Cluster science from ROSAT to *e*ROSITA

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Hans Böhringer
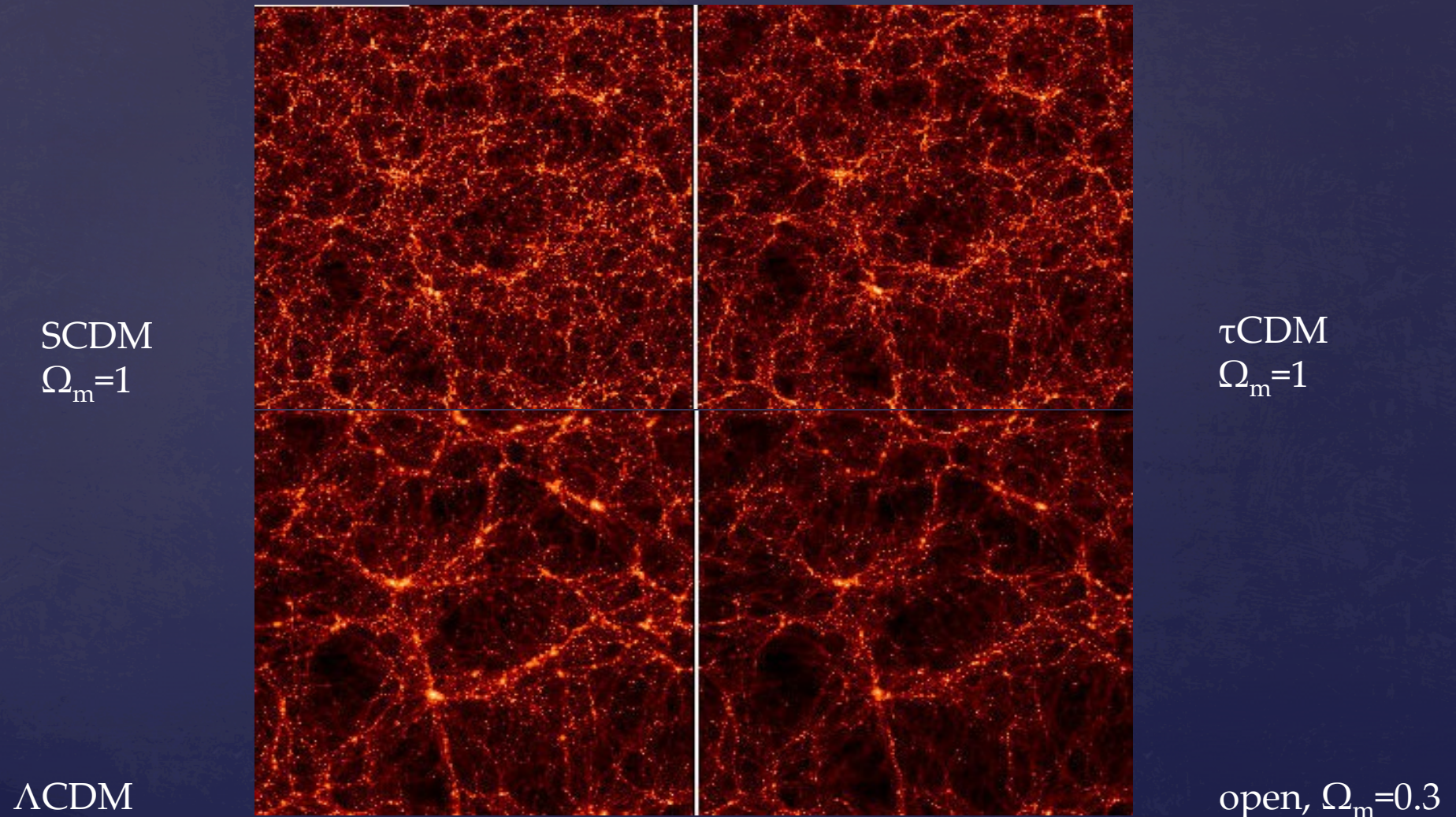
[co-PI *e*ROSITA ,   Chair of Cluster science group]

Overview

- Galaxy clusters as cosmological probes
- Cosmology and large-scale-structure with ROSAT clusters

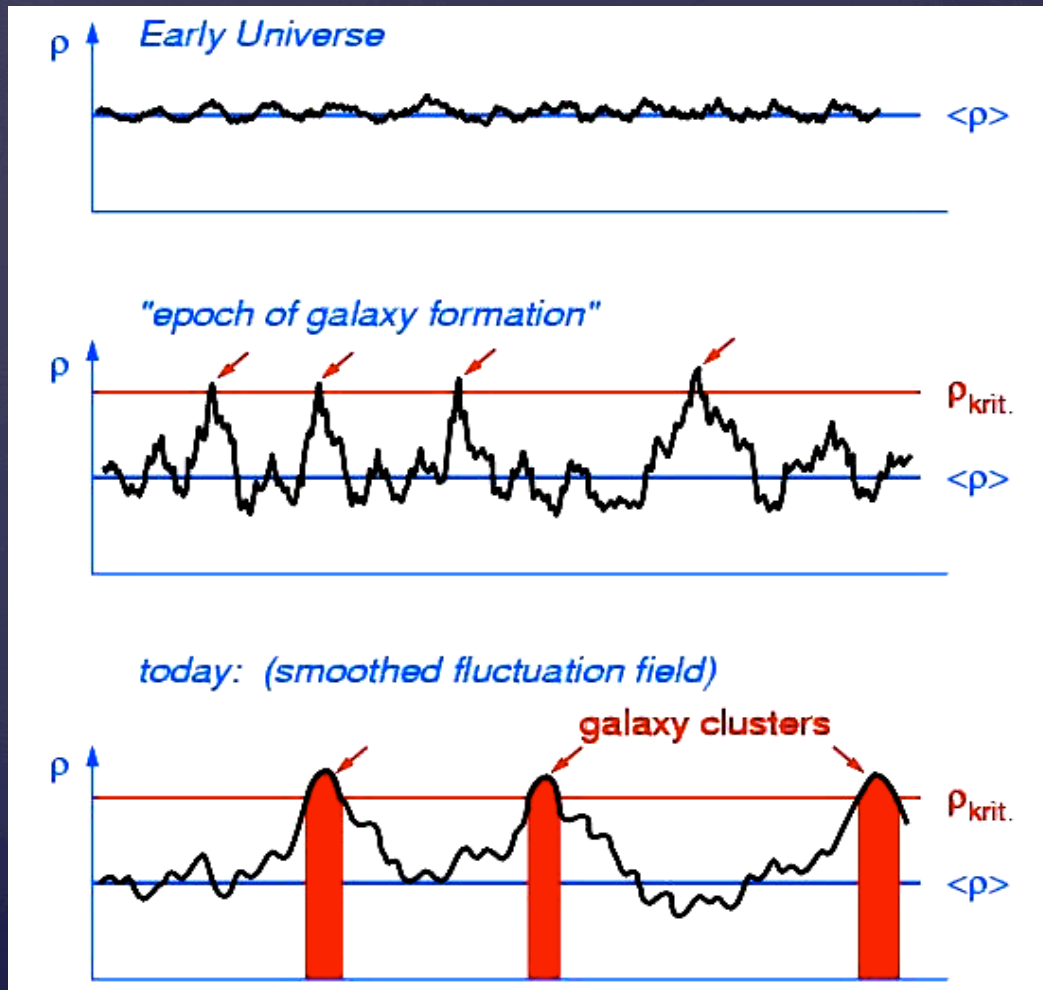- *e*ROSITA mission
- Prospects for *e*ROSITA survey
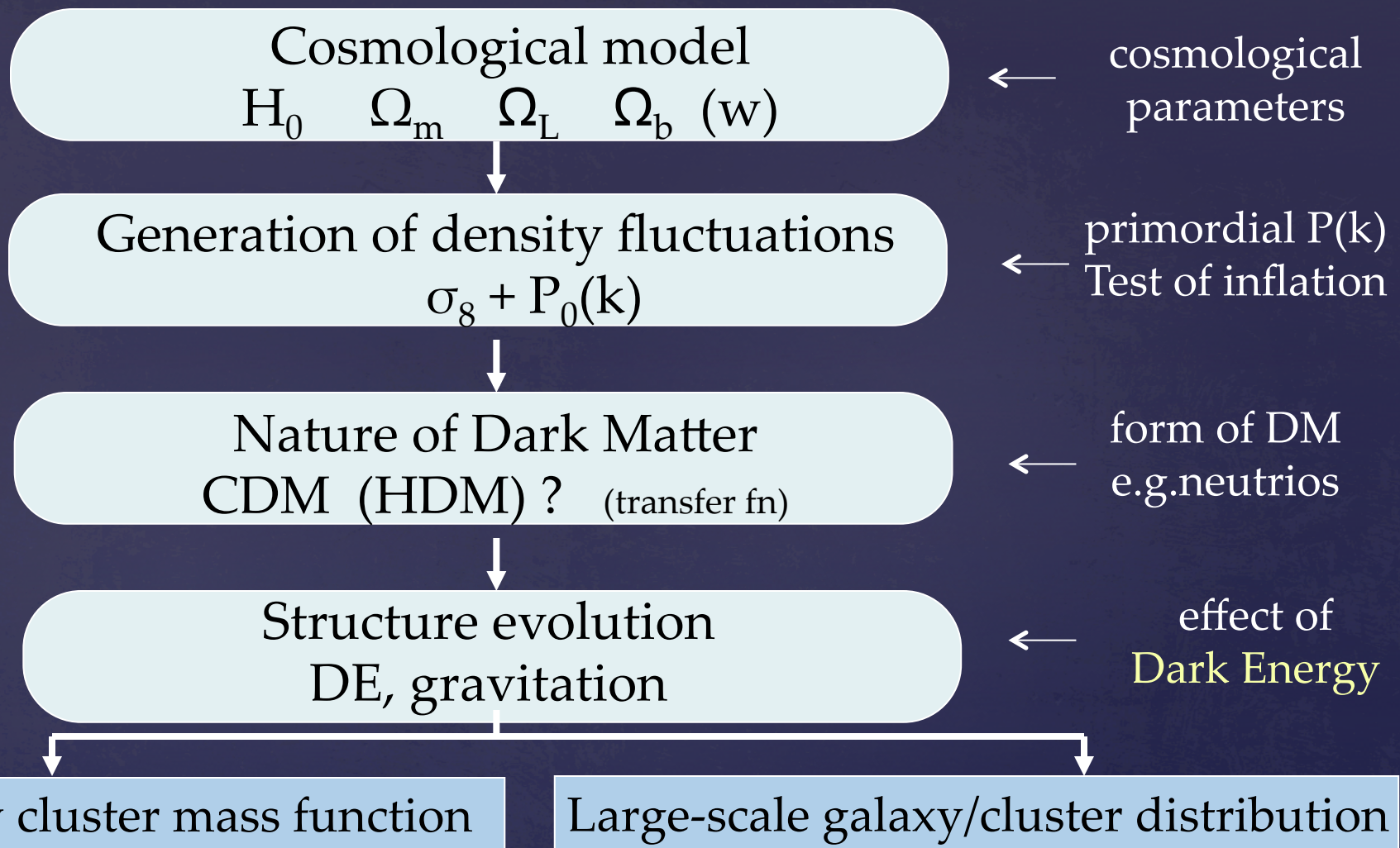- Conclusion

