Development of Flux-Color-Apparent Size method as new X-ray cluster cosmology test

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DE LA RECHERCHE À L'INDUSTRIE

cea

Milano

Bachelor studies in Physics
Università degli studi Milano-bicocca (2006-2010)
“The primordial nucleo-sinthesis”
Precision cosmology and 7Li data
G. La Vacca, A. Valotti, S. A. Bonometto

Master Studies in Astrophysics
Università degli studi Milano-bicocca (2010-2012)
“Measure of galaxy clustering from big radio sample in 21 cm line”
Advisor L.Guzzo

Plan of the talk

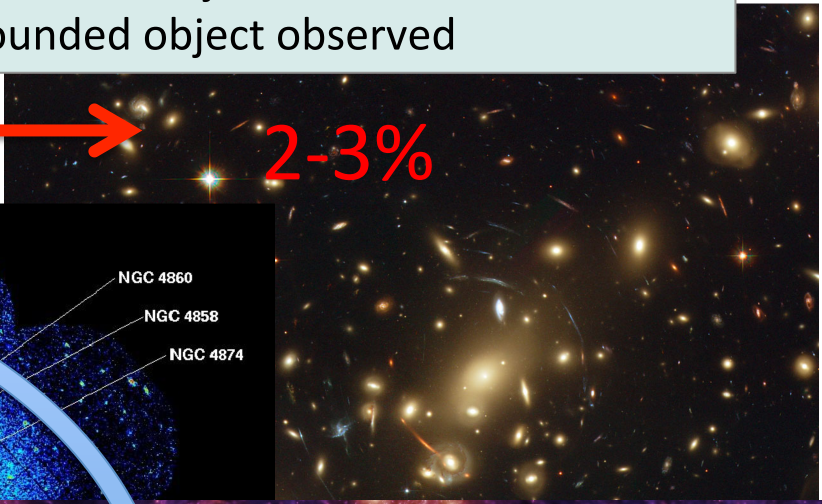
1. What is a cluster
2. Cosmology with clusters
3. The flux-color-apparent size diagram
4. Some practical issues
5. Results

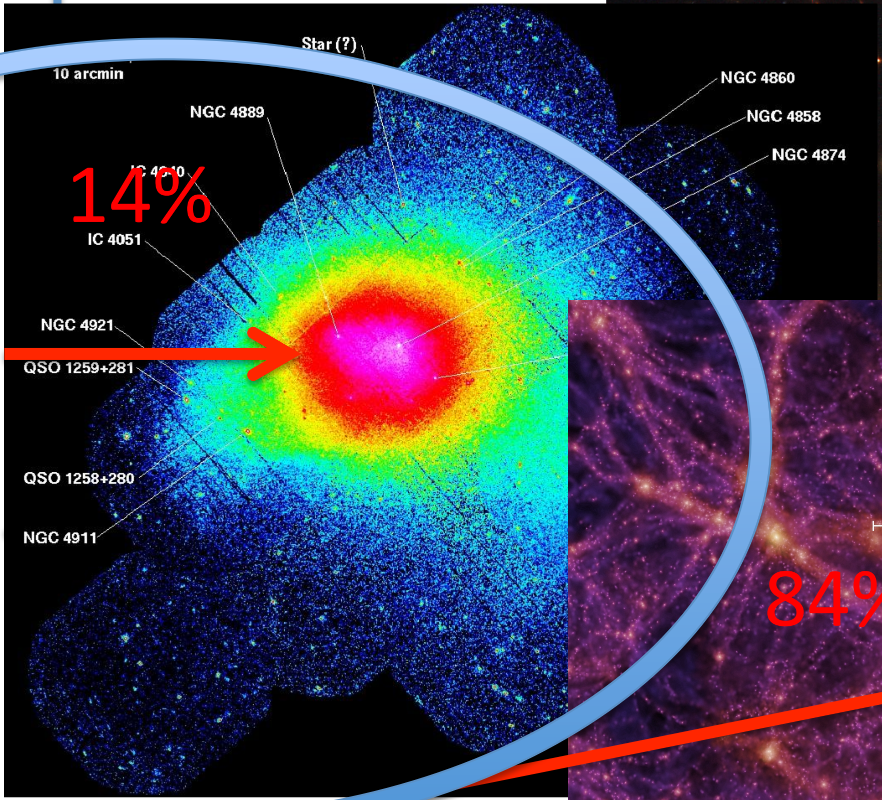
1. What is a cluster

Galaxies cluster

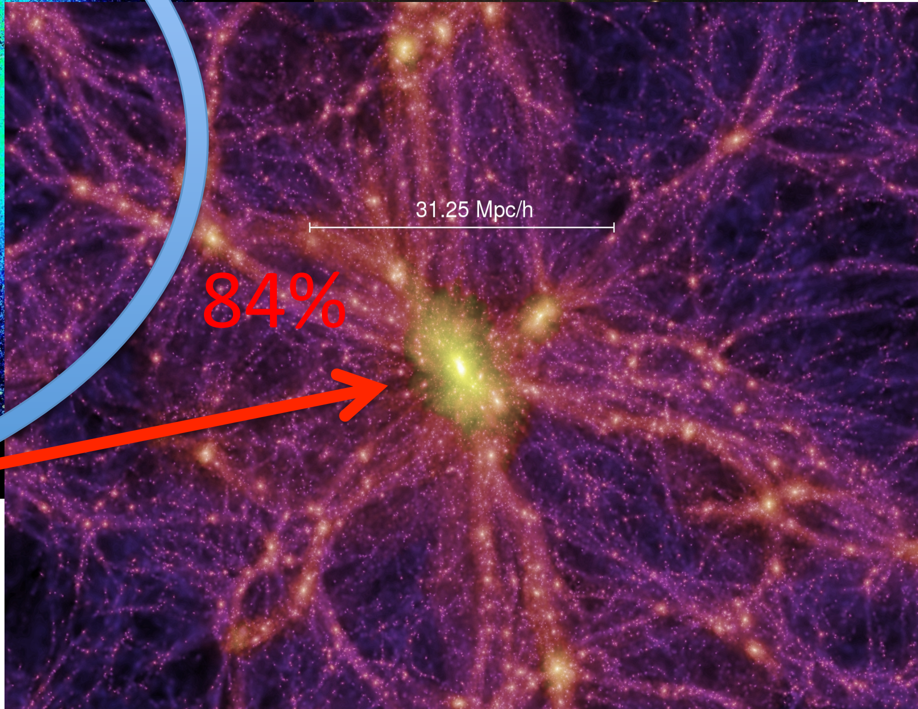
- Clusters = Multi components objects
- Most massive gravitational bounded object observed

Galaxy (optical)
Stellar emission





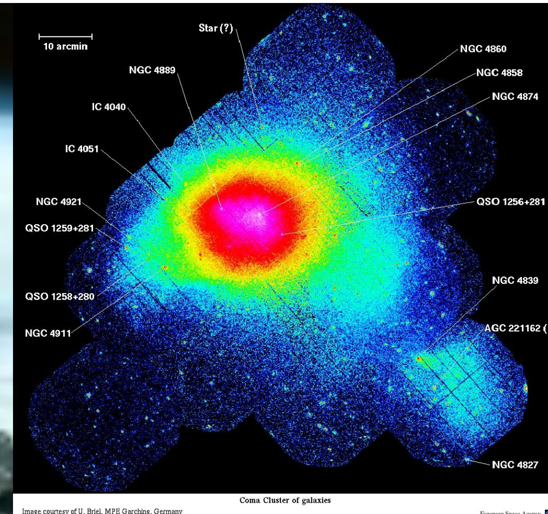
Hot gas (X-ray)
Thermal
Bremsstrahlung
emission

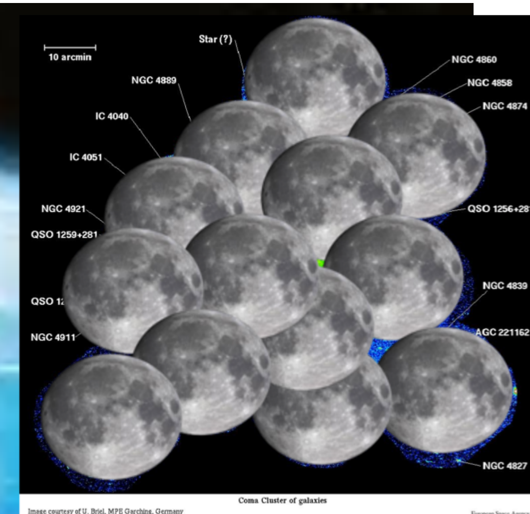


Dark matter(?)
No observed emission

X-ray cluster with XMM

Launched in 1999





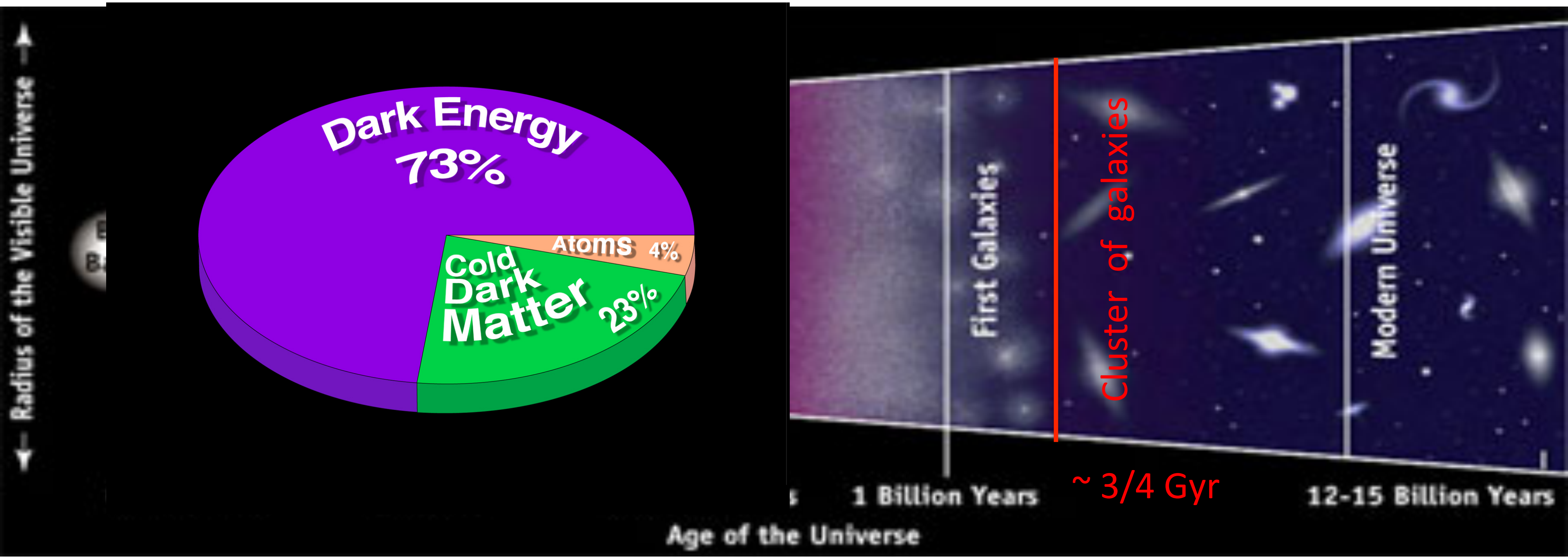
Work range [0.1 -12] keV

Best response [0.5-2] keV

Angular aperture 30 arcmin

2. Cosmology with clusters

Vocabulary

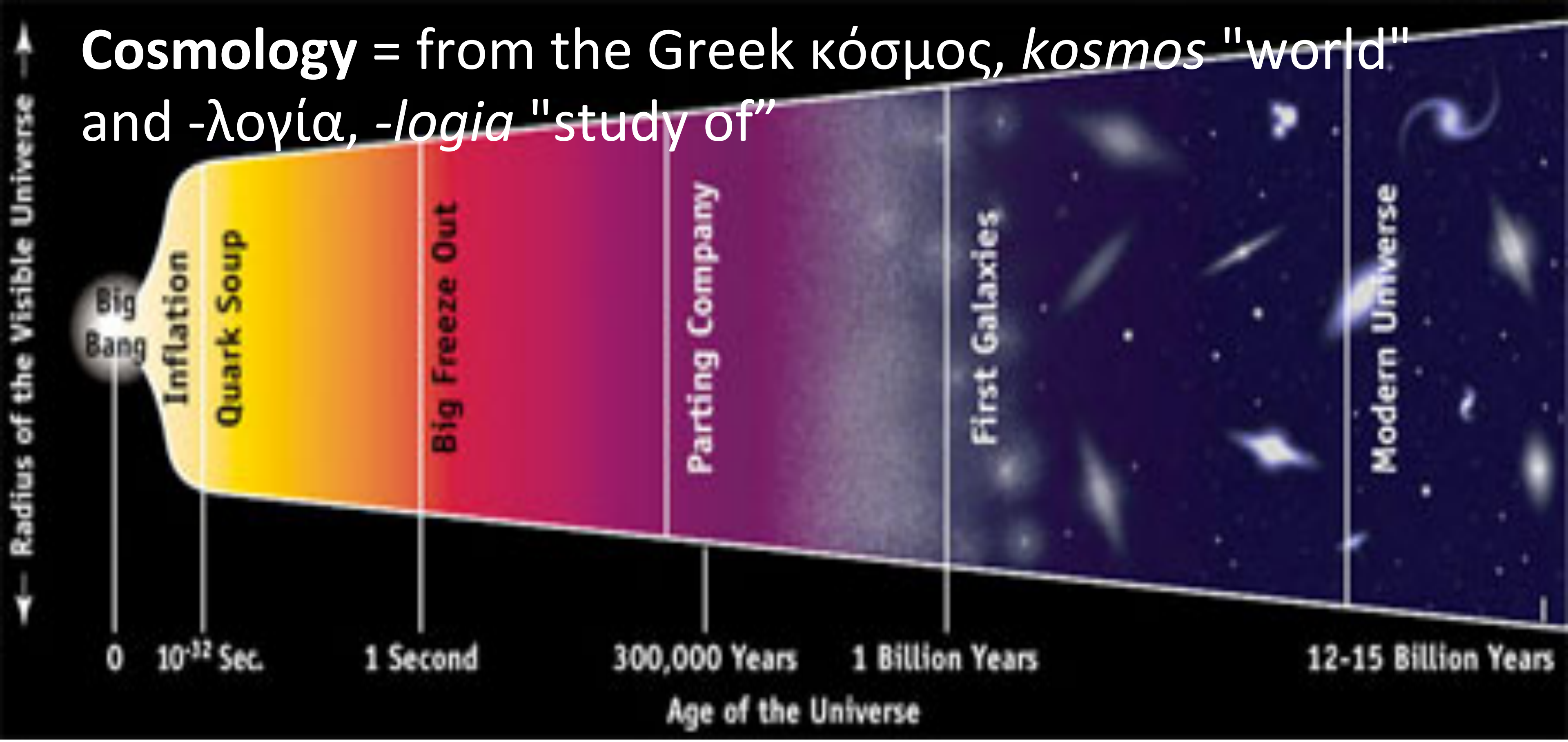


Redshifts (z) = it is the shift of the galaxy spectrum toward the red, due their recession velocities. To convert redshift into distances, we need a cosmological model **(IF WE WANT TO KNOW DISTANCES WE NEED SPECTRA OF OBJECTS)**

d_a = angular diameter distance. Allows us to convert apparent (angular) sizes into real sizes (is cosmology dependent)

w_0 = equation of state for DE.

