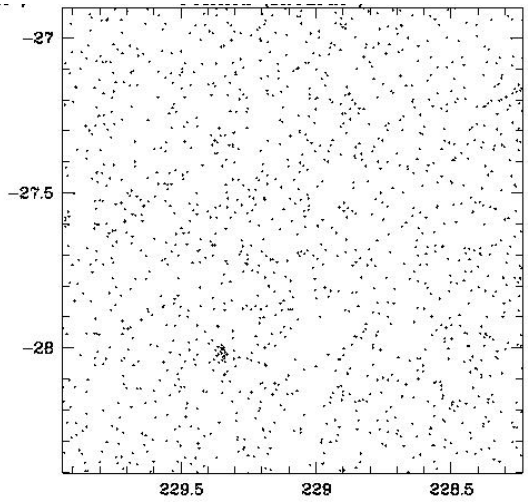
Prospects for Cluster Surveys

Characterization of Clusters in X-rays with RASS

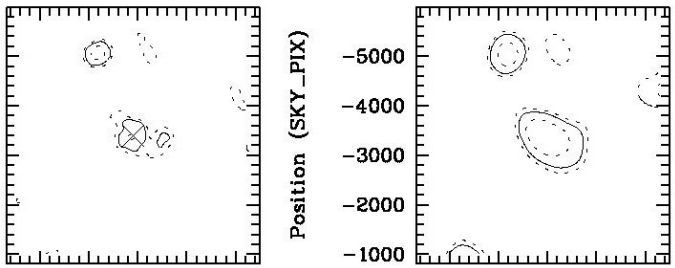
hard image (0.5 – 2 keV)



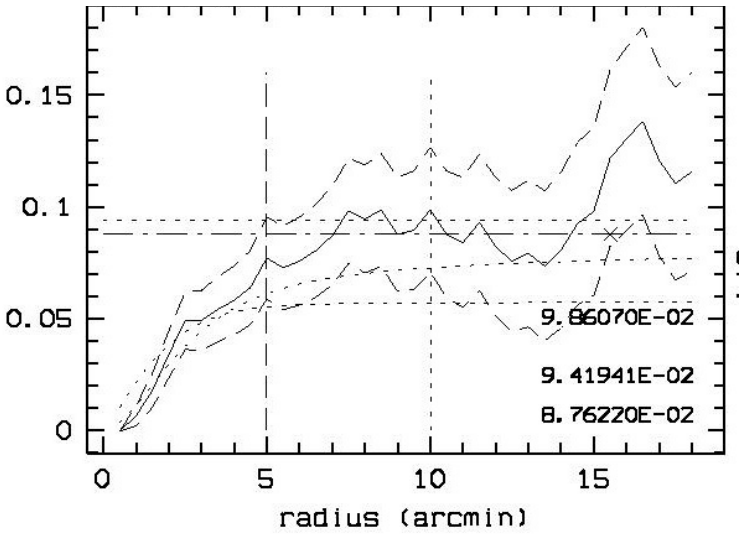
soft (0.1 – 0.4 keV)



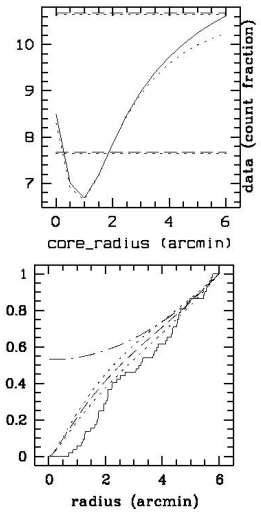
smoothed hard image 1’ & 2’