Different LSS for different cosmology

SCDM
$\Omega_m=1$

τCDM
$\Omega_m=1$

ΛCDM

open, $\Omega_m=0.3$

Virgo consortium @ MPA
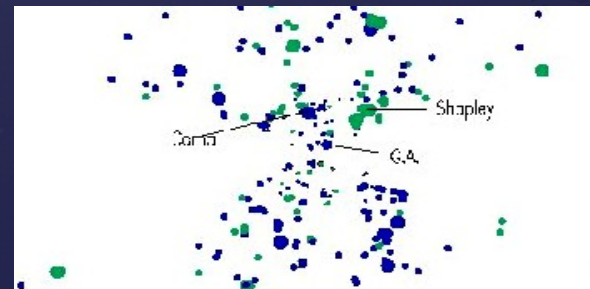
Galaxy clusters in LSS hierarchy

- Amplitude of **P(k)** from cluster abundance, **n(L_X)**

- **P(k)$_{CL}$** of cluster distribution on large scale
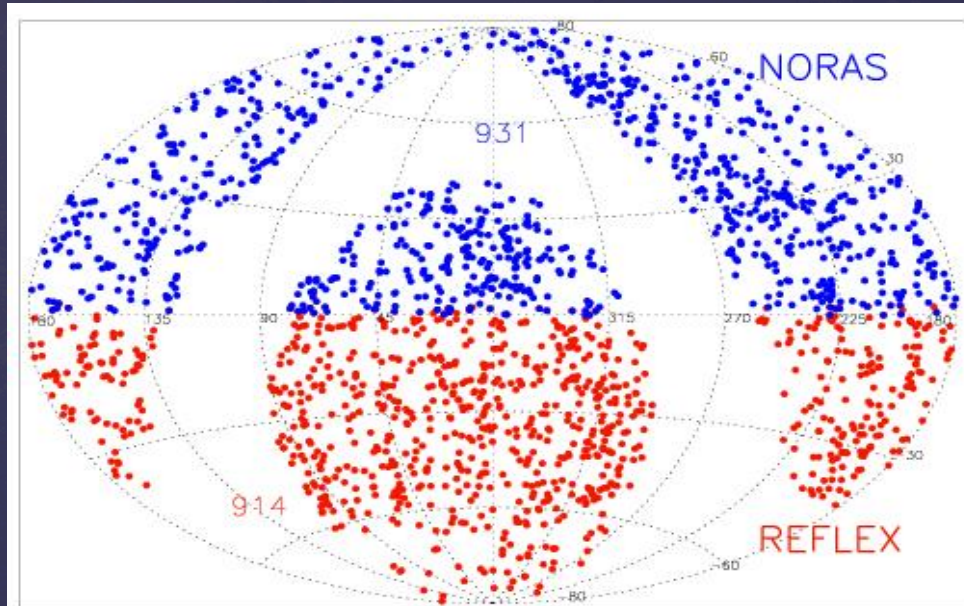
- **Evolution** of cluster population in n(L_X) and P(k)

Cosmological model
H_0 Ω_m Ω_L Ω_b (w)   ← cosmological parameters

Generation of density fluctuations
$\sigma_8 + P_0(k)$ ← primordial P(k) Test of inflation

Nature of Dark Matter
CDM (HDM) ?   (transfer fn)   ← form of DM e.g.neutrios

Structure evolution
DE, gravitation   ← effect of Dark Energy

Galaxy cluster mass function   Large-scale galaxy/cluster distribution

$$\dfrac{d^2N}{dMdz}$$ $P(k)_{CL}$

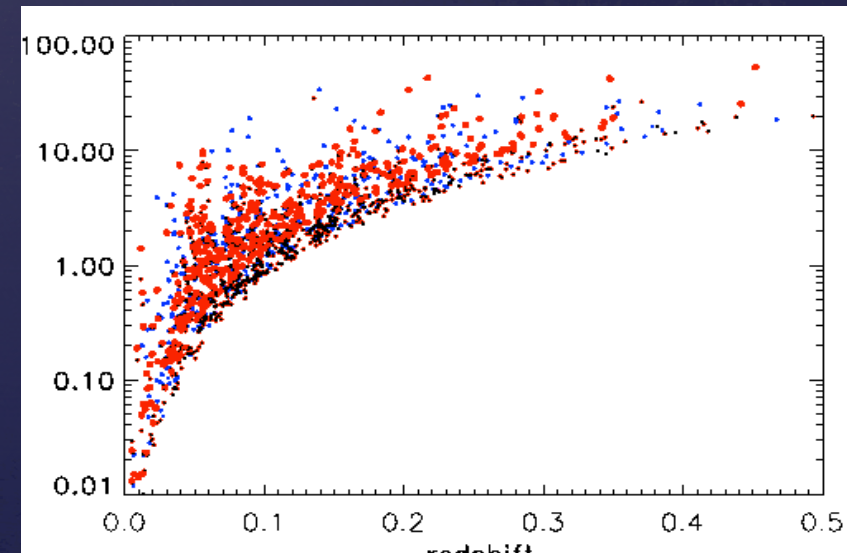# REFLEX and NORAS cluster survey

REFLEX II 919 clusters

NORAS II 934 clusters

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

REFLEX I: 18 runs La Silla
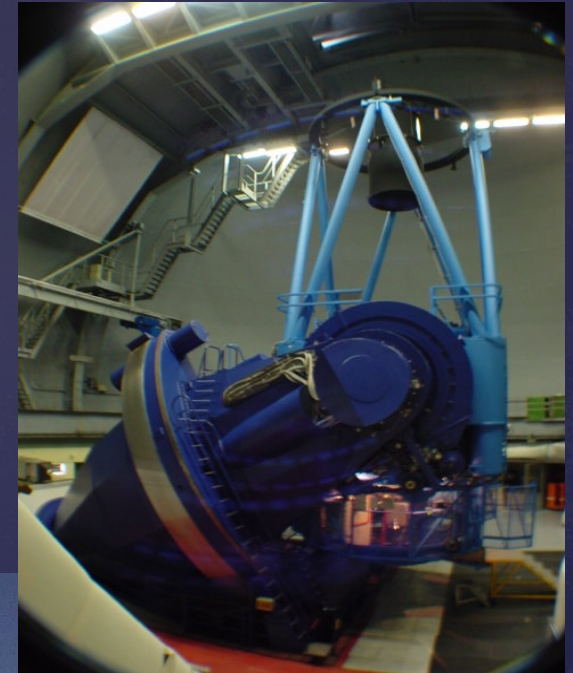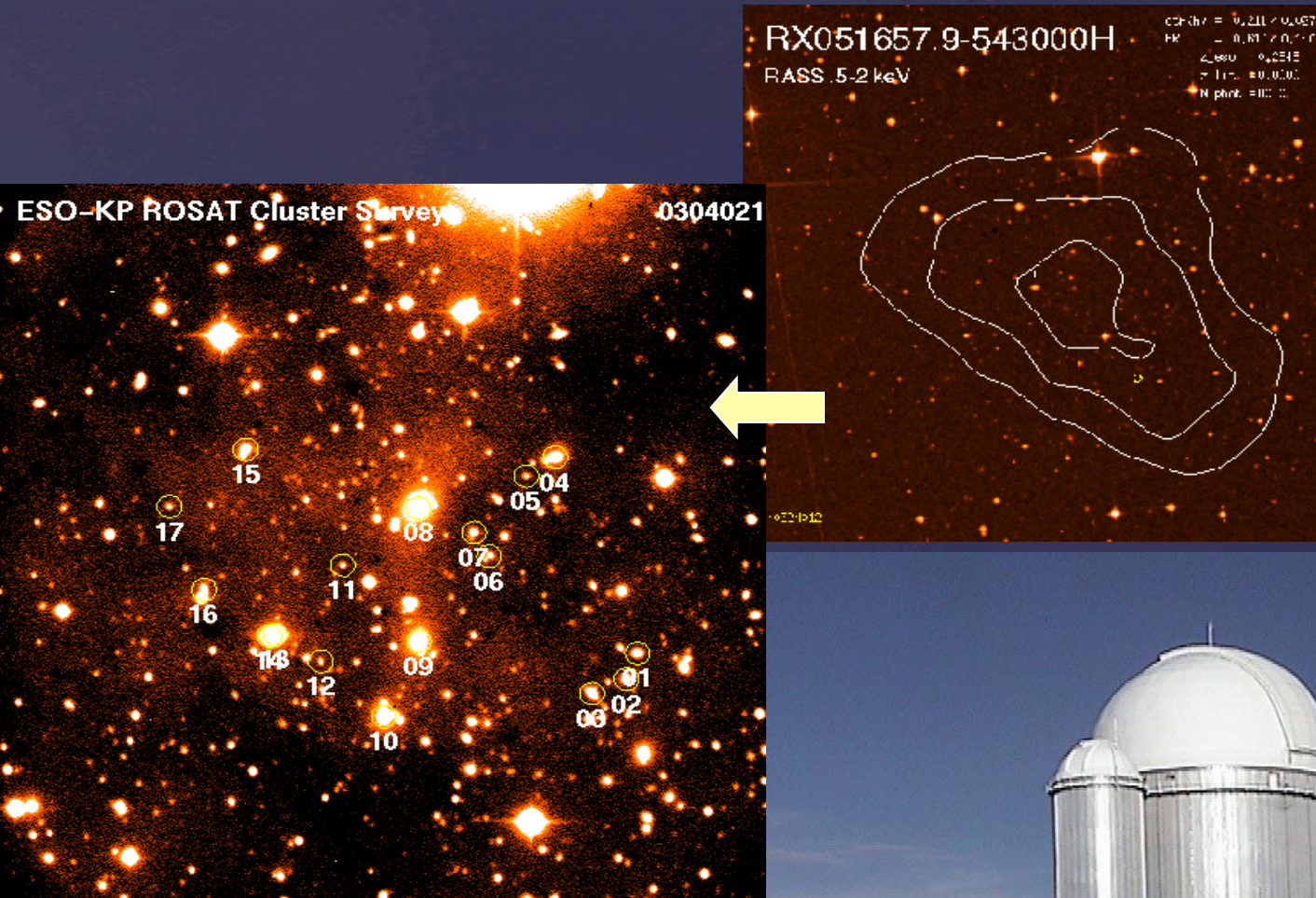
REFLEX II: 9 runs ESO 3.6m/NTT

NORAS 10 runs C.A. 2 runs K.P.