Cosmology = from the Greek κόσμος, *kosmos* "world" and -λογία, *-logia* "study of"



$$H^2(z) = H_0^2\left(\Omega_M(1+z)^3 + \Omega_{de}(1+z)^{3(1+w)}\right).$$

z (redshift) =

w = equation state parameter of DE (tell us if it has evolved or not)

Ω_x =

Why Cosmology with clusters?

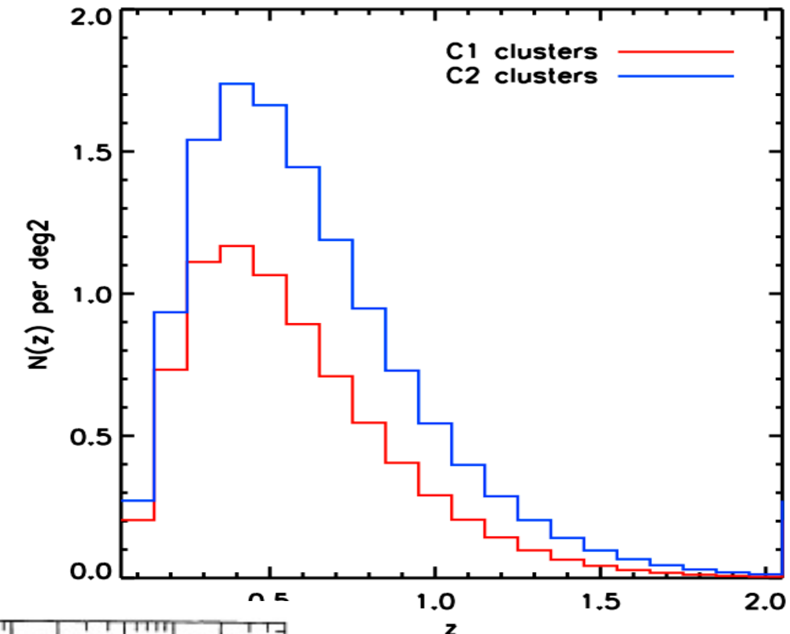
- Because are the most massive gravitational bounded structures in the Universe (~ $10^{13} – 10^{14}$ M_{sun})

- Hence they are particularly linked to the total matte of the Universe

Cosmology with clusters

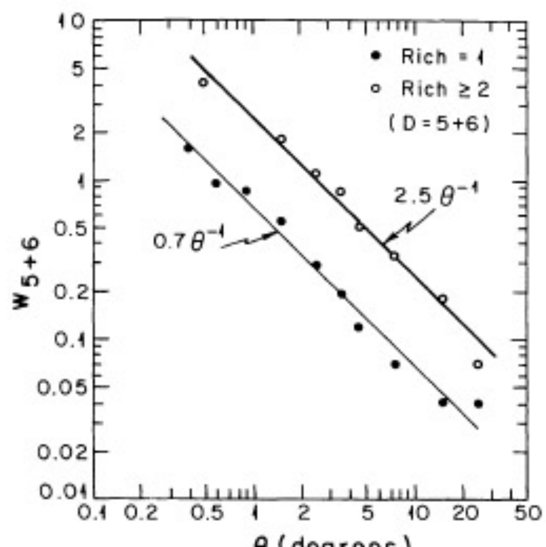
$f_{gas} = M_{gas}/M_{tot} \sim \Omega_b/\Omega_m$

needs high S/N



#count: dn/dz

Mass function: dn/dm/dz



Correlation function

Critical point: link theory and observables

“χ^2”

Bottom-up approach

Cosmology (ΛCDM,...)

$$\frac{dn}{dM\,dz\,d\Omega}$$

Estimated mass distribution

Selection effects M(z) ?

Scaling laws, HE...
➔ Individual masses

T_X, Mgas(r), Y_X, T_X(r)

+redshifts

X-ray observables:
Count-rates in given bands and errors
ICM spectrum

- Fiducial cosmology
- Mass distribution
- Selection function with a proxy *(Lx,T,flux,σ_v,Y...)*

key point → mass is cosmology dependent

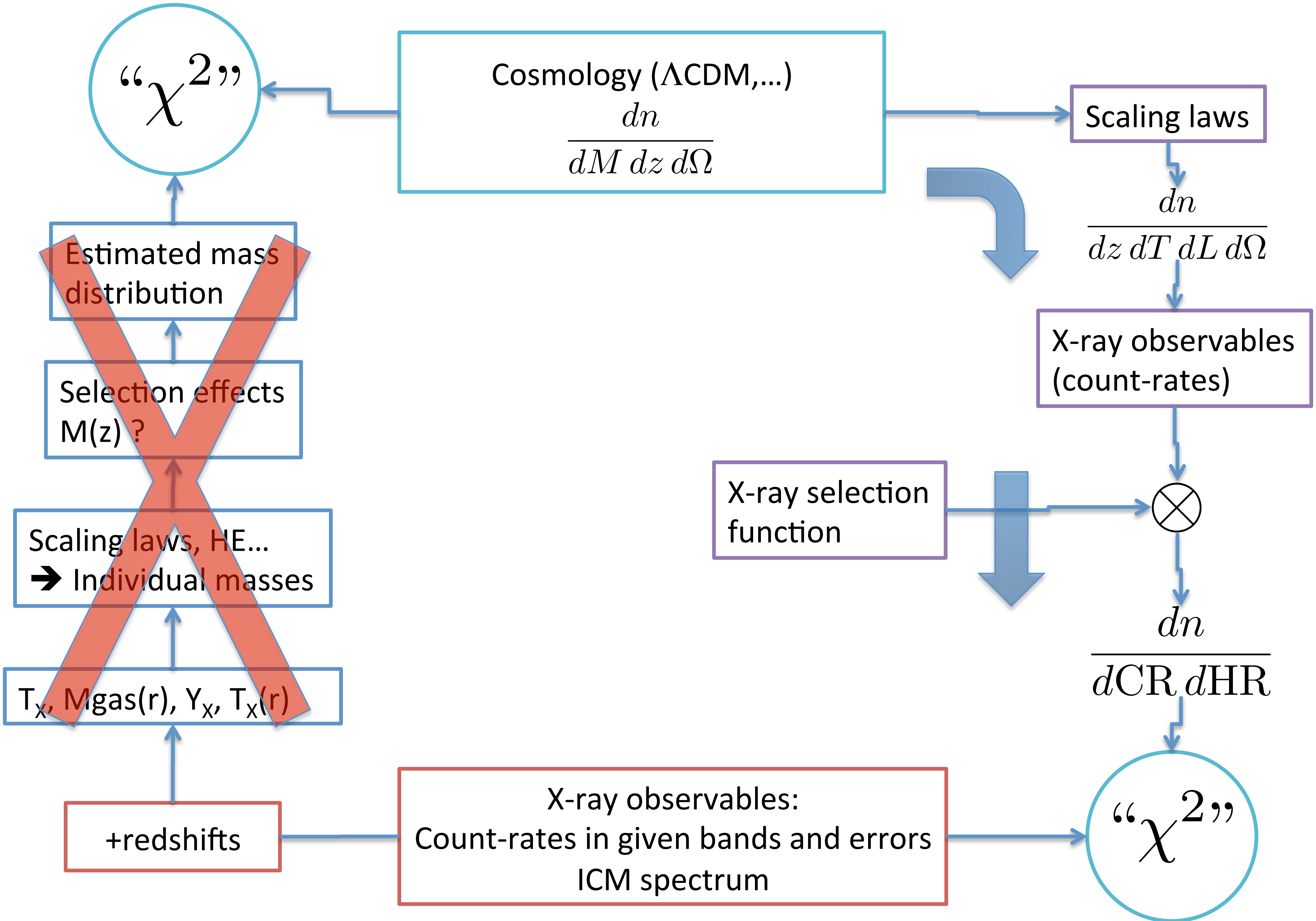
not univocal correspondence between proxies and Mass → *scatters*

Mass function

Standard way of doing cosmology with cluster

1. Requires redshifts
2. Masses are cosmological dependent
3. Are not directly observable
4. Long time computing

Switching to signals variables



Signal variable function

THE IDEA BEHIND

1. Create a semi-analytical simulation that reproduce cluster population in a observed instrumental quantities (like number of cluster observed for number of photons detected etc…)