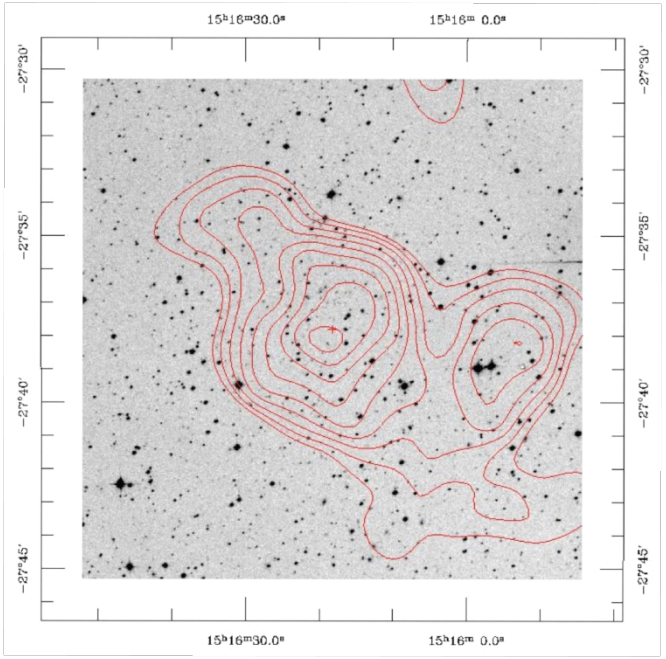
Growth curve in hard band



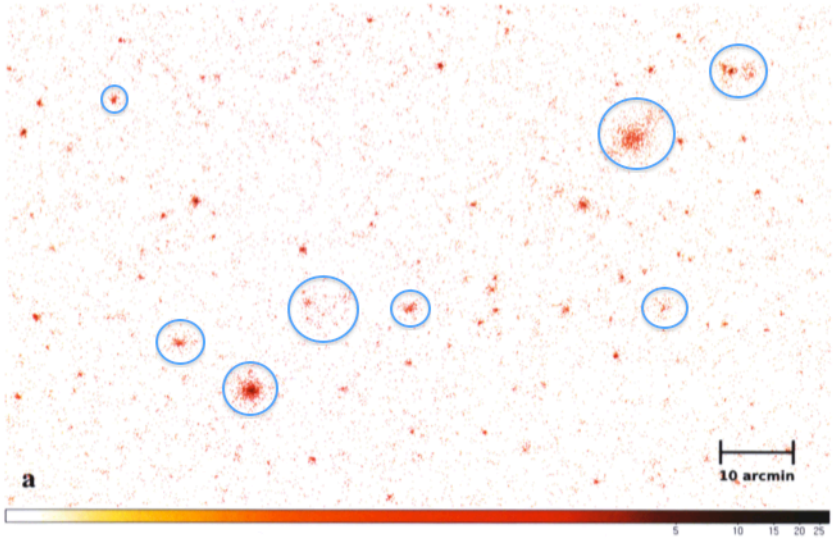
Source extent

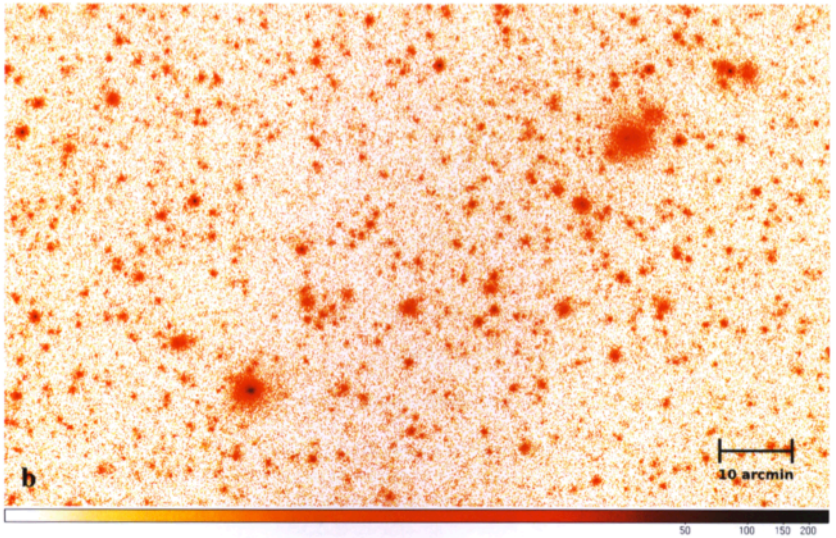


Overlay over DSS image



Simulated eROSITA Survey Fields





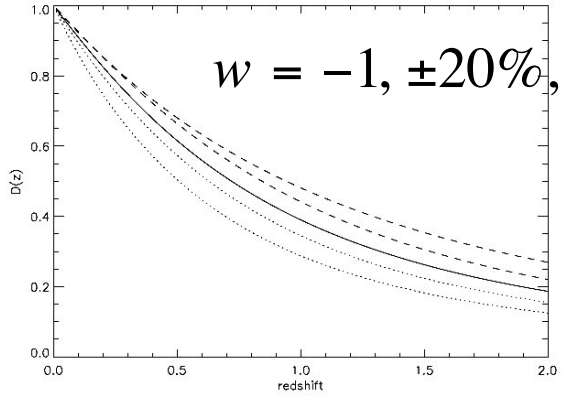
1.9 x 1.2 deg

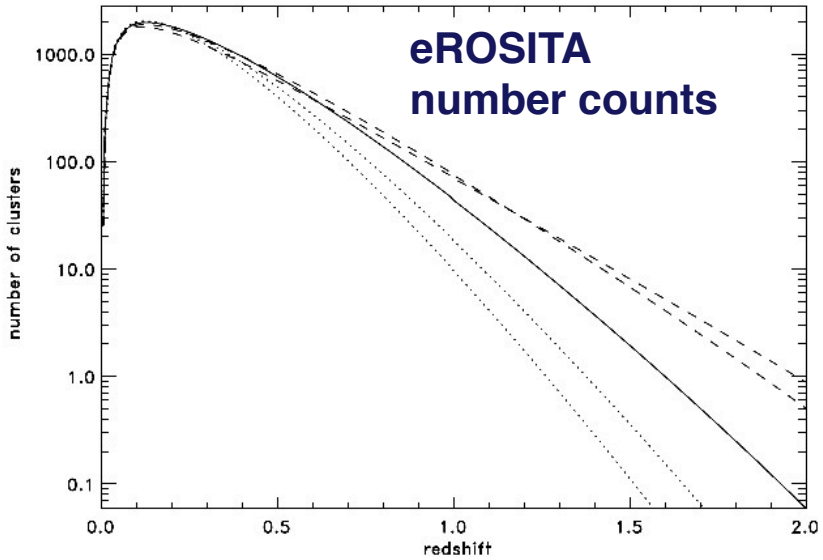
top: 2.2 ks
(mean Survey)

bottom: 30 ks
(ecliptic poles)

Results of cluster number forecast for different cosmological models

fluctuation growth factor





	refer:w=-1	w = -1.3	w = -0.7
z > 0.4	41600	42300	43600
z > 0.8	4800	3900	6300
z > 1.2	490	327	830

Chon & Böhringer 2013

Conclusions

- Galaxy clusters are good probes for cosmology
  - to test cosmological models
  - to constrain the neutrino mass
  - to map the local LSS matter distribution

- The success in constraining cosmological parameters is limted by the imprecise knowledge of scaling relations and mass calibration
  - needs to be improved !!!

- Ongoing and future surveys (XMM-Newton Surveys and eROSITA) will add redshift dimension
  – understanding the high-z ICM will be very important