Böhringer et al. 2000, 2001, 2004, 2012
Chon & Böhringer, 2012

ESO – Key Program
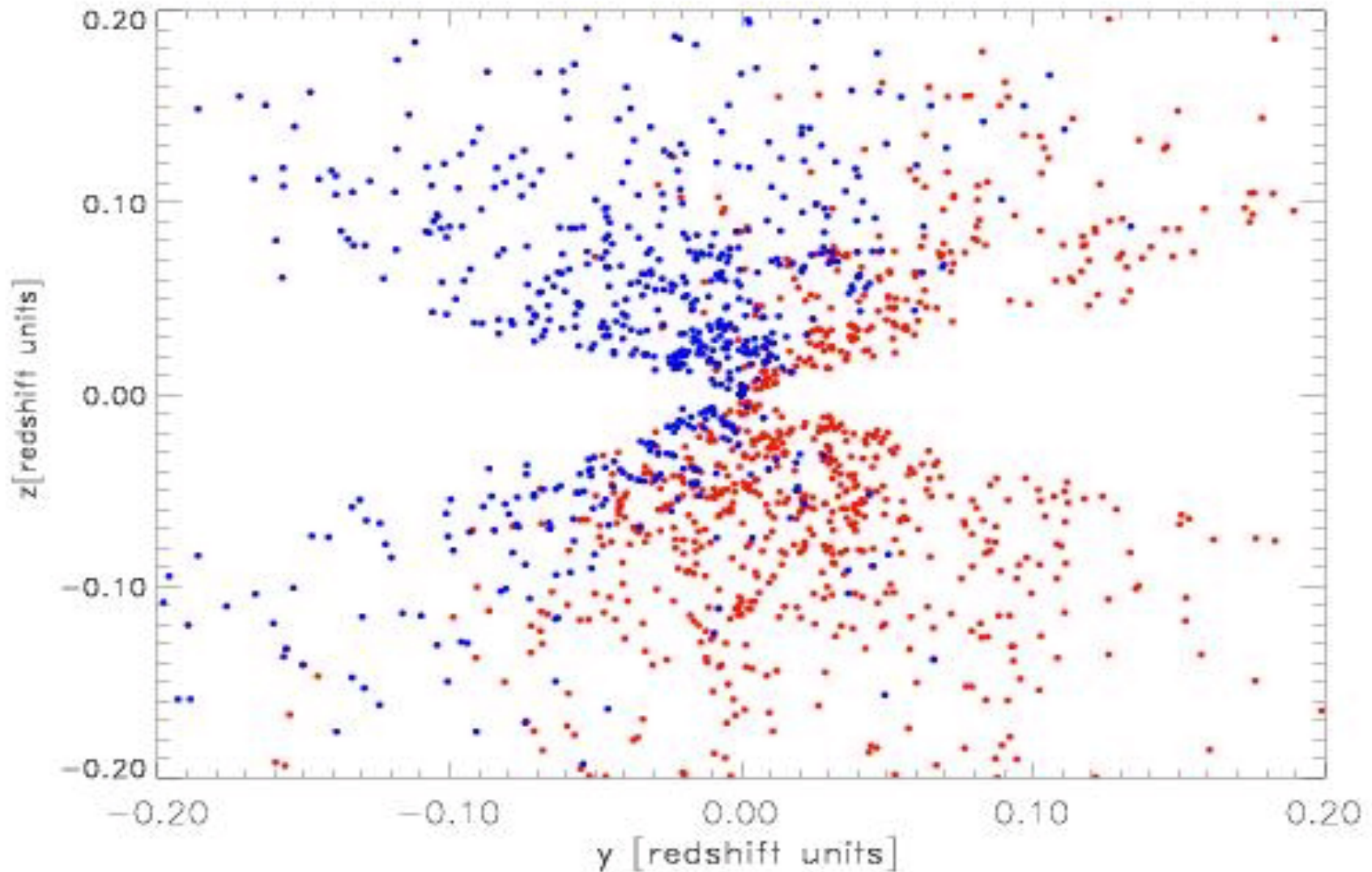# @ La Silla 1992 - 99 (II) - 2011

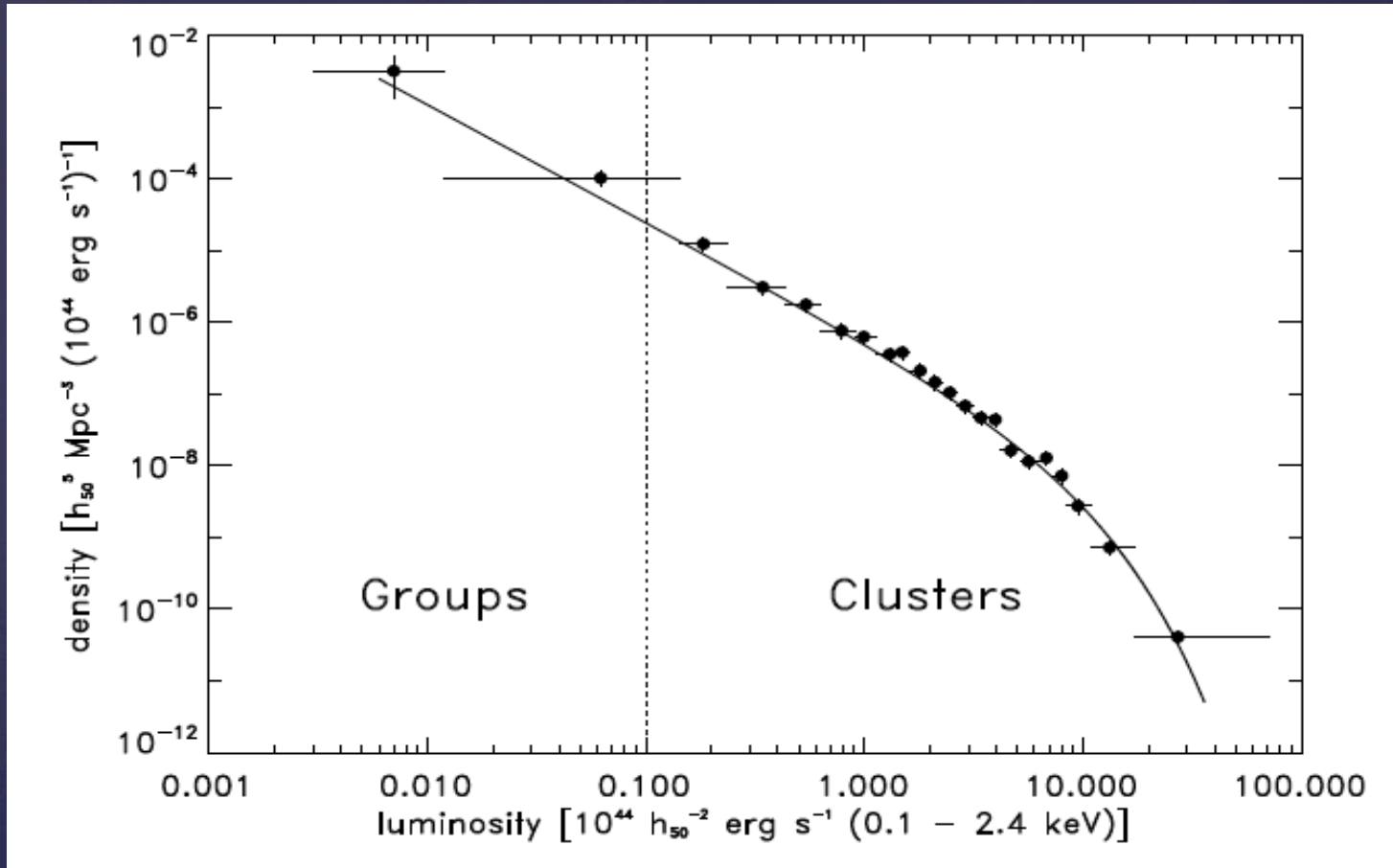Chon & Böhringer, 2012

ESO 3.6m & NTT
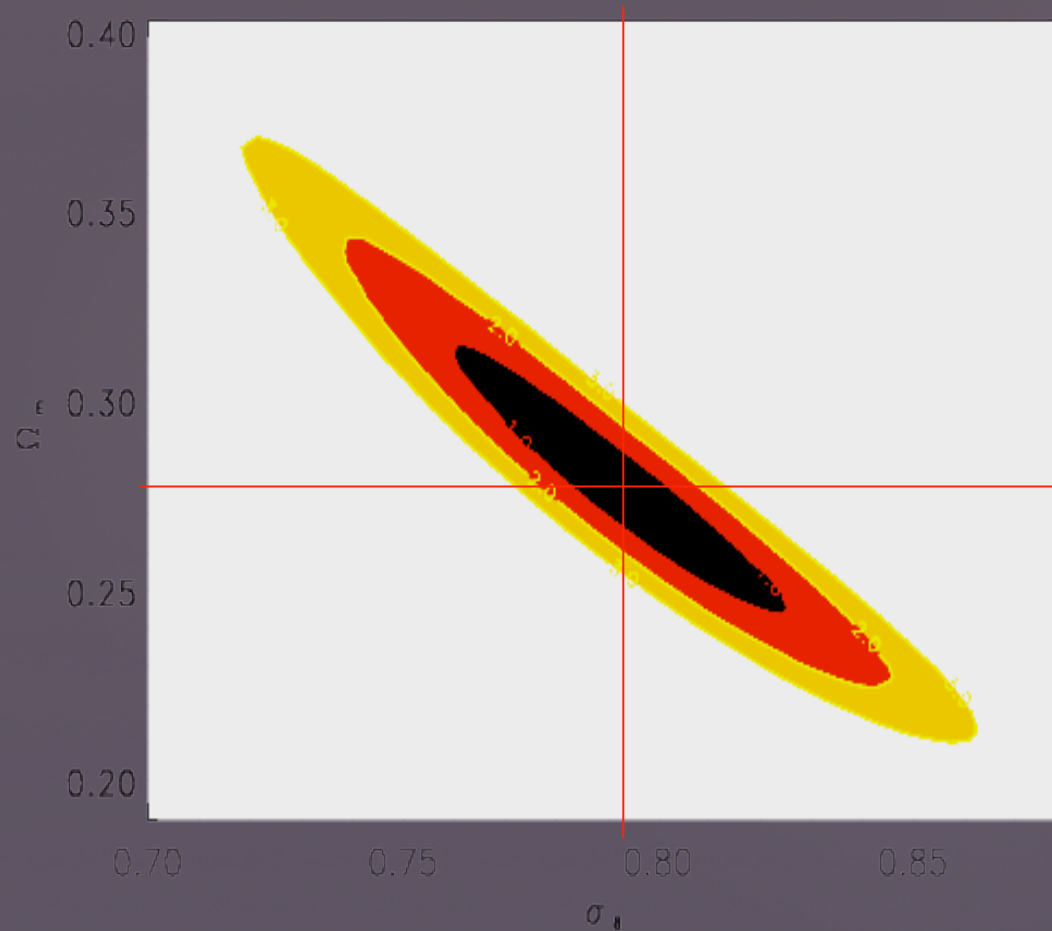
3D distribution of ROSAT clusters