2. Constraints together cluster physics and cosmology

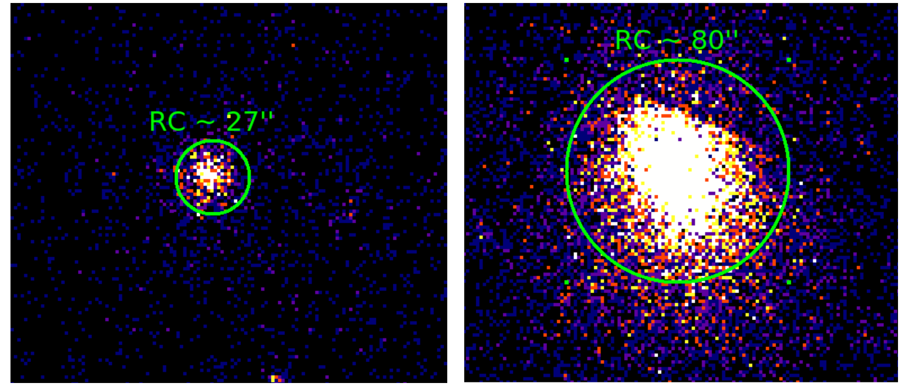
3.The flux-color-apparent size diagram

The signal variables

Rc [arcsec] ➔ Rc ~ d_a

~ apparent size Rc ~ M

Instrumental selection parameter



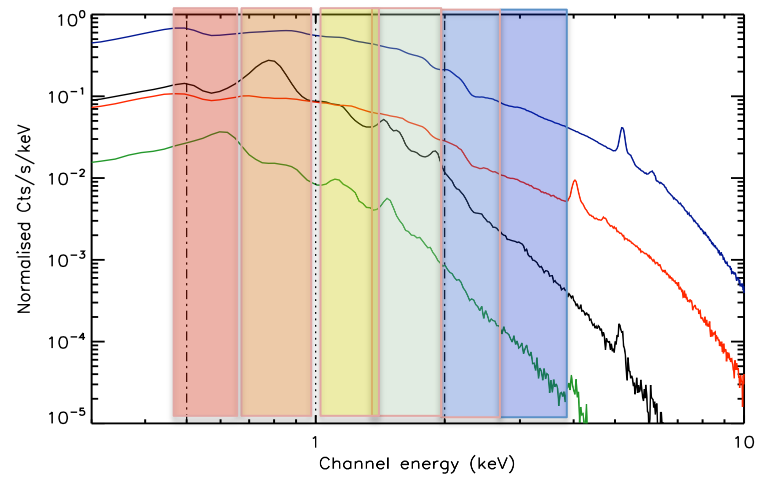
Clerc et al. 2012

HR= CR1/CR2

CR1 in [1-2] keV

CR2 in [0.5-1] keV

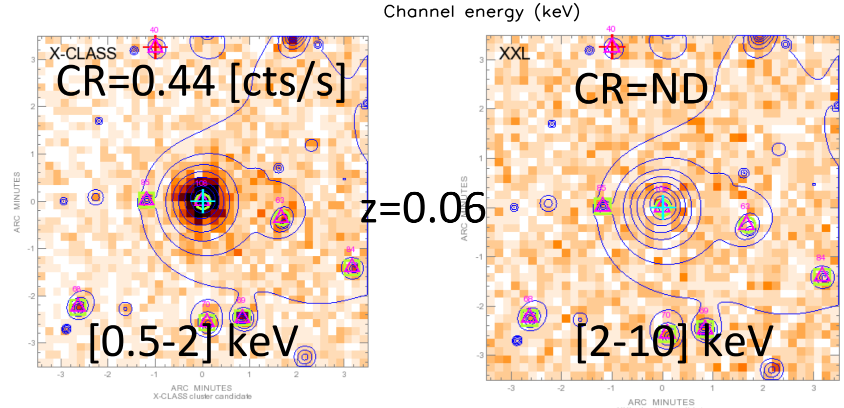
~ colour



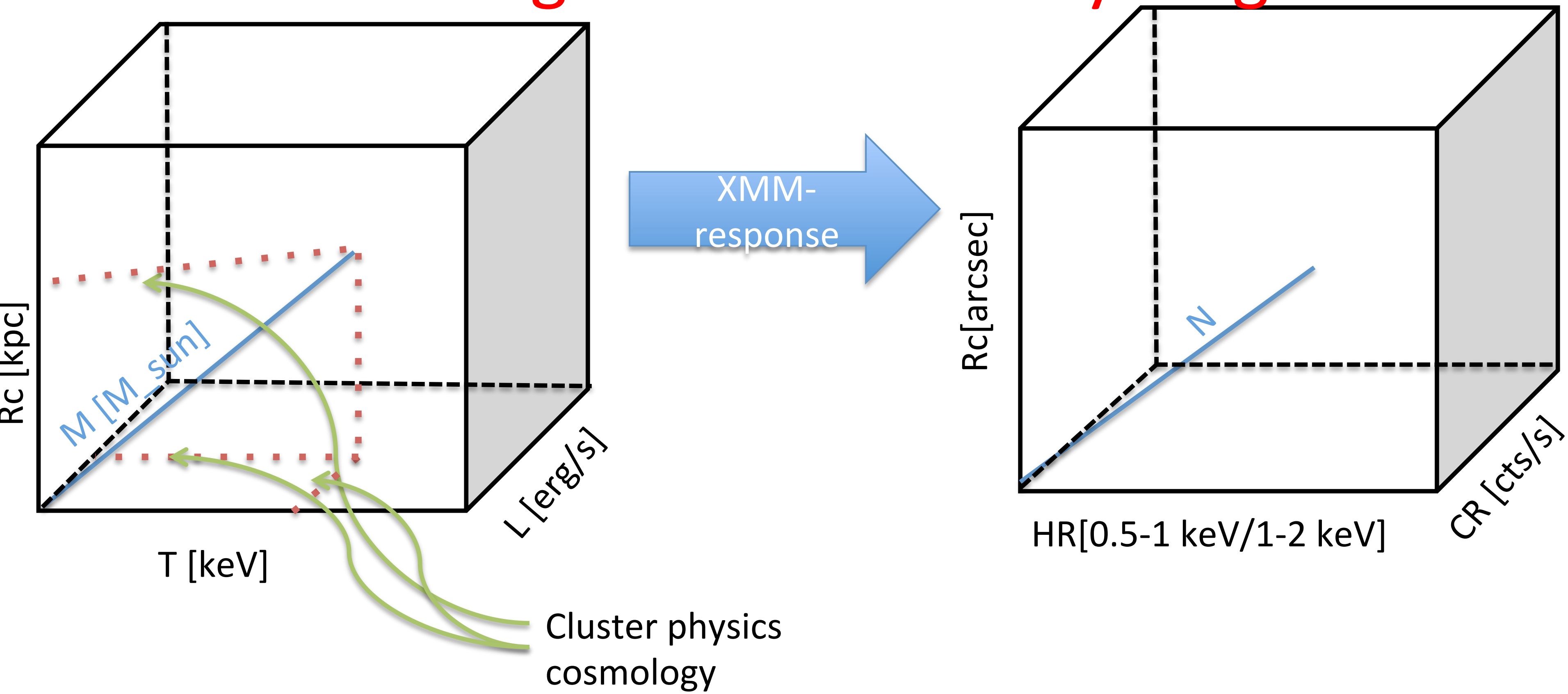
CR in [0.5-2.0] keV

~ flux

Instrumental selection parameter



CR-HR-Rc clusters distribution:
A color-magnitude-size X-Ray diagram



REAL UNIVERSE

INSTRUMENTAL PARAMETER SPACE

CR-HR-Rc cluster distribution:
A color-magnitude-size X-Ray diagram

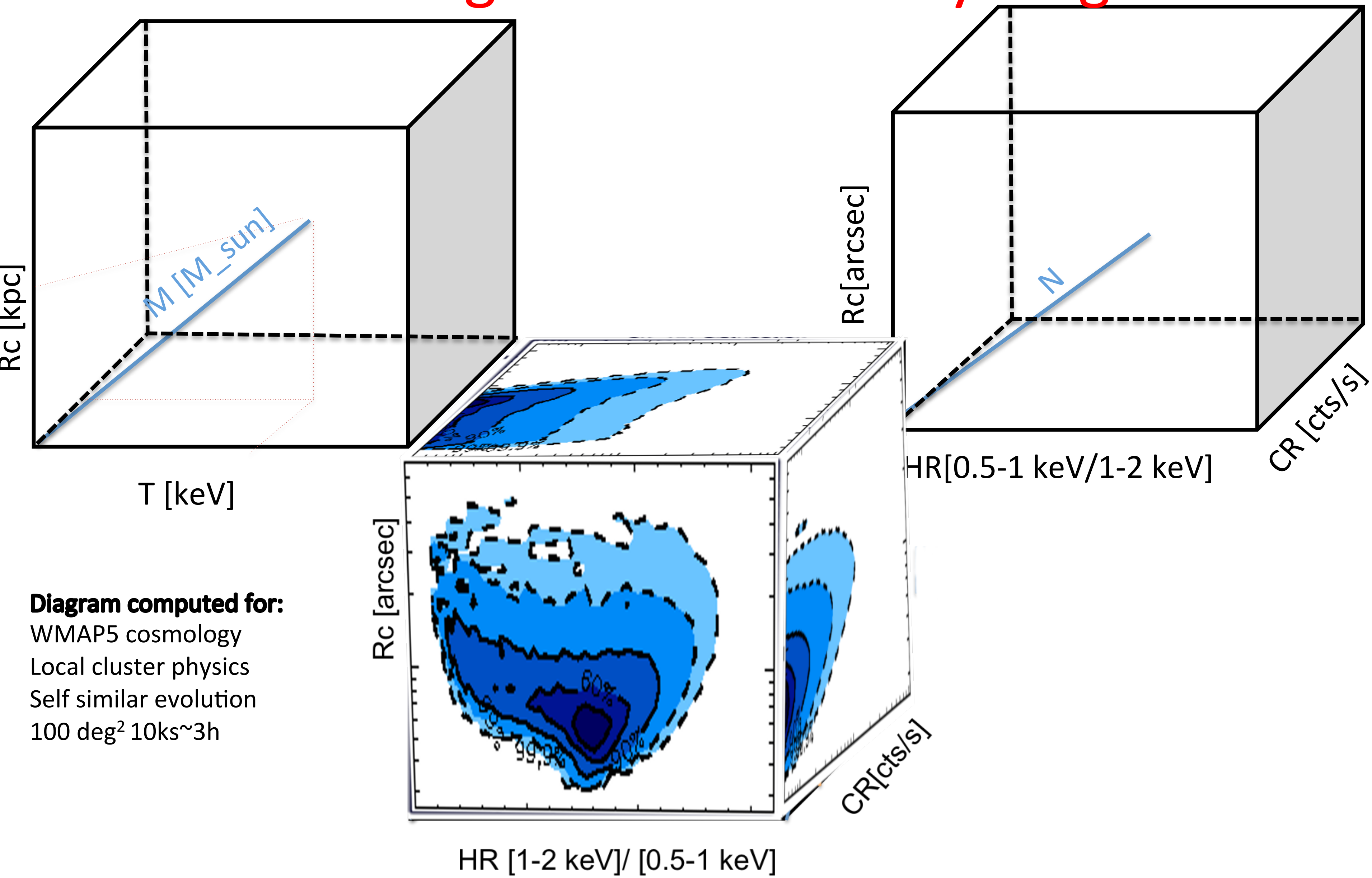
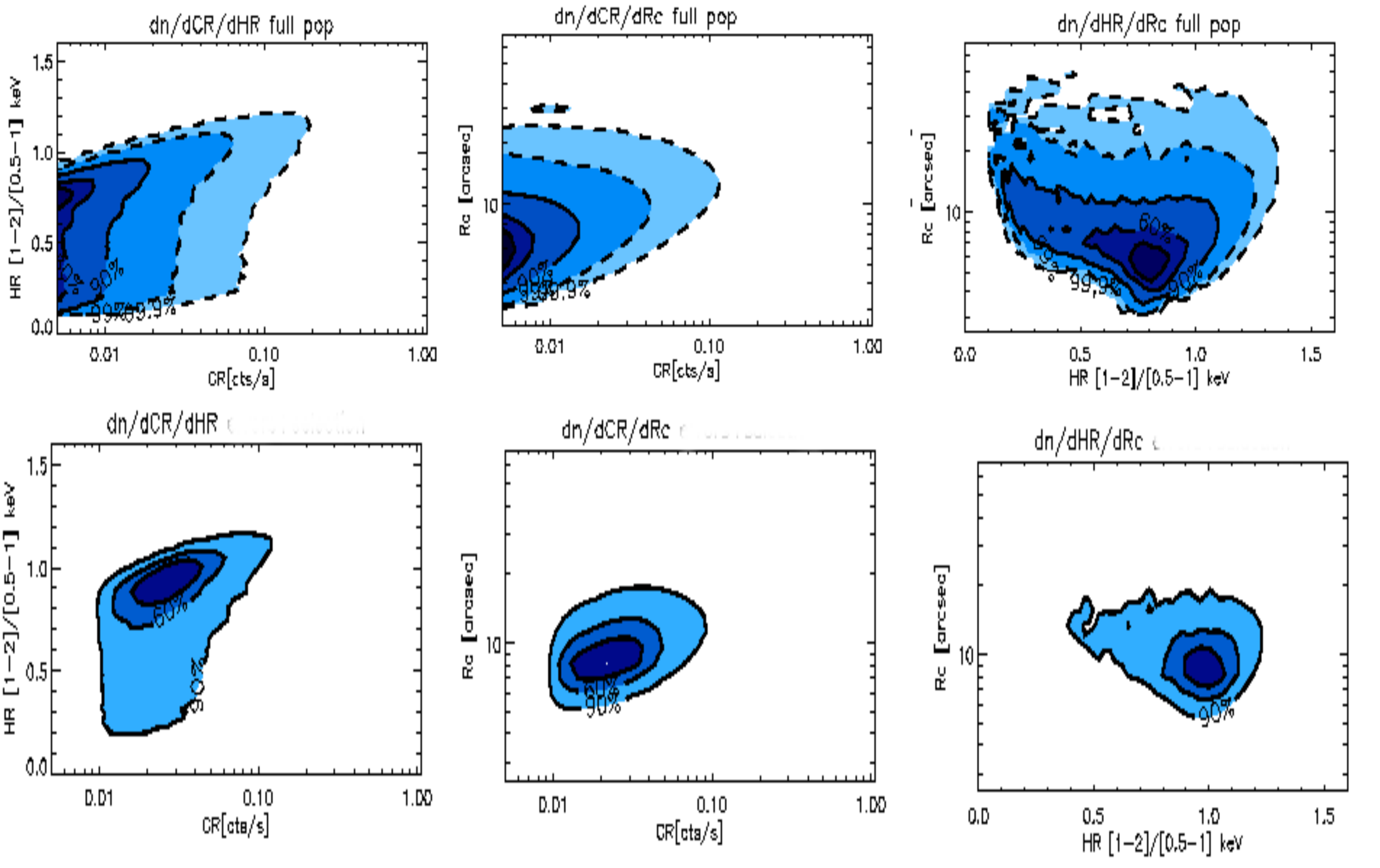


Diagram computed for:
WMAP5 cosmology
Local cluster physics
Self similar evolution
100 deg^2 10ks~3h

