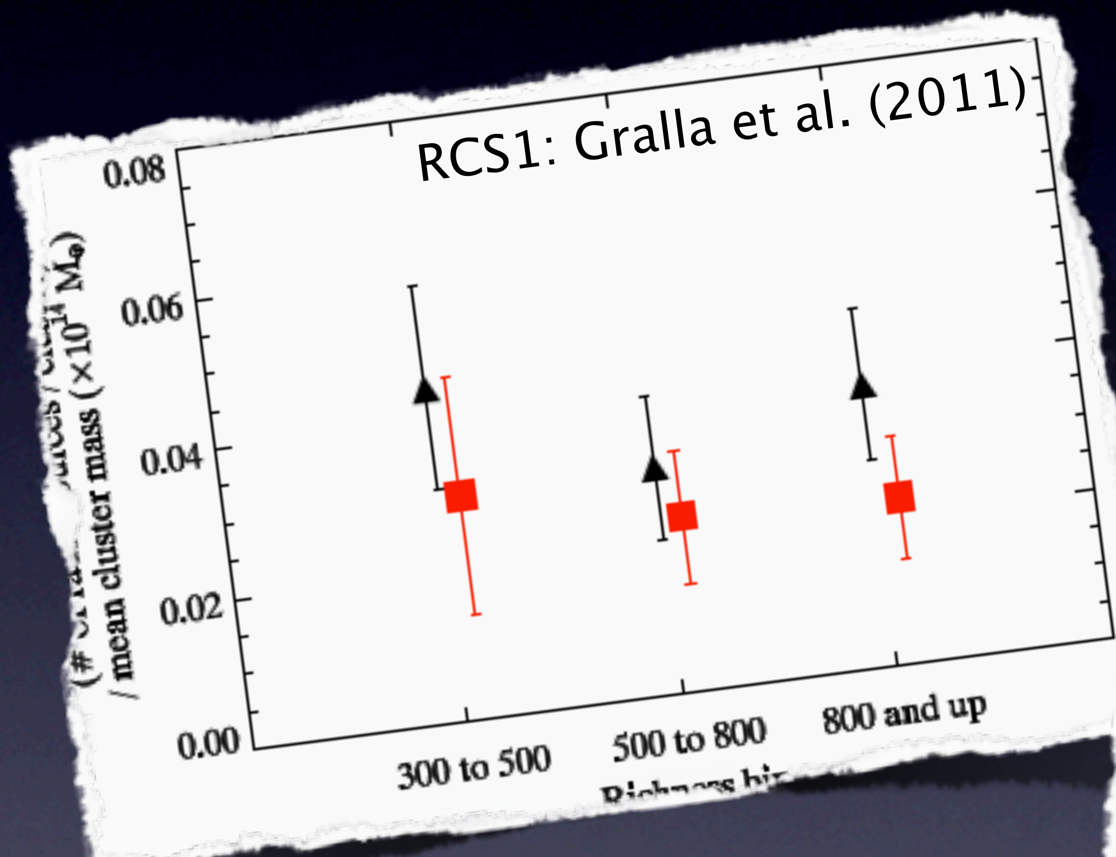