Observed and predicted XLF

REFLEX I survey (Böhringer et al. 2002) : fit of prediction from a concordance model, $\Omega_m = 0.29$, $\sigma_8 = 0.79$ to the REFLEX XLF

Cosmological constraints from XLF
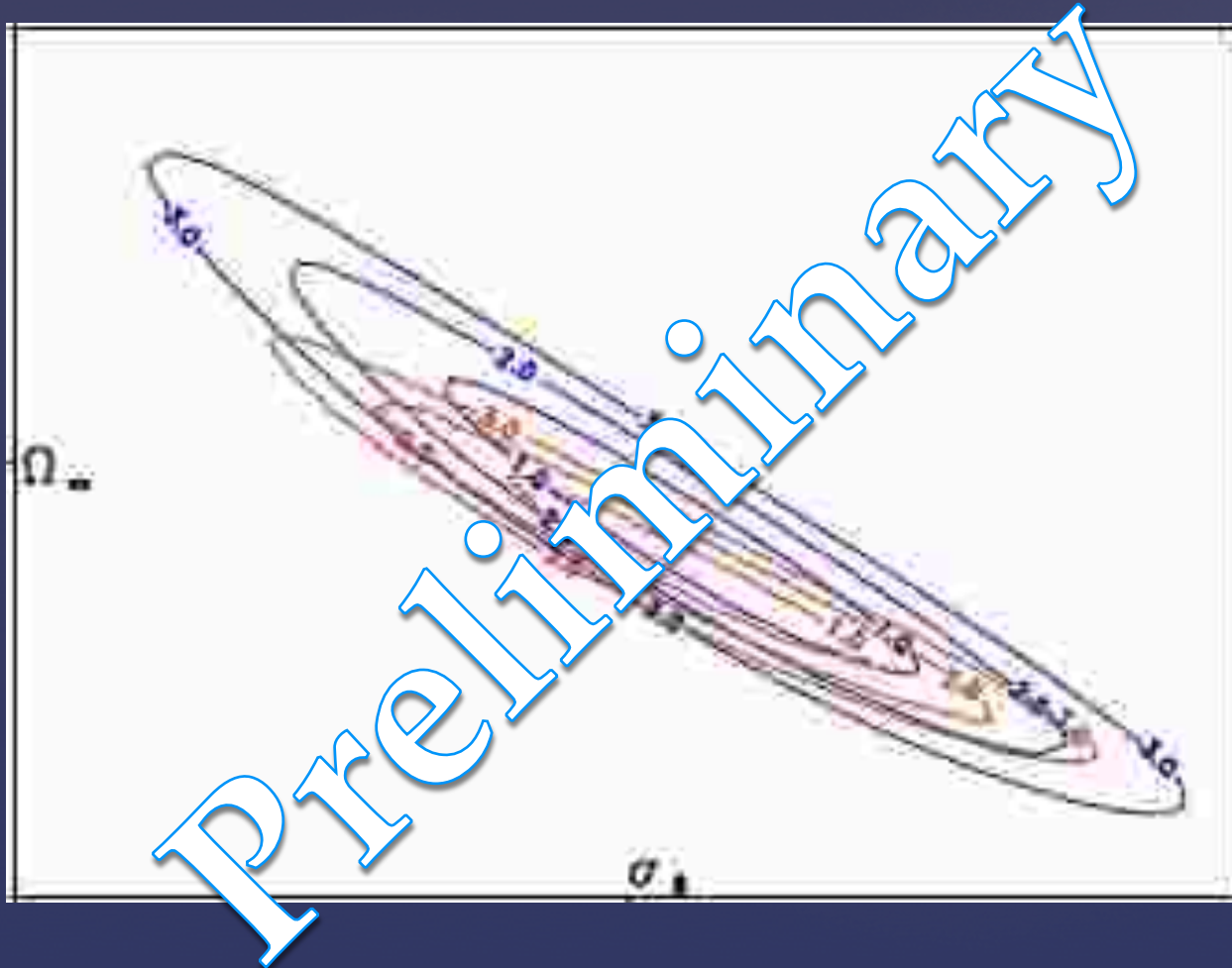

$\Omega_m = 0.28 +- 0.05$
$\sigma_8 = 0.79 +- 0.04$

statistical errors

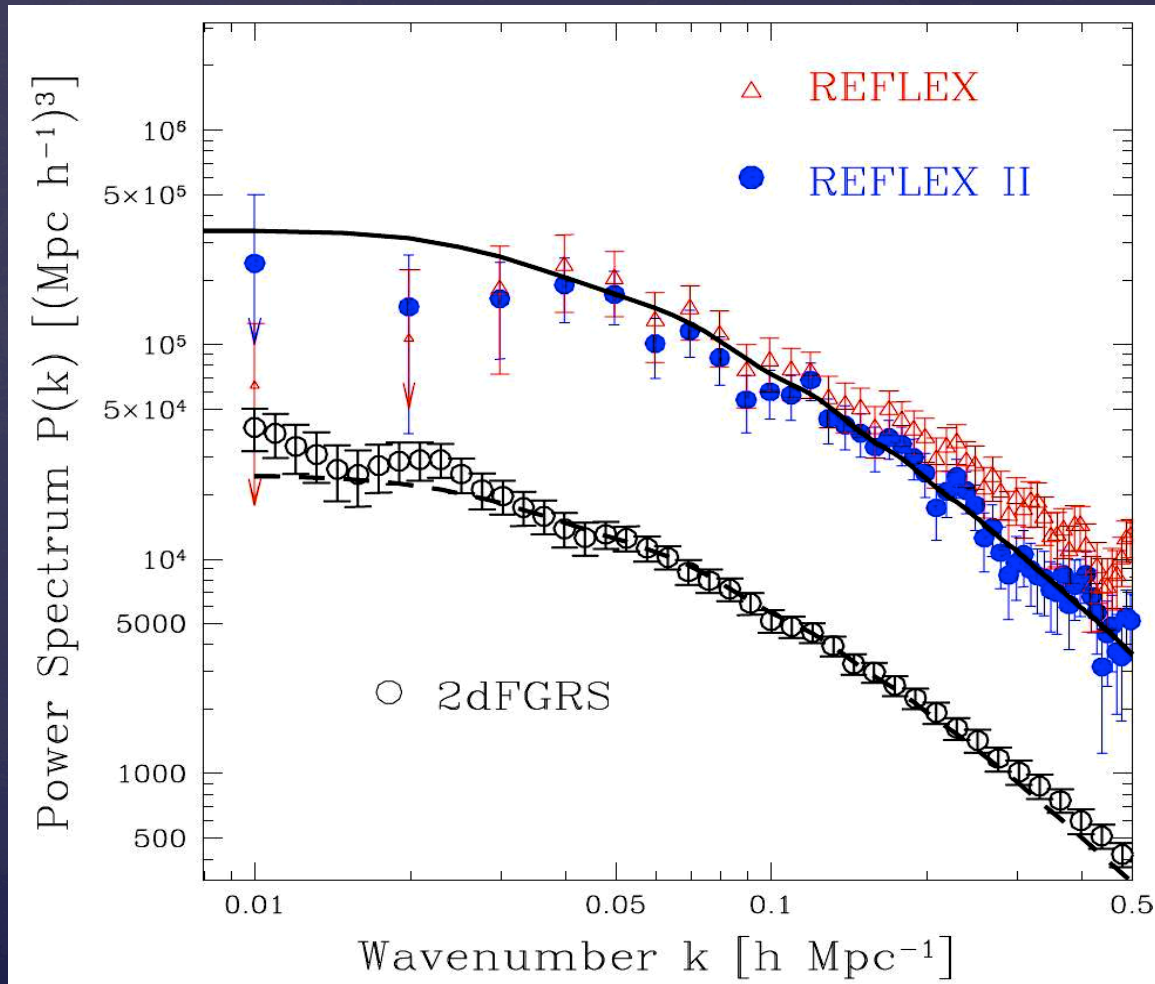+- 0.05 for
systematics

REFLEX I survey (Böhringer+ 2002, 2010)

Improvement of statistical uncertainties of constraints from REFLEX I to REFLEX II