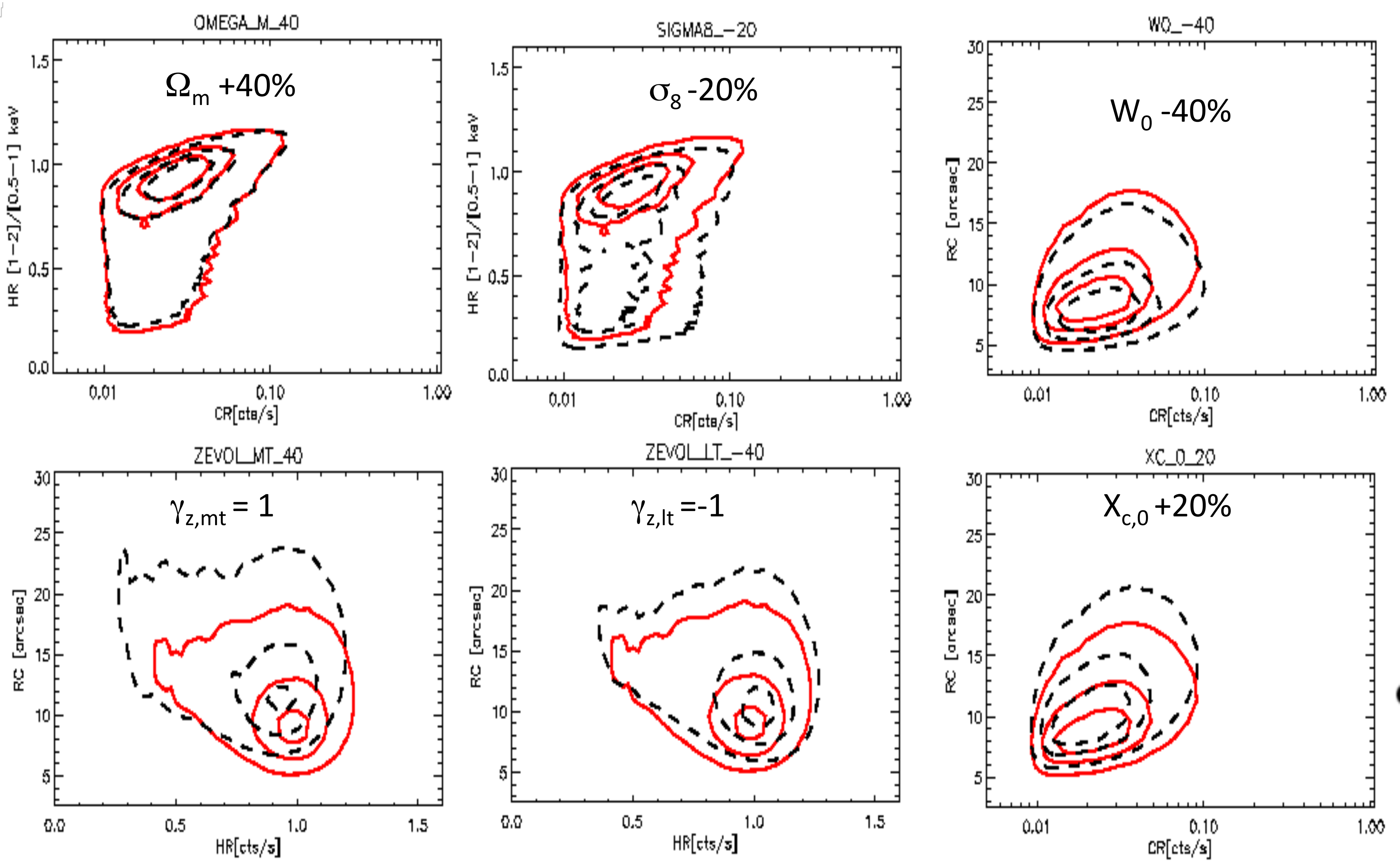
CR-HR-Rc cluster distribution: A color-magnitude-size X-Ray diagram



Ingredients of the fiducial model

- Profile : β-model with core-radius $\propto R_{500c}$
- Known local scaling laws
  - –M200c-T (Arnaud, Pointecouteau & Pratt 2005) + scatter
  - –LX – T (Pratt et al. 2009) + scatter
- Evolution of the normalisations : $(1+z)^{\gamma_{MT}}$, $(1+z)^{\gamma_{LT}}$
- Cosmo : WMAP priors except w_0 , Ω_m , σ_8
- 100 deg^2 survey with the instrumental selection

Different cosmo & phy cubes



- ➔ Test the power of flux-color-size diagram for cosmo using a Fisher analysis

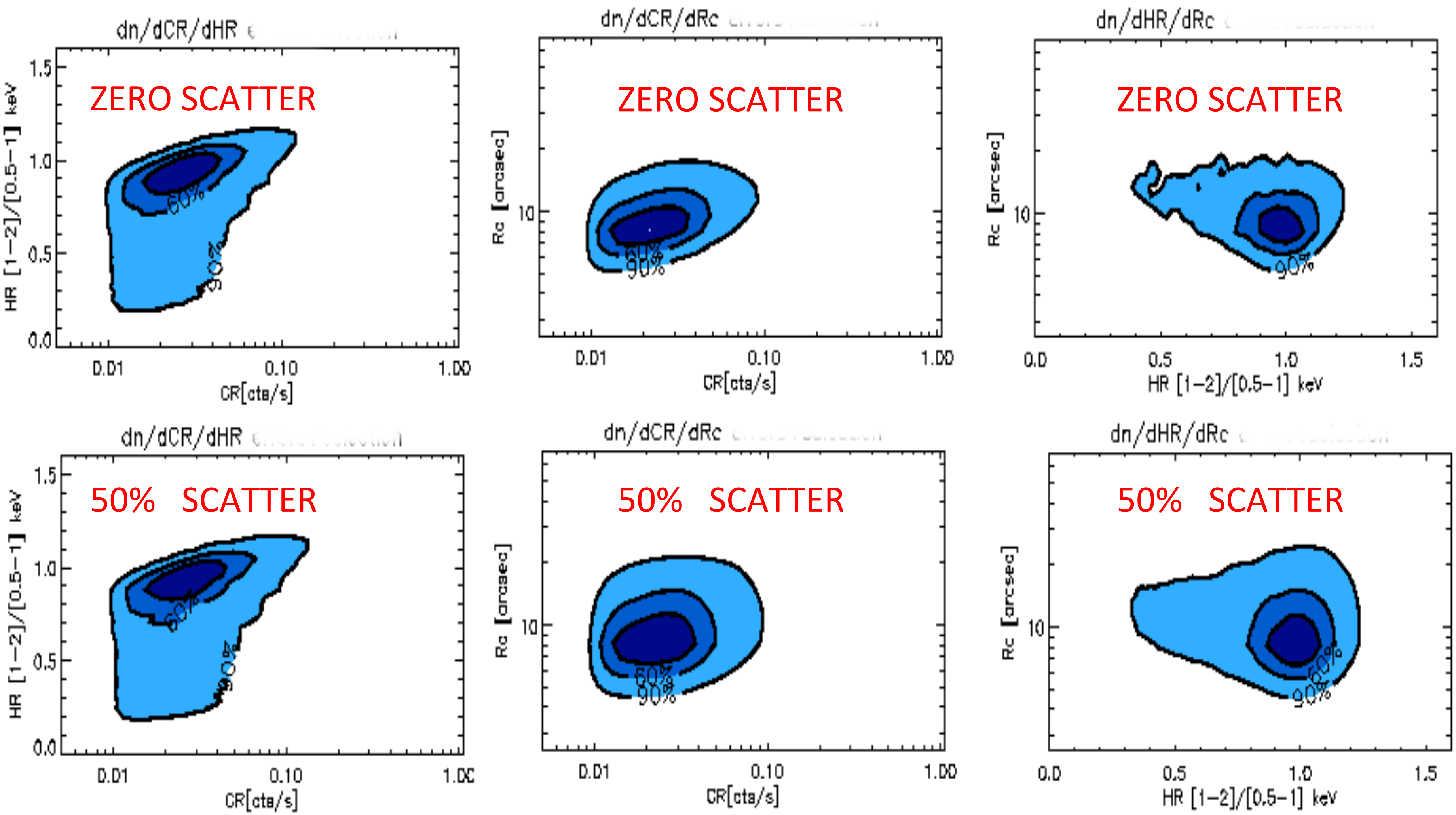
3. Some practical issues

- There are no a one-to-one relations between M-T , **M-Rc**, …

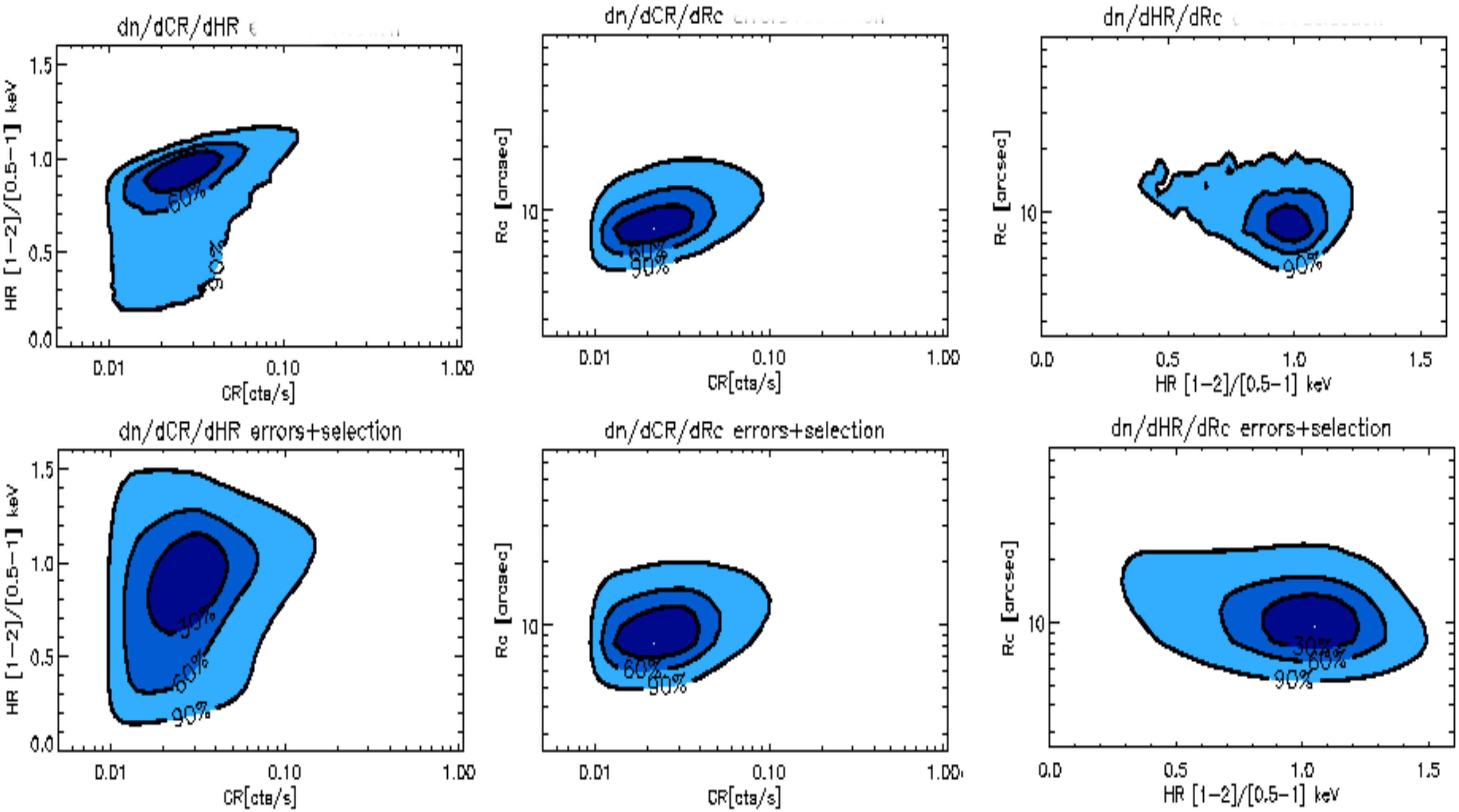
- Measurement errors

- Covariance between the parameters: Flux – colour and size

Effects of scatter on size



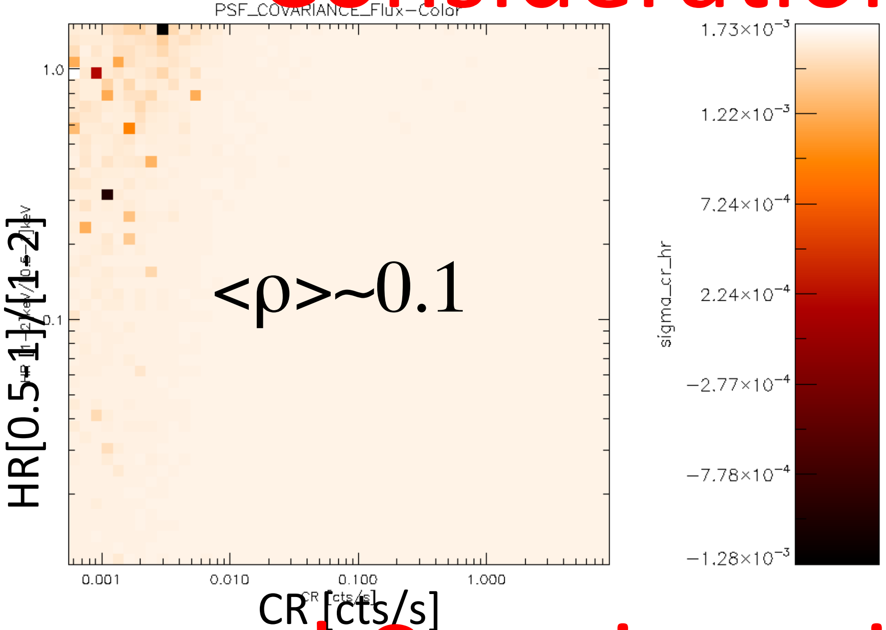
ERRORs model from simulated XMM observations

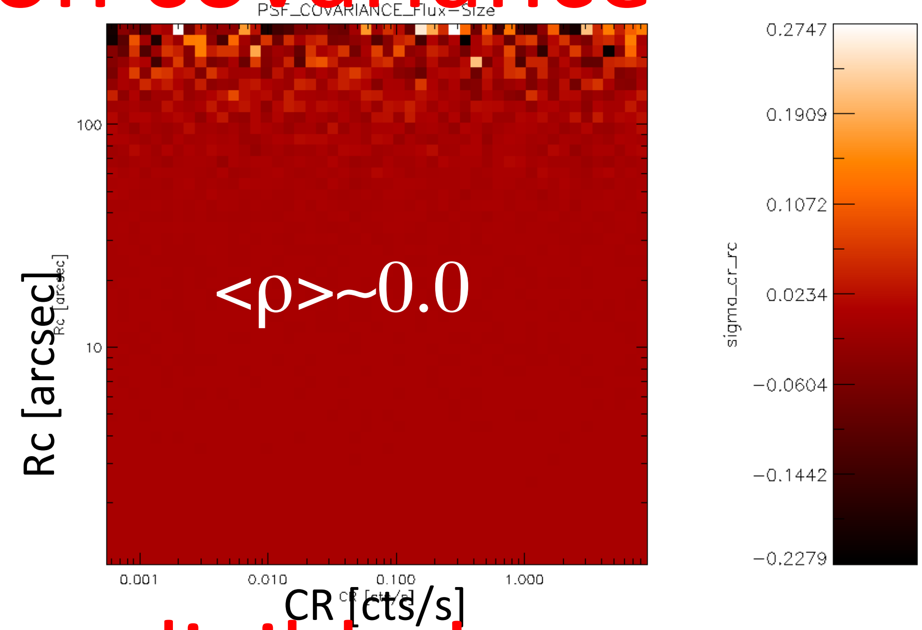


10% relative error for 300 collected photons

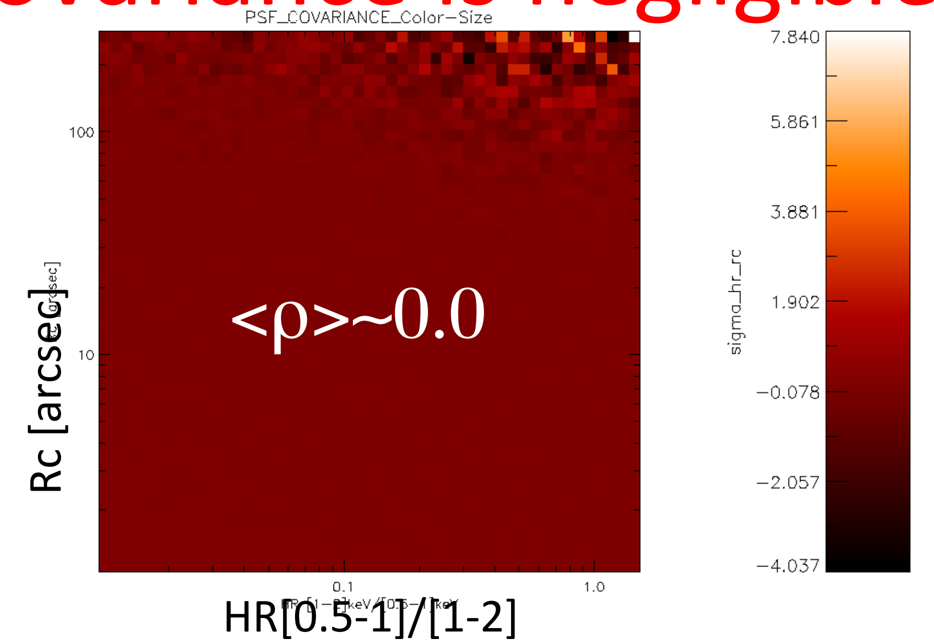
Errors on RC obtained fitting simulations of XMM observations ~ (RC,CR)

Consideration on covariance





! Covariance is negligible !



4.Results from the Fisher Analysis

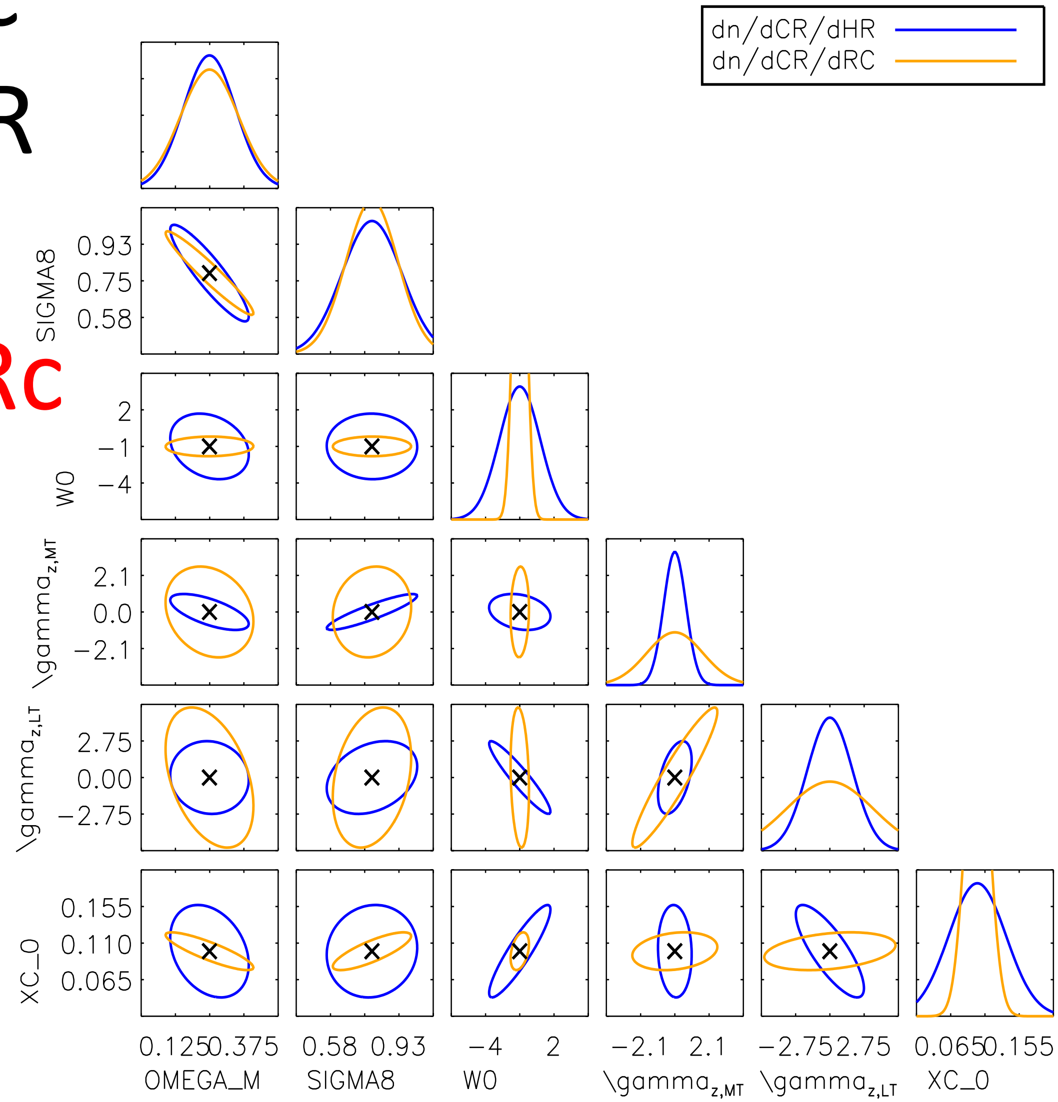
Compare the power of colour vs size

errors: Rc CR, Rc

HR HR, CR

CR CR

ZERO SCATTER on Rc



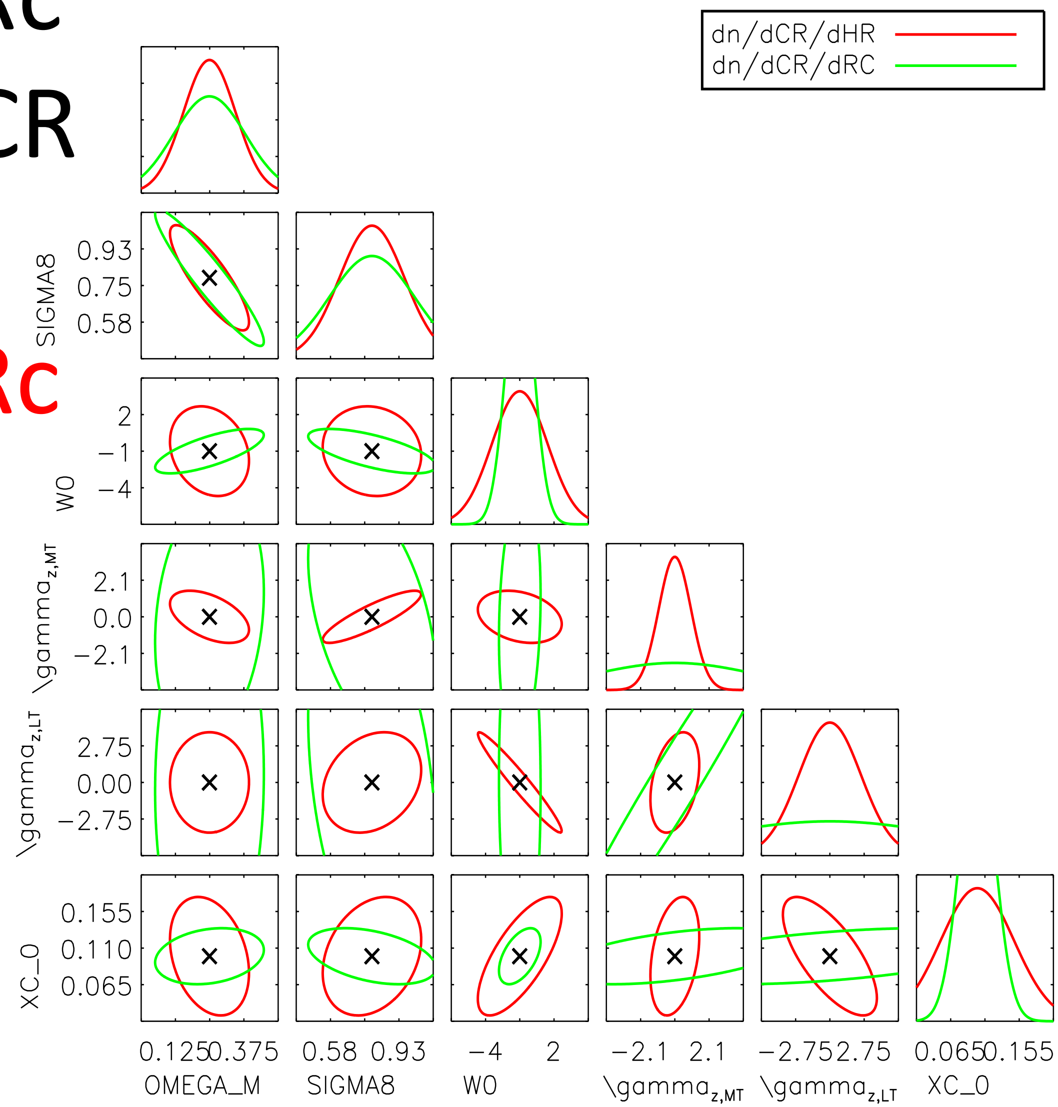
Compare the power of colour vs size

errors: Rc CR, Rc

HR HR, CR

CR CR

50% SCATTER on Rc



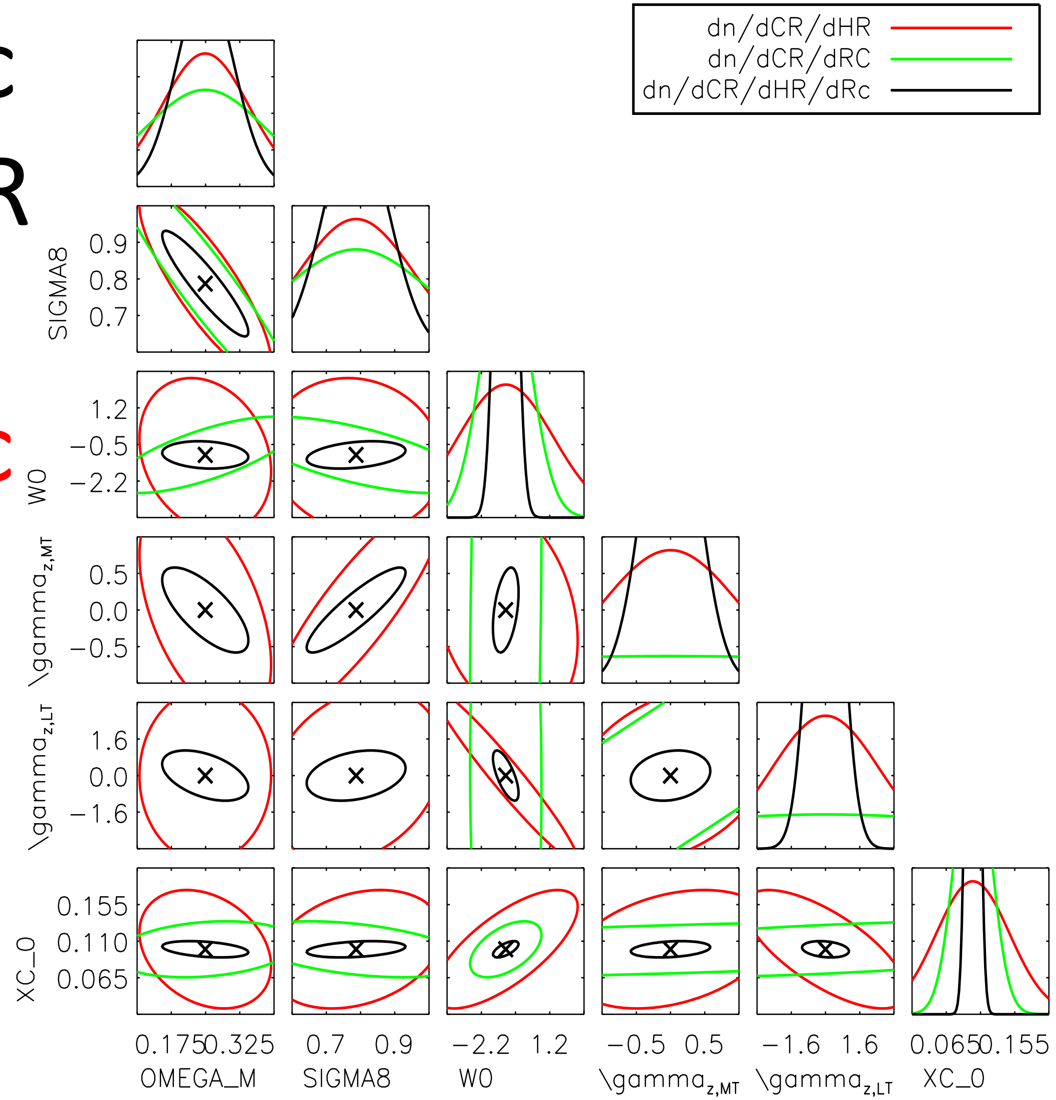
Final cosmo predictions combing colour and size and flux

errors: Rc CR, Rc

HR HR, CR

CR CR

50% SCATTER on Rc



Summary table

	CR-HR	CR-HR	CR-Rc	CR-HR-Rc	CR-HR-Rc
scatter	-	50%	50%	50%	100%
Ω_m	0.10	0.10	0.13	0.06	0.08
σ_8	0.15	0.17	0.22	0.10	0.12
w_0	1.8	2.4	1.2	0.43	0.62
$\gamma_{z,mt}$	0.68	0.99	4.9	0.39	0.45
$\gamma_{z,lt}$	1.8	2.5	9.7	0.73	0.87
$x_{c,0}$	0.04	0.06	0.02	0.01	0.01