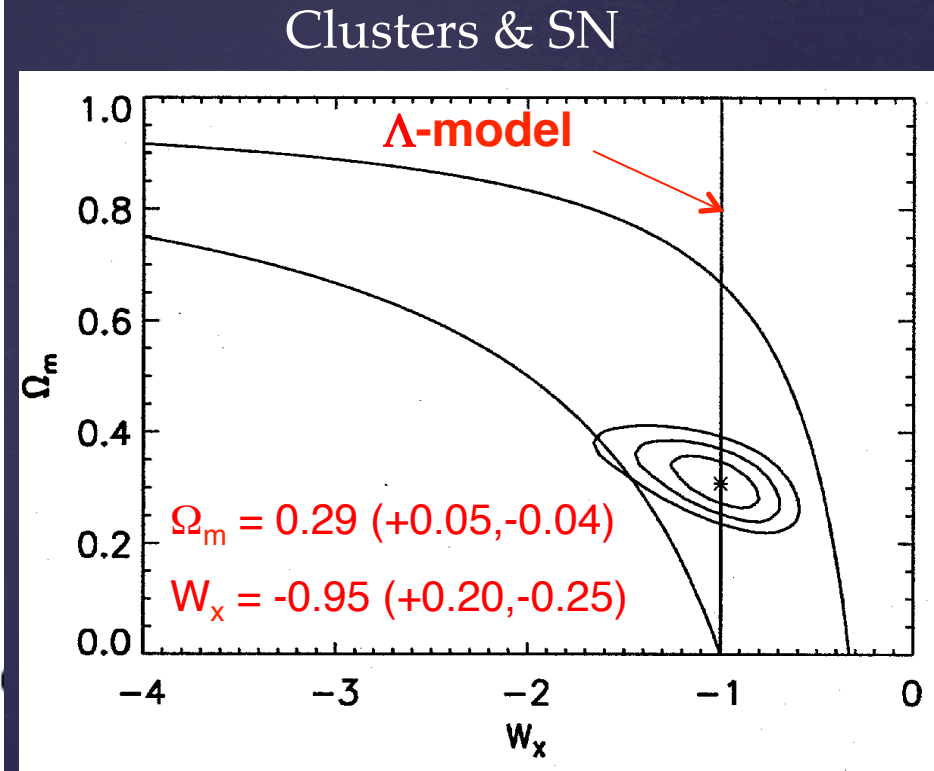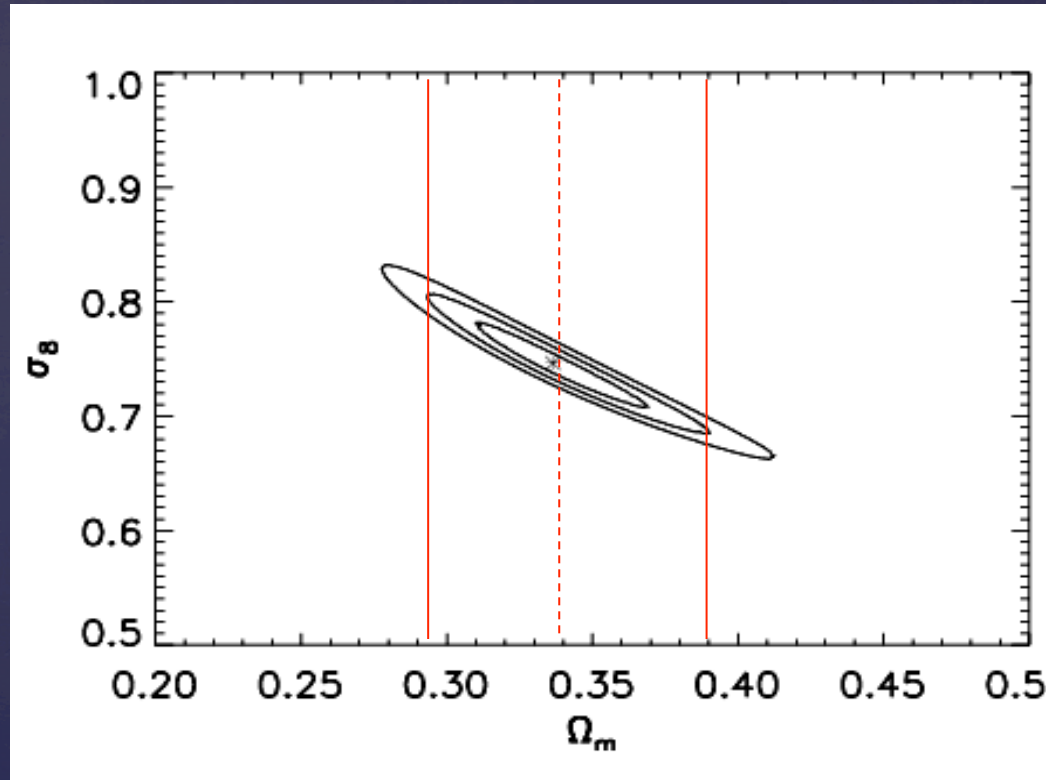Böhringer, Chon +
in prep.

REFLEX II power spectrum (ΛCDM)

Flat ΛCDM,
 Ω_m=0.25, h =0.7, w= -1

Balaguera-Antolinez+ 2010

Cosmological constraints from REFLEX abundance and P(k)

Clusters & SN

Λ-model

$\Omega_m = 0.29$ (+0.05,-0.04)

$W_x = -0.95$ (+0.20,-0.25)
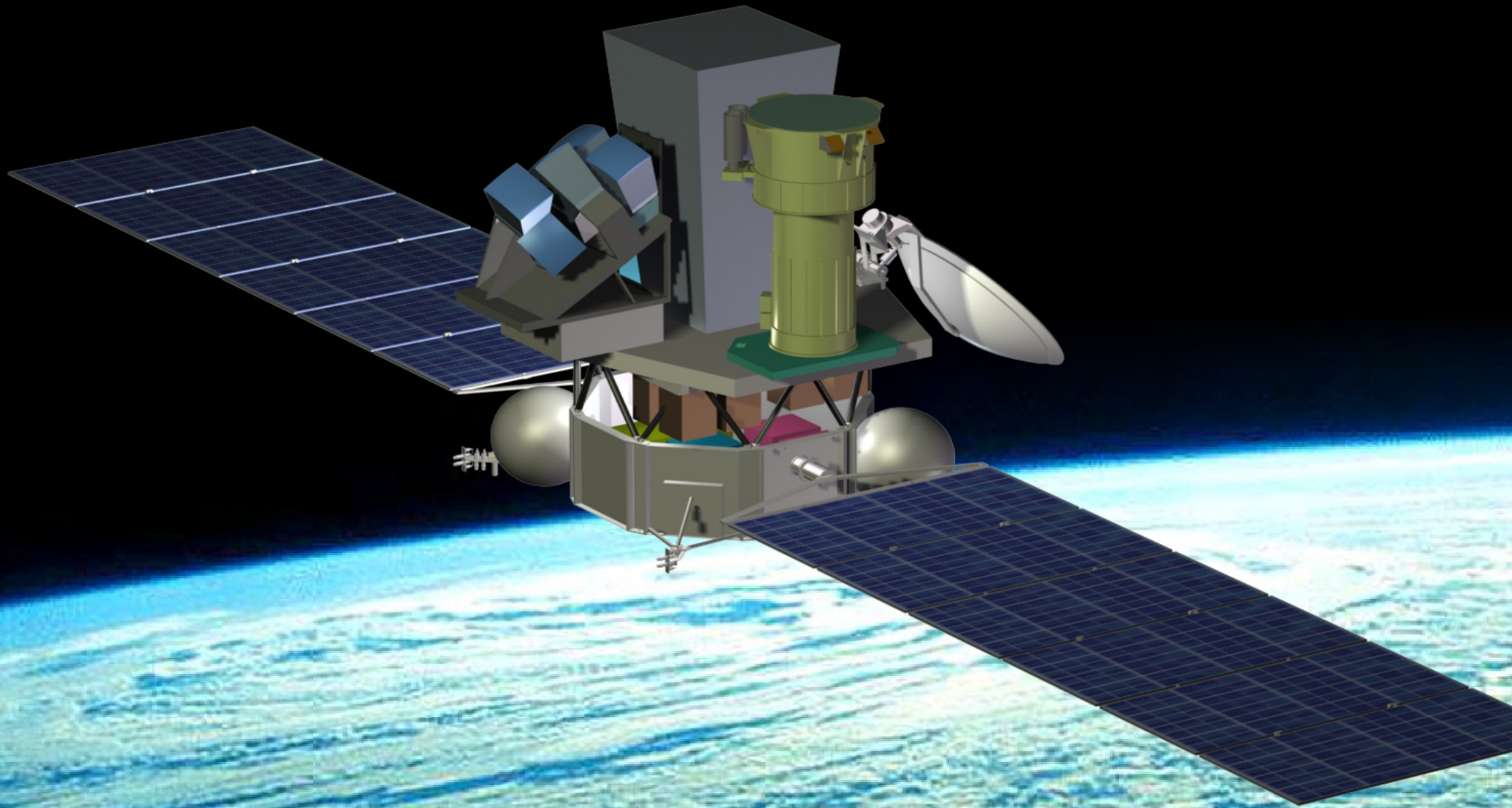
$\Delta\Omega_m$ ~ 0.34 +-0.05   (+-0.05)

Schuecker+ 2002, 03a,b

Prospects of *e*ROSITA mission

[extended Roentgen Survey with an Imaging Telescope Array]

Science goals for *e*ROSITA survey

- **Clusters of galaxies and cosmology**
- Active Galactic Nuclei (AGN) – 3 million sources
- Physics of galactic X-ray source populations
- Stellar mass compact objects
- Active stars
- Diffuse X-ray emission
- Solar system
- Variable X-ray sources
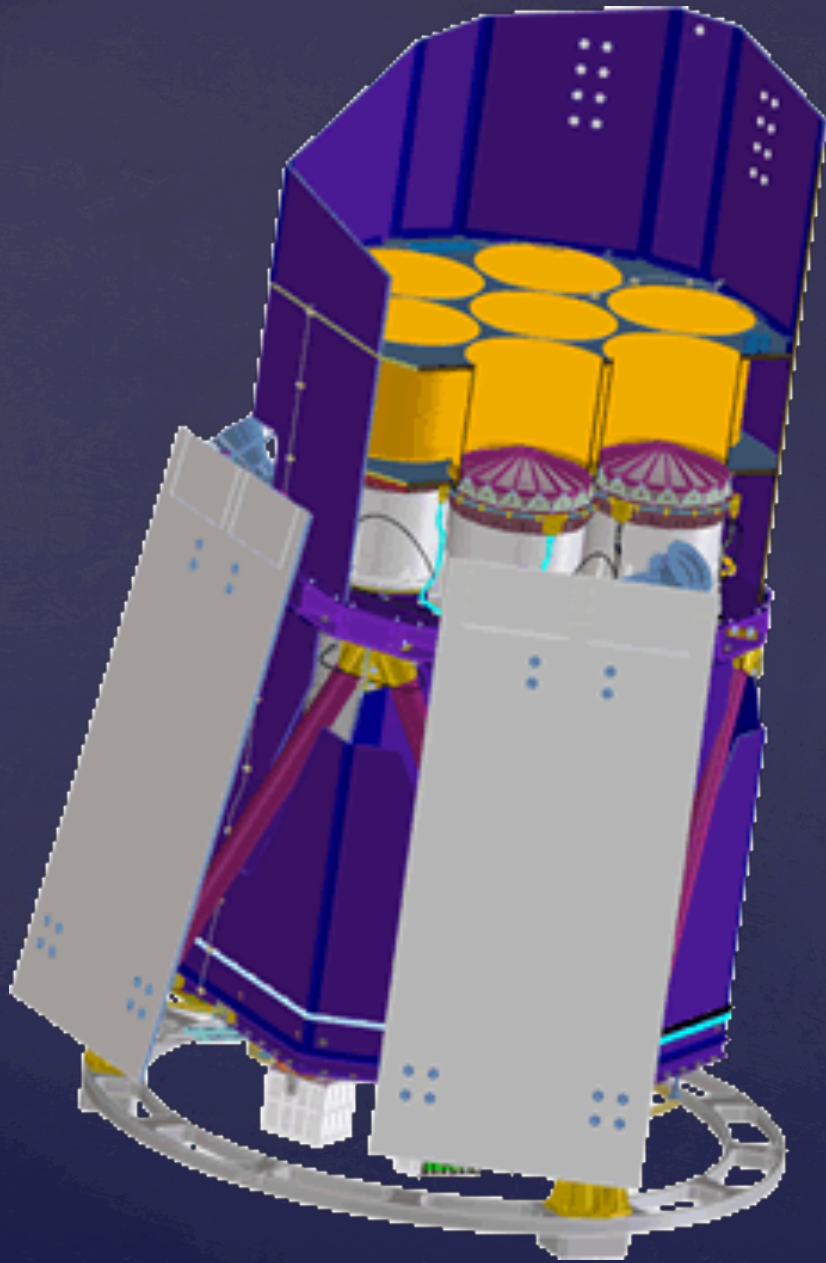
*e*ROSITA telescope

Focal length 1.6m

Field of View 1°Ø

7 identical mirror modules

54 nested mirror shells

Energy range 0.3-10 keV

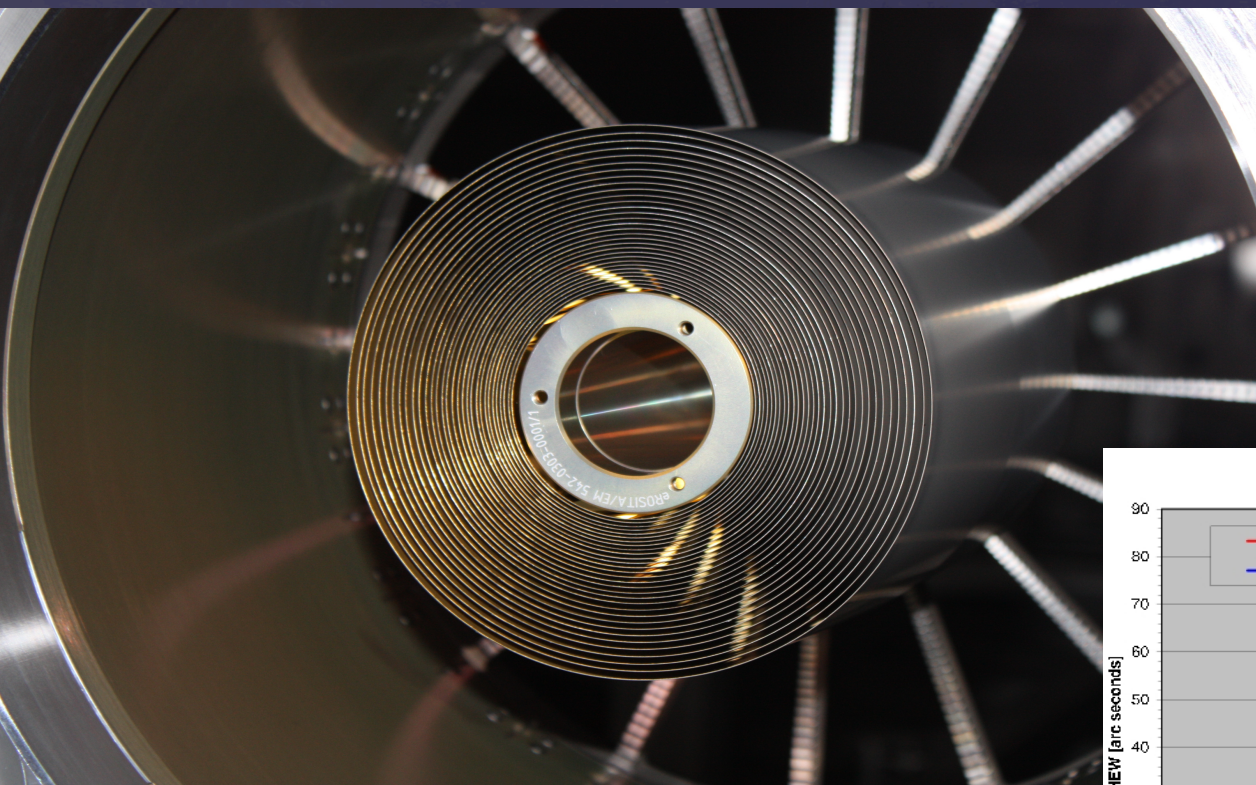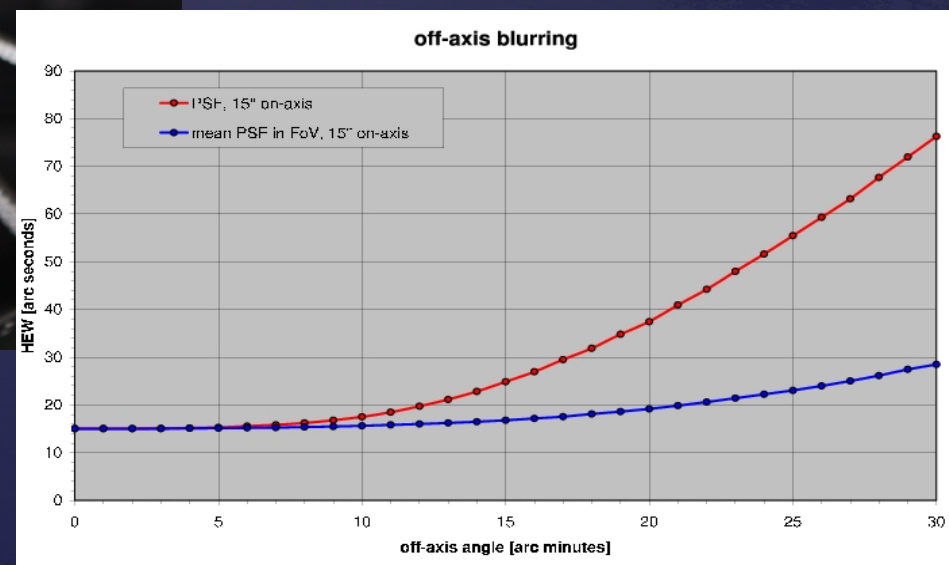Resolution 138 eV @ 6 keV

Dimensions 3.2m x 1.9m Ø

Weight 750 kg
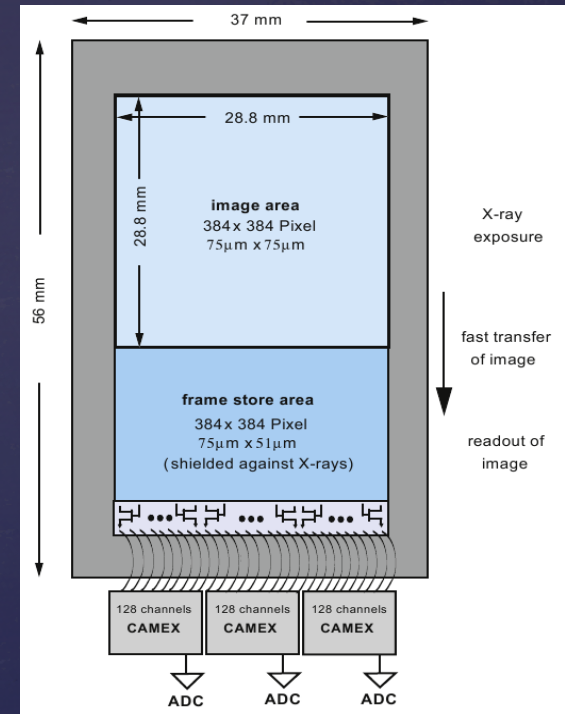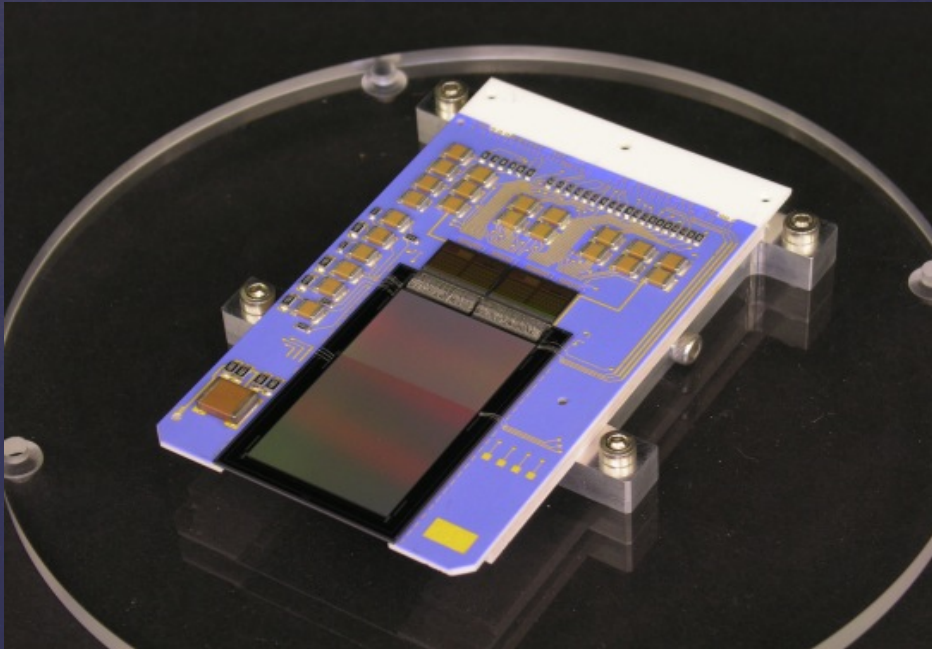
*e*ROSITA mirror module

16 arcsec on-axis,
28 arcsec on average
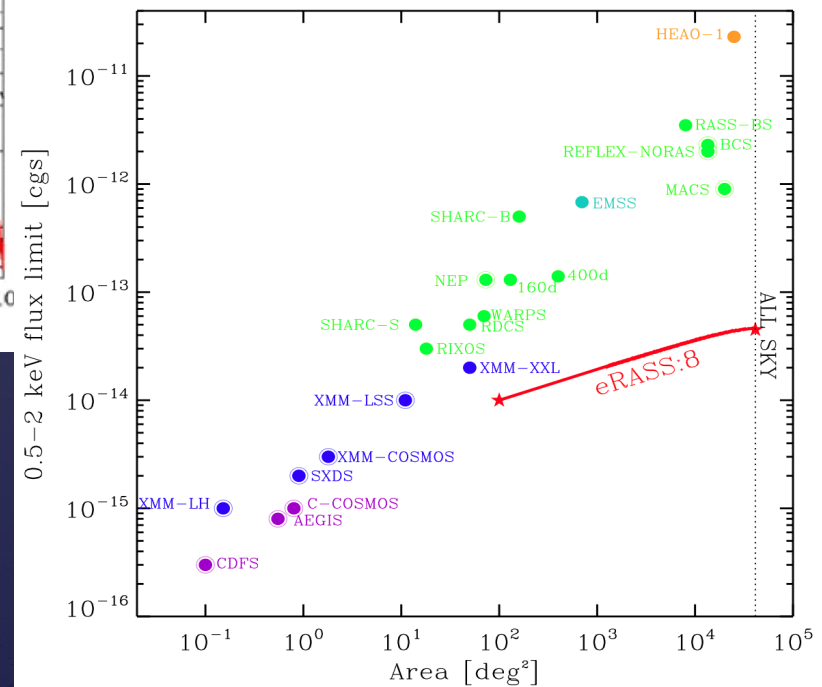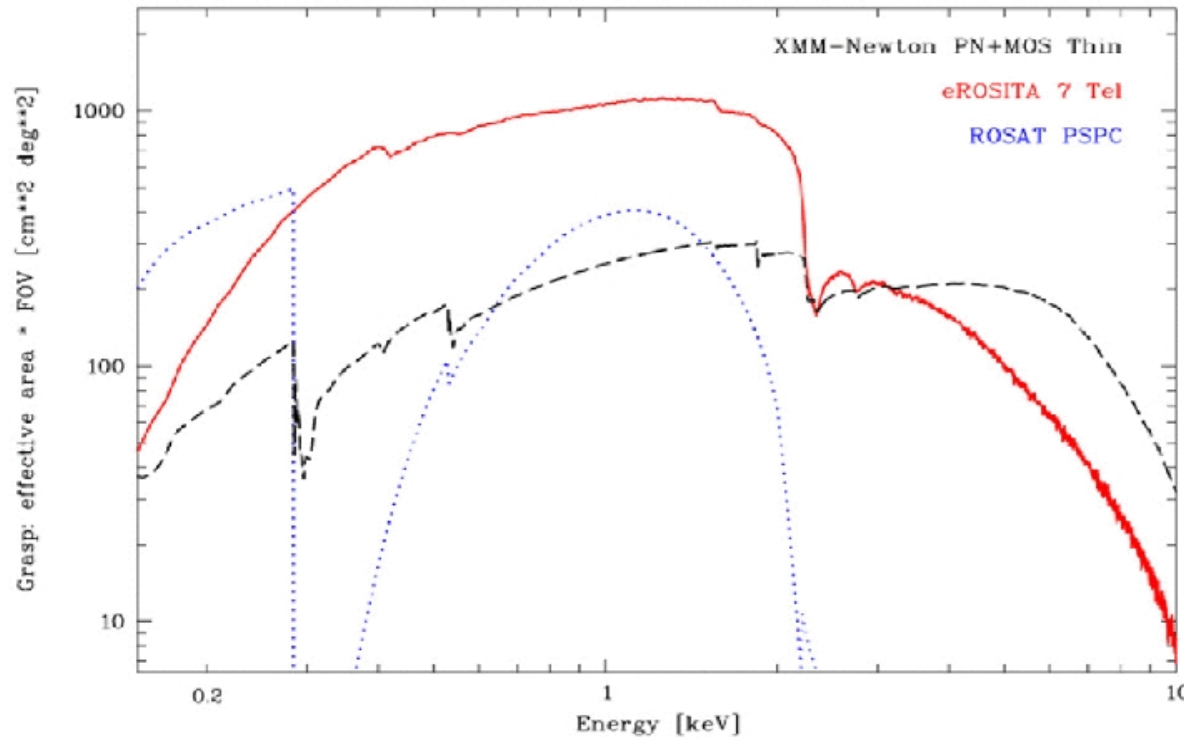
*e*ROSITA detector system

X-ray CCD with 384 x 384 pixels   (FoV 1.03°)
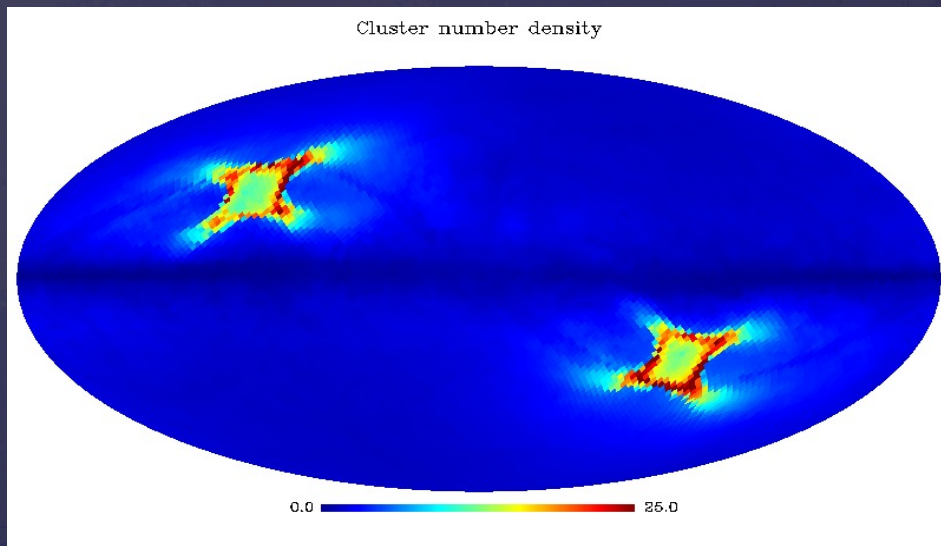
Pixelsize 75 μm x 75 μm   (9.6'' x 9.6'')

Integration time 50 ms (shift time to storage 100 μsec)

*e*ROSITA performance and cluster detectability
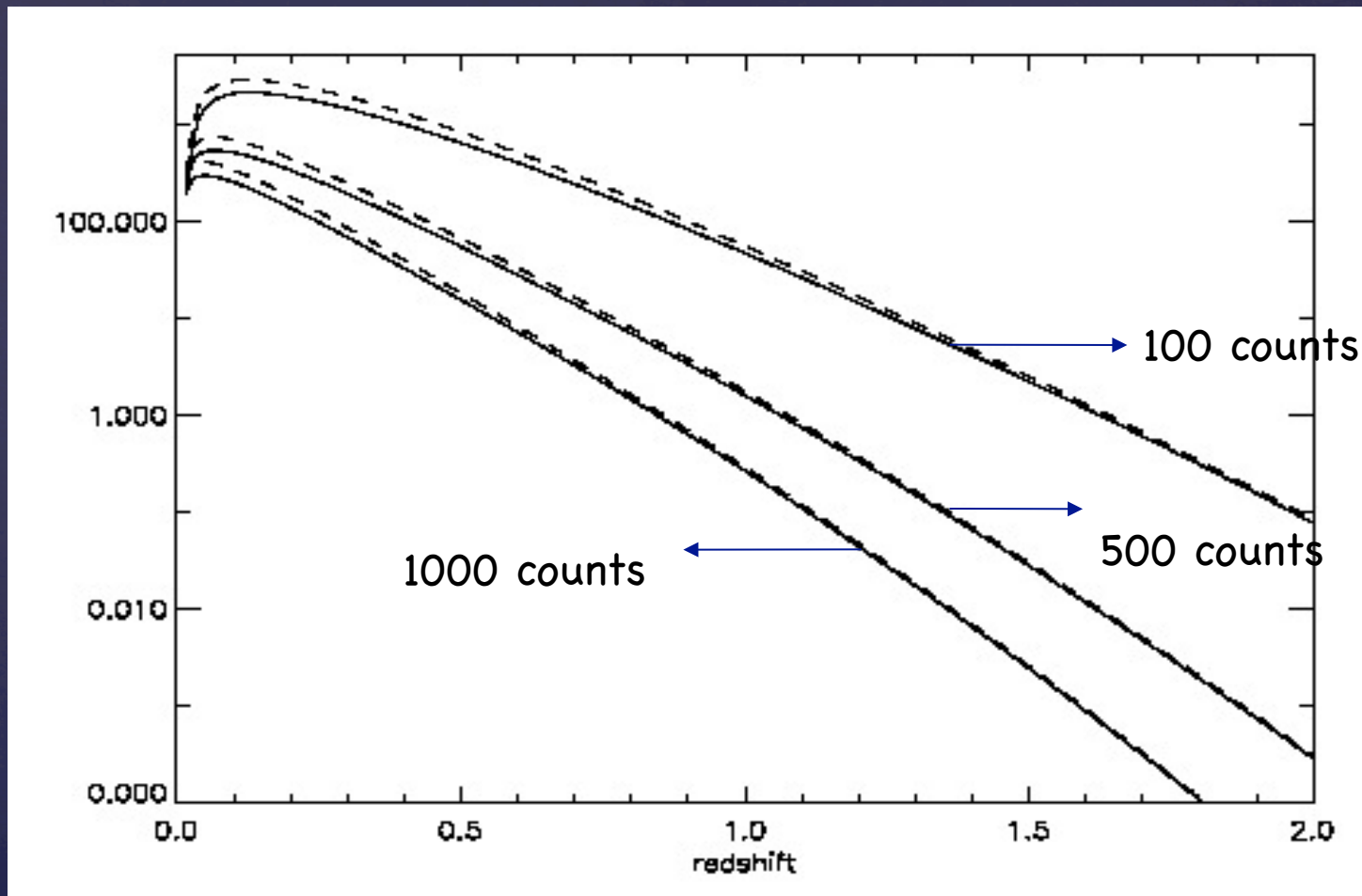
Cluster number counts in *e*ROSITA survey

Photon counts	All sky	Ext. Gal
100	111000	83200
500	18700	14100
1000	8300	6300

	Number count
>0.3	31000
>0.6	7100
>0.8	2330
>1.0	770

Böhringer+ in prep

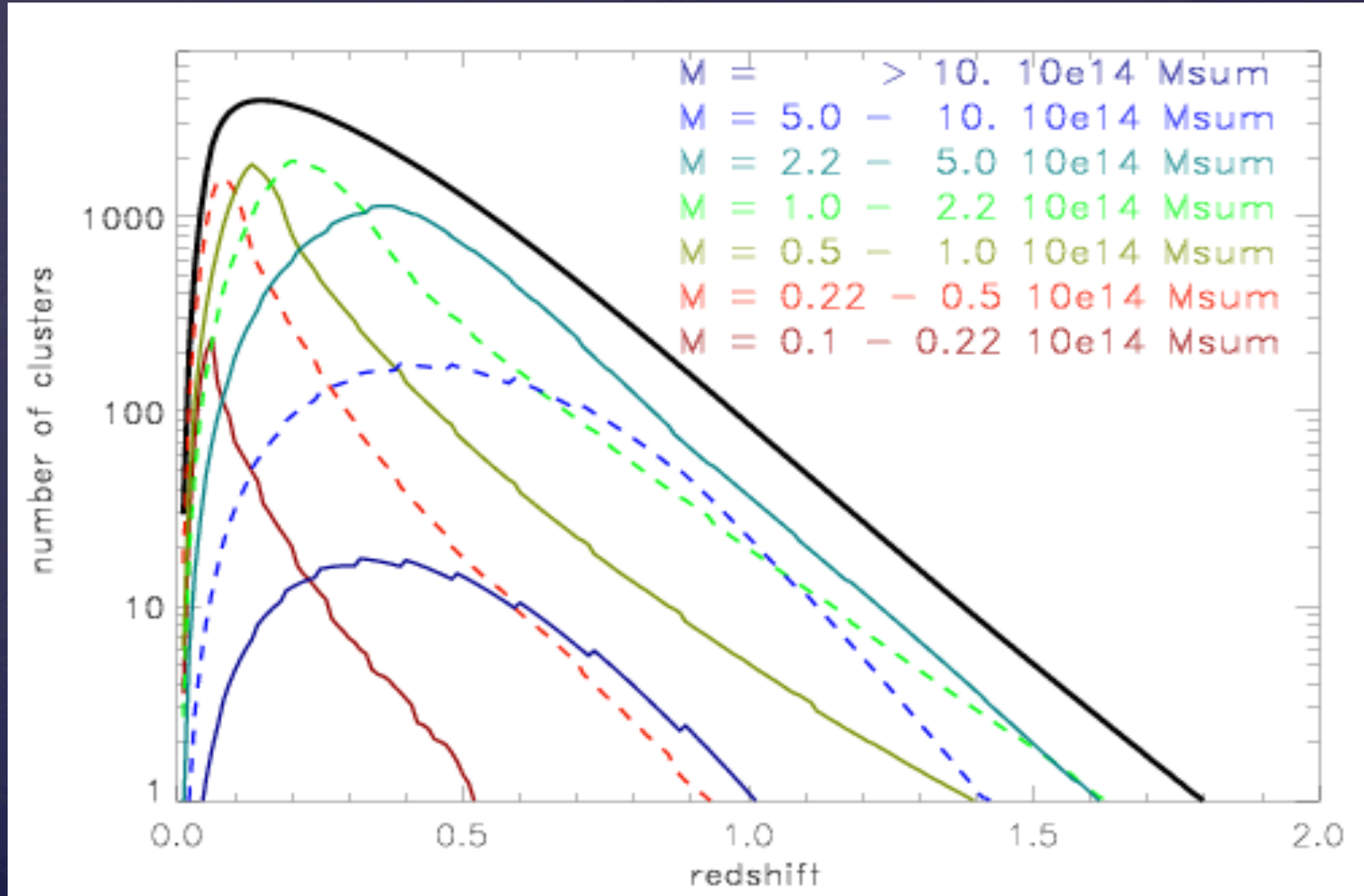# Cluster number counts in *e*ROSITA survey

Chon, Böhringer, 2012
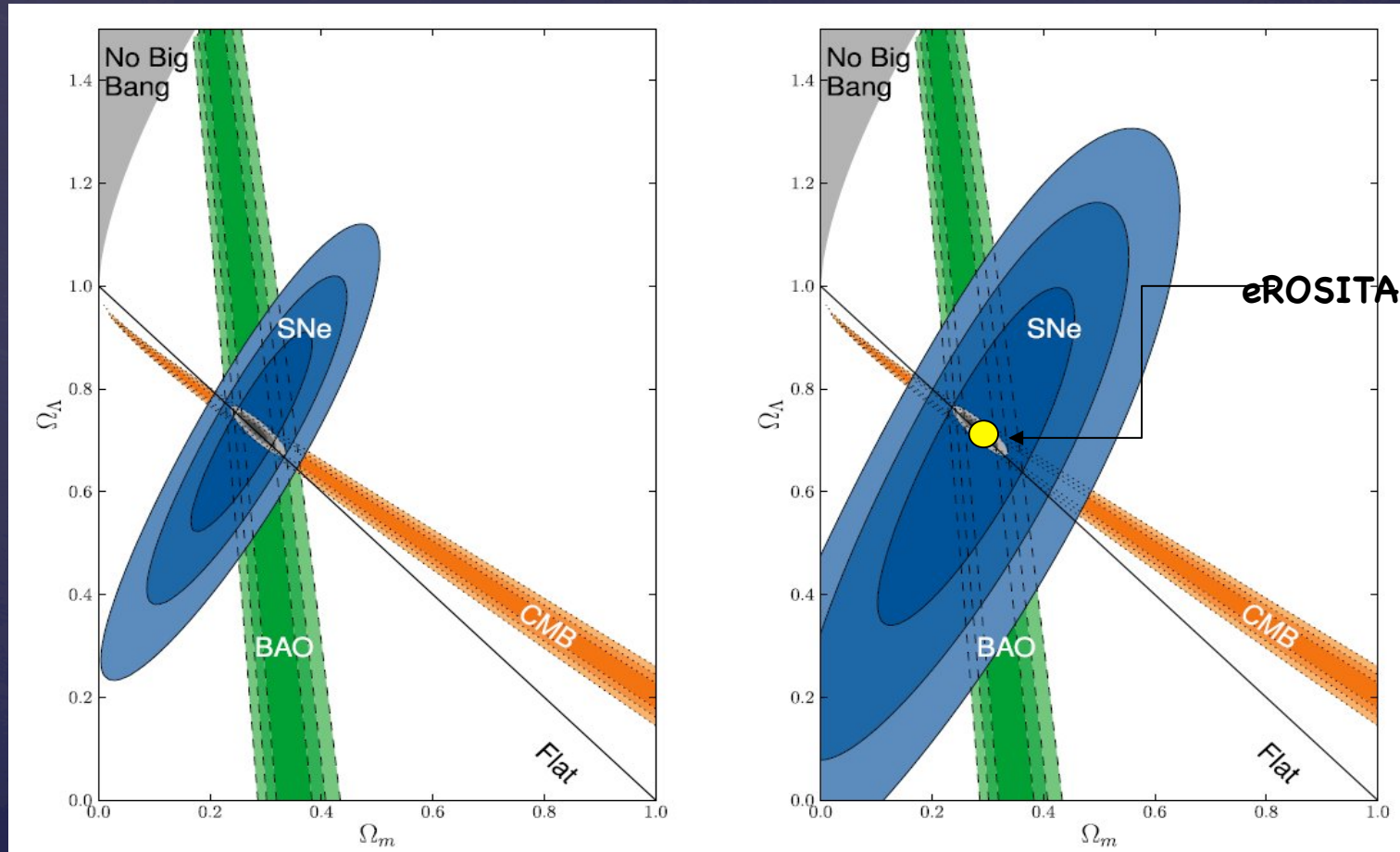
*e*ROSITA cluster mass and redshift distrubtion

Constraints from *e*ROSITA and more
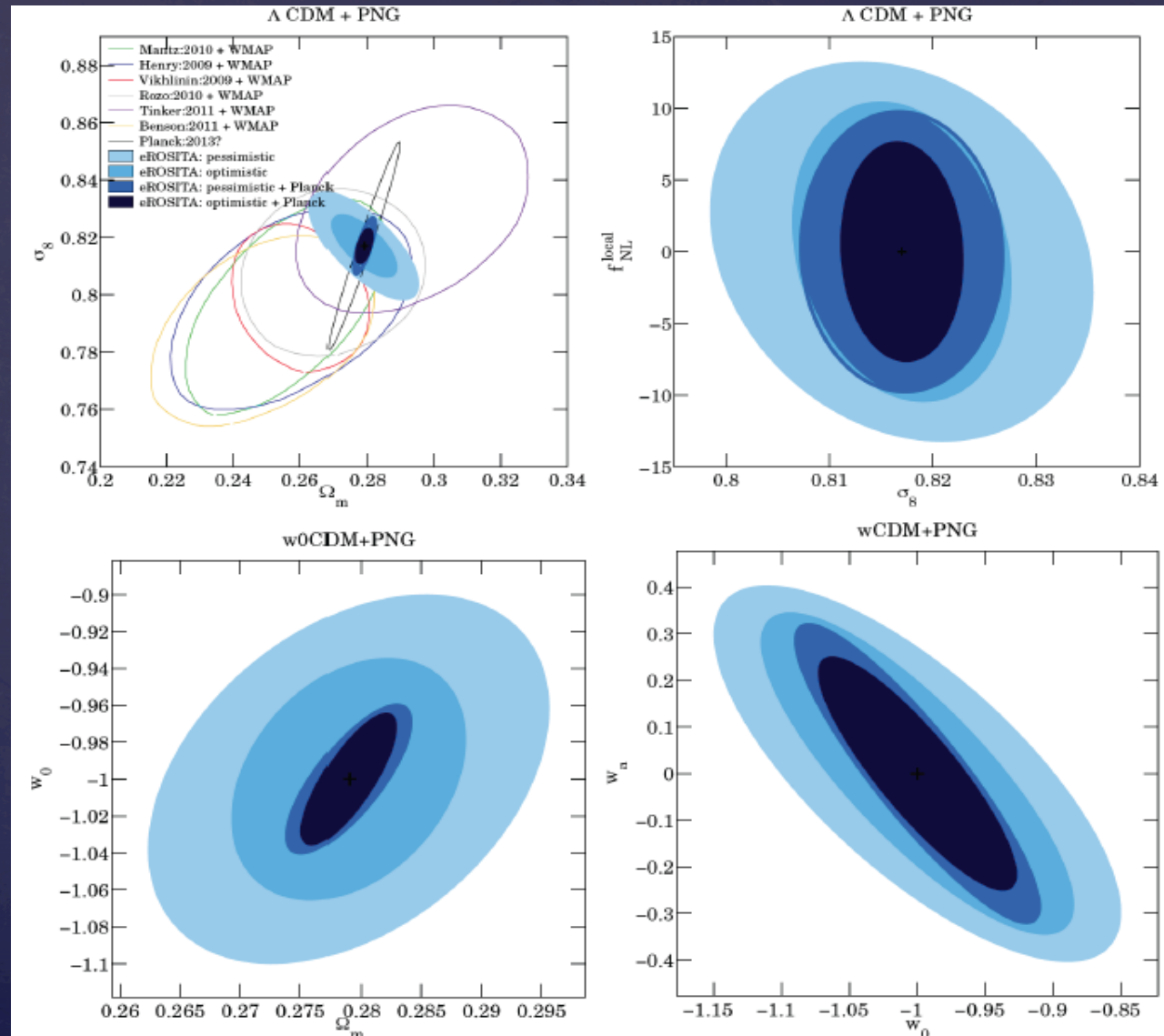
*e*ROSITA white book

Cosmological constraints after *e*ROSITA

Suzuki+ 2011

Conclusion

Present:
- Clusters probe cosmological model in several ways -- we have shown that it works well, complementing other probes.
- Strong support that the assumed structure formation model is correct.

Next 10 – 20 Years:
- Cosmological constraints should become better by more than an order of magnitude, due to:

    *e*ROSITA !

    *e*ROSITA follow-up -- Ground based optical/NIR Sky surveys.
    4MOST, EUCLID (gravitational lensing by clusters + redshifts)

    Other sky surveys – DES, Pan-Starrs, Euclid, SkyMapper etc.