CONCLUSION and FUTURE

MAIN RESULTS on CR-HR-Rc method

- GREAT method: no need to go to the tedious step of mass calculation – do not need reshift
- Under reasonable hypotheses, adding cluster size information improves the cosmo constraints by factor ~3 with respect to CR-HR and CR-Rc alone

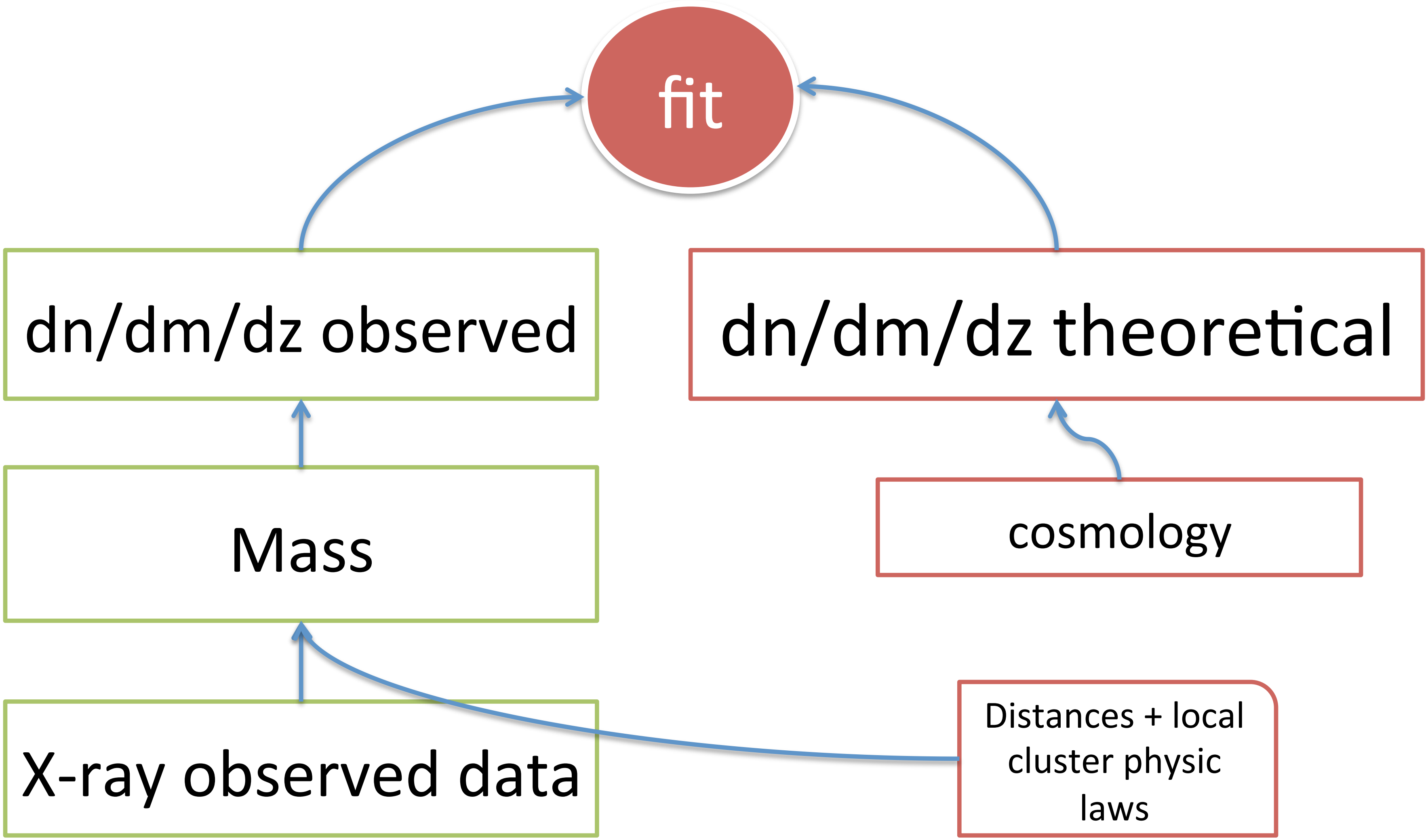
OPEN QUESTIONS => FUTURE

- 1 Scatter in the scaling relations is a critical issue. Currently very poorly known.
- => use hydrodynamical simulations to estimate the various scatters (and test the precision of RC,….)
- 2 Not all information is used
- => use information from the hard part of the X-ray spectrum (more colours)
- => use redshift information => Construct colour-magnitude-size diagrams in redshift slices


END

Mass function

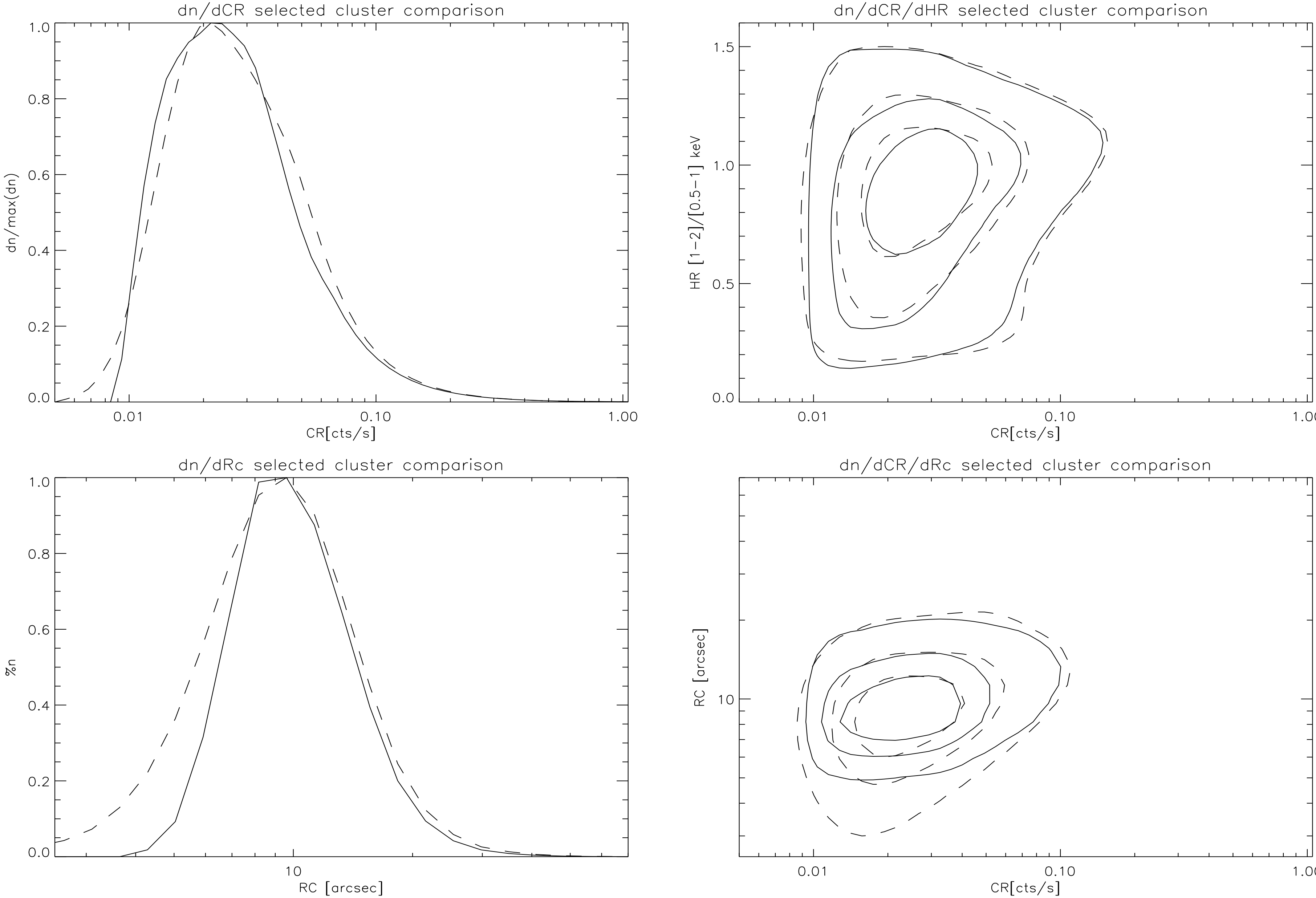
Standard way of doing cosmology with cluster



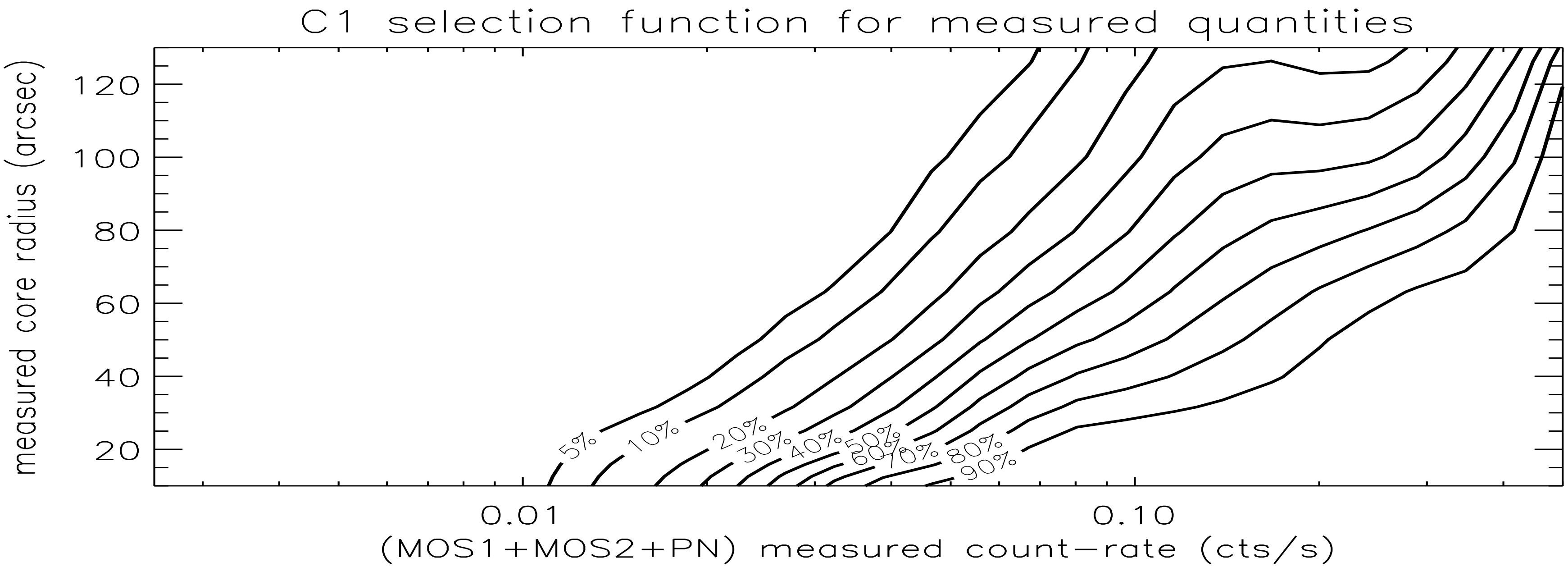
List spare slides

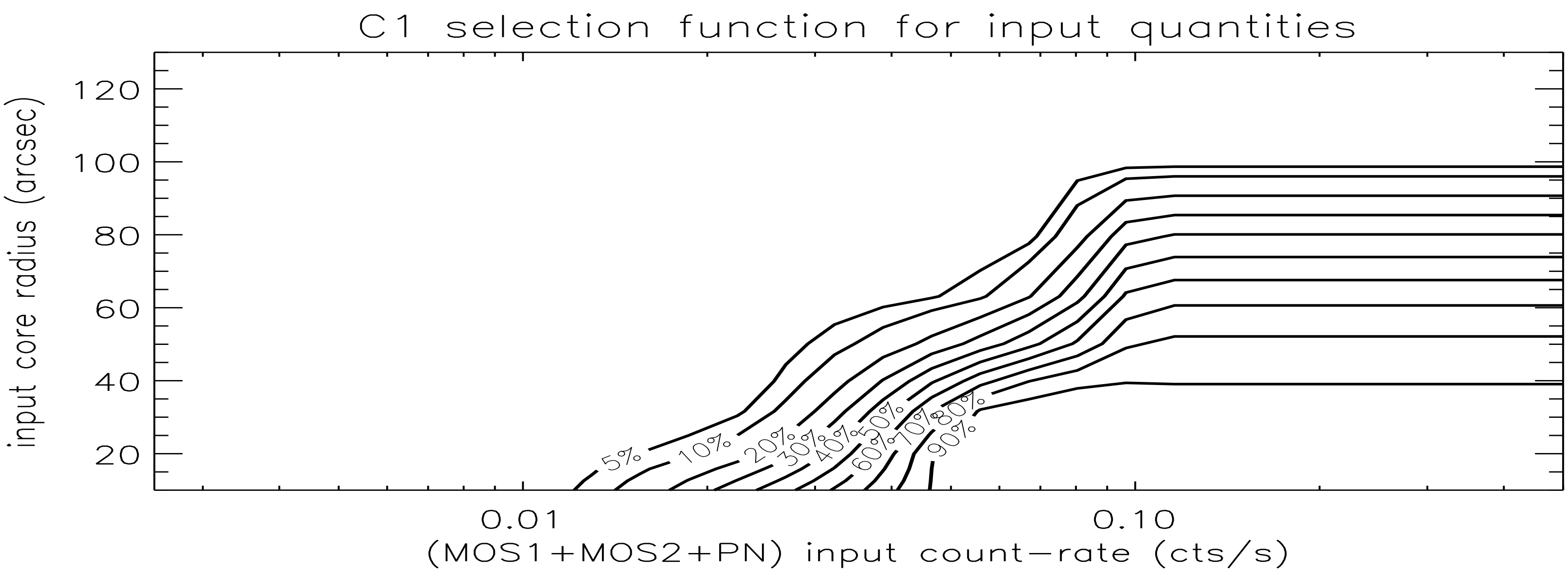
- Nicolas: already CR-HR (not using z) is more powerful than the traditional dn/dz
- Fisher analysis pipe errors
- Effec of int scatter on xc0 o number detected cluster

New selection function

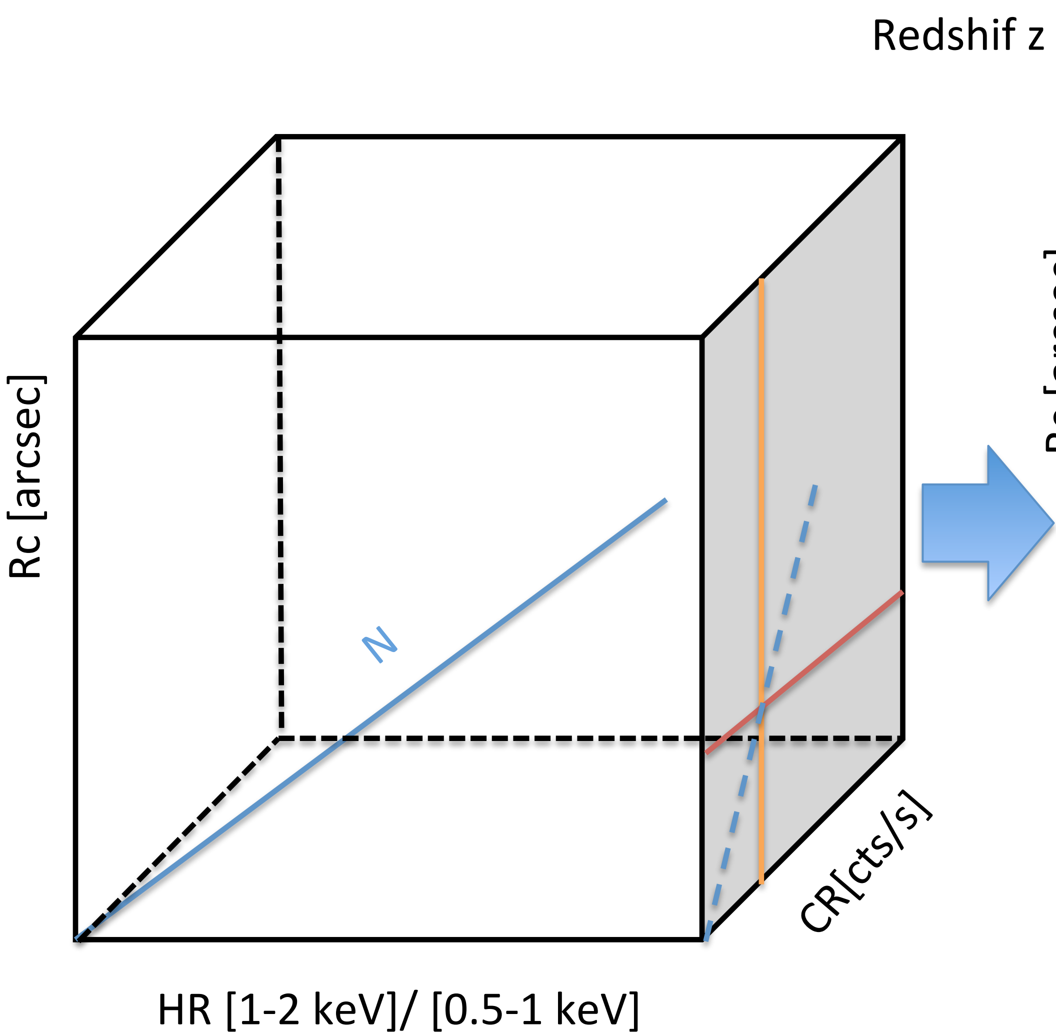


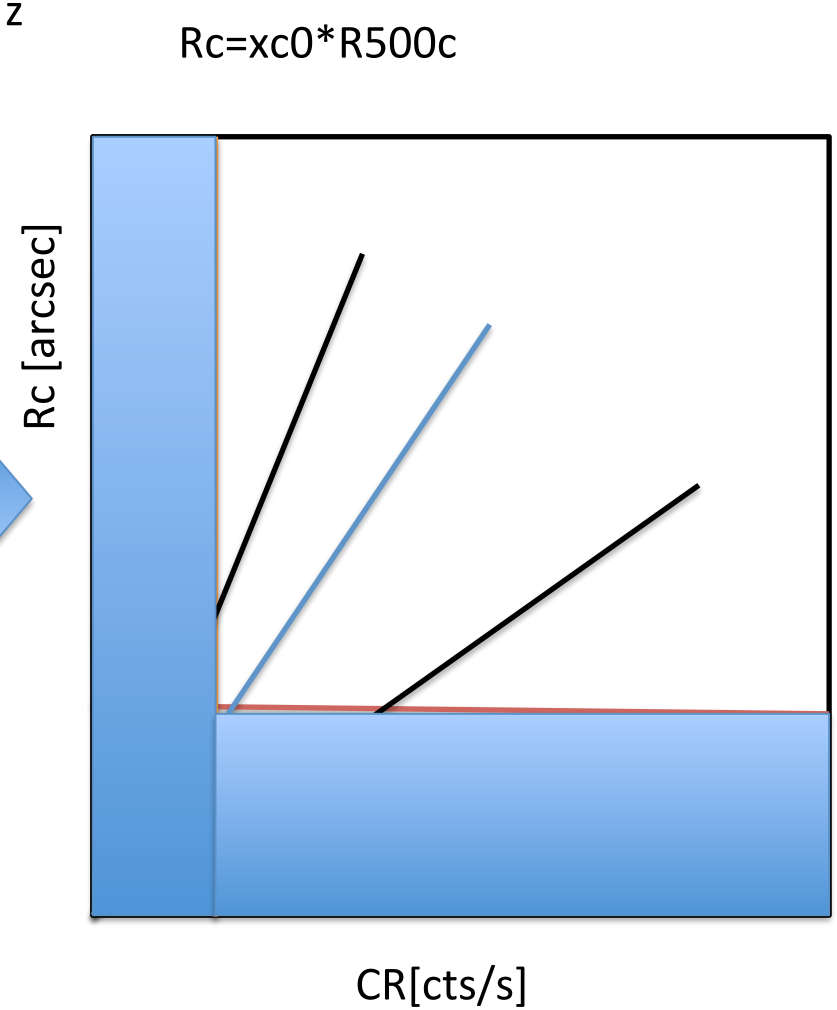
New selection function



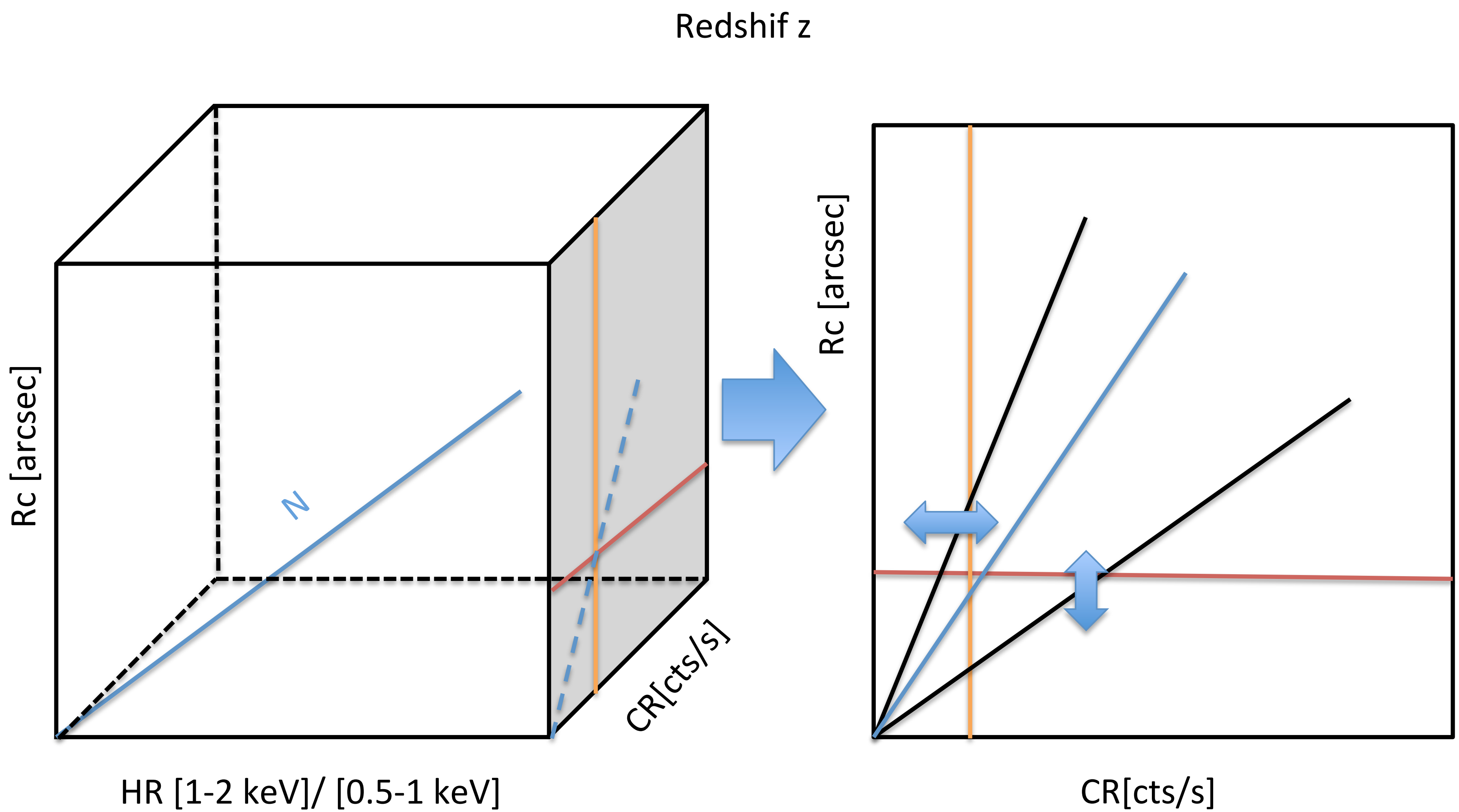


The intrinsic scatter on Rc-R500c relation

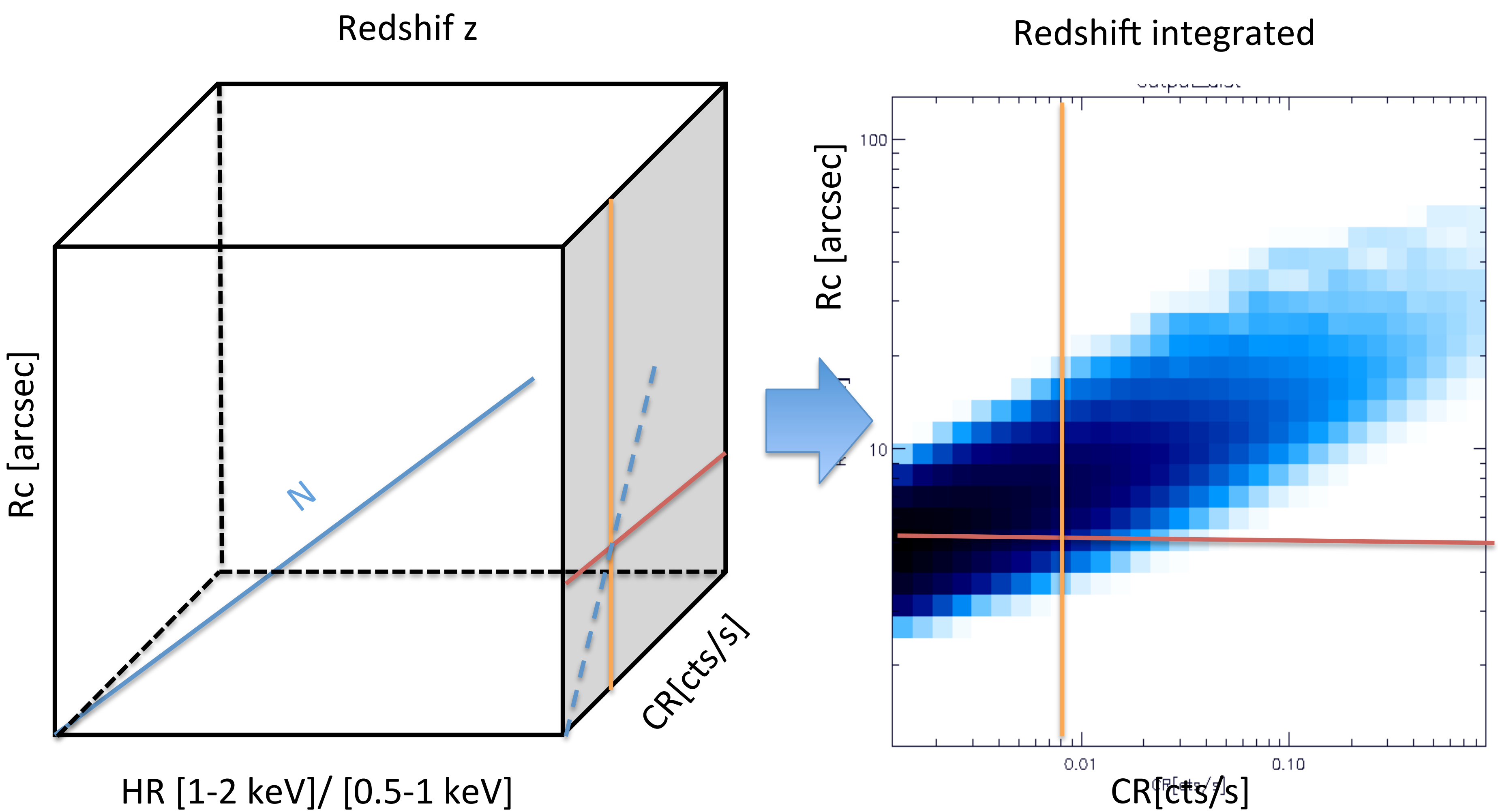




The intrinsic scatter on Rc-R500c relation



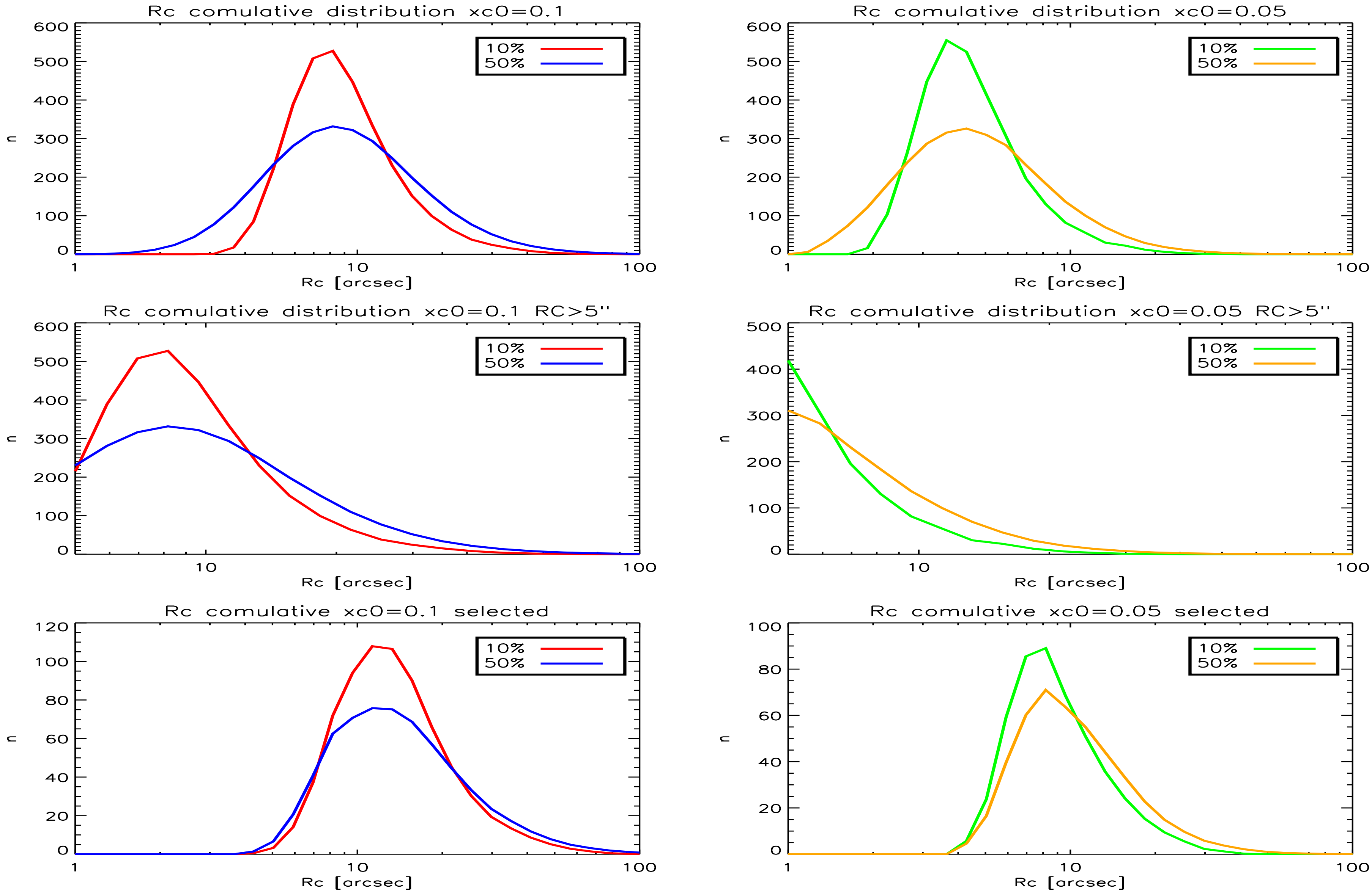
The intrinsic scatter on Rc-R500c relation



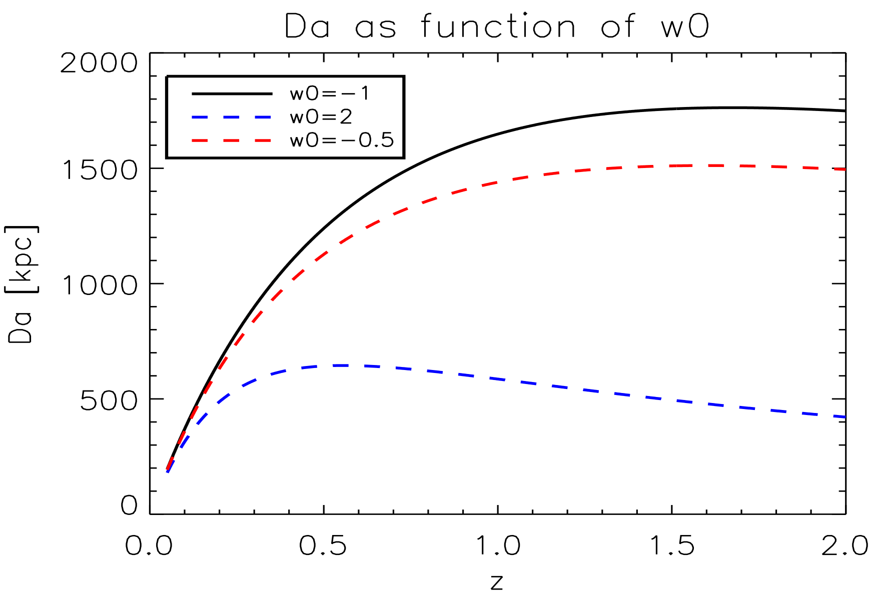
The intrinsic scatter on Rc-R500c: effects on total number

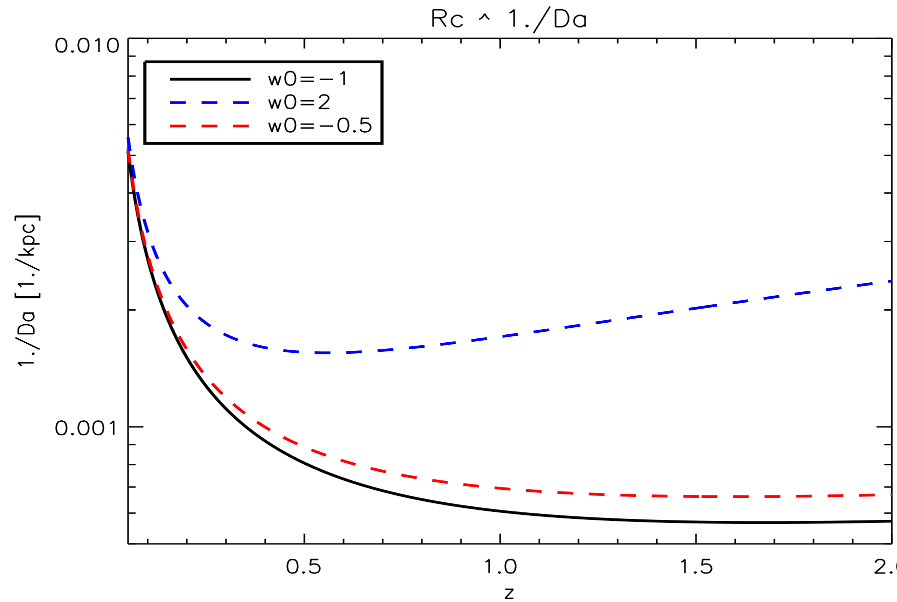
Xc,0=0.1

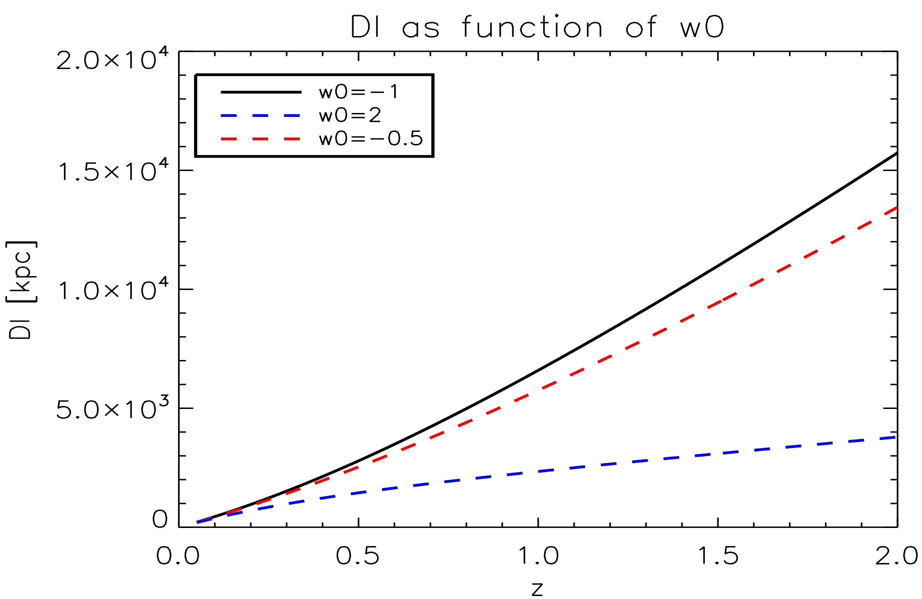
Xc,0=0.05

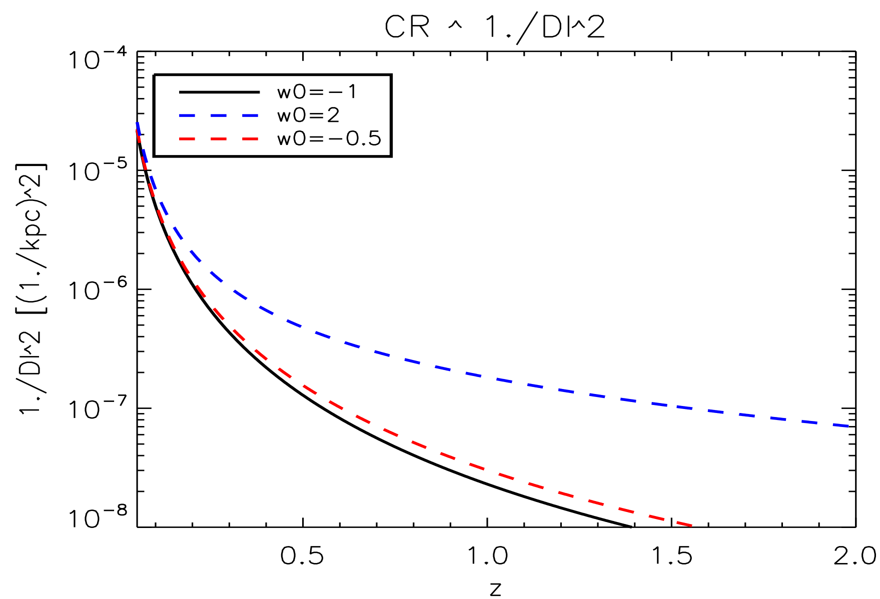


Distances


Da as function of w0
w0=−1
w0=2
w0=−0.5
Da [kpc]
z
0
500
1000
1500
2000
0.0
0.5
1.0
1.5
2.0


Rc ^ 1./Da
w0=−1
w0=2
w0=−0.5
1./Da [1./kpc]
z
0.010
0.001
0.5
1.0
1.5
2.0


Dl as function of w0
w0=−1
w0=2
w0=−0.5
Dl [kpc]
z
0
5.0×10³
1.0×10⁴
1.5×10⁴
2.0×10⁴
0.0
0.5
1.0
1.5
2.0


CR ^ 1./Dl^2
w0=−1
w0=2
w0=−0.5
1./Dl^2 [(1./kpc)^2]
z
10⁻⁴
10⁻⁵
10⁻⁶
10⁻⁷
10⁻⁸
0.5
1.0
1.5
2.0

Apparent size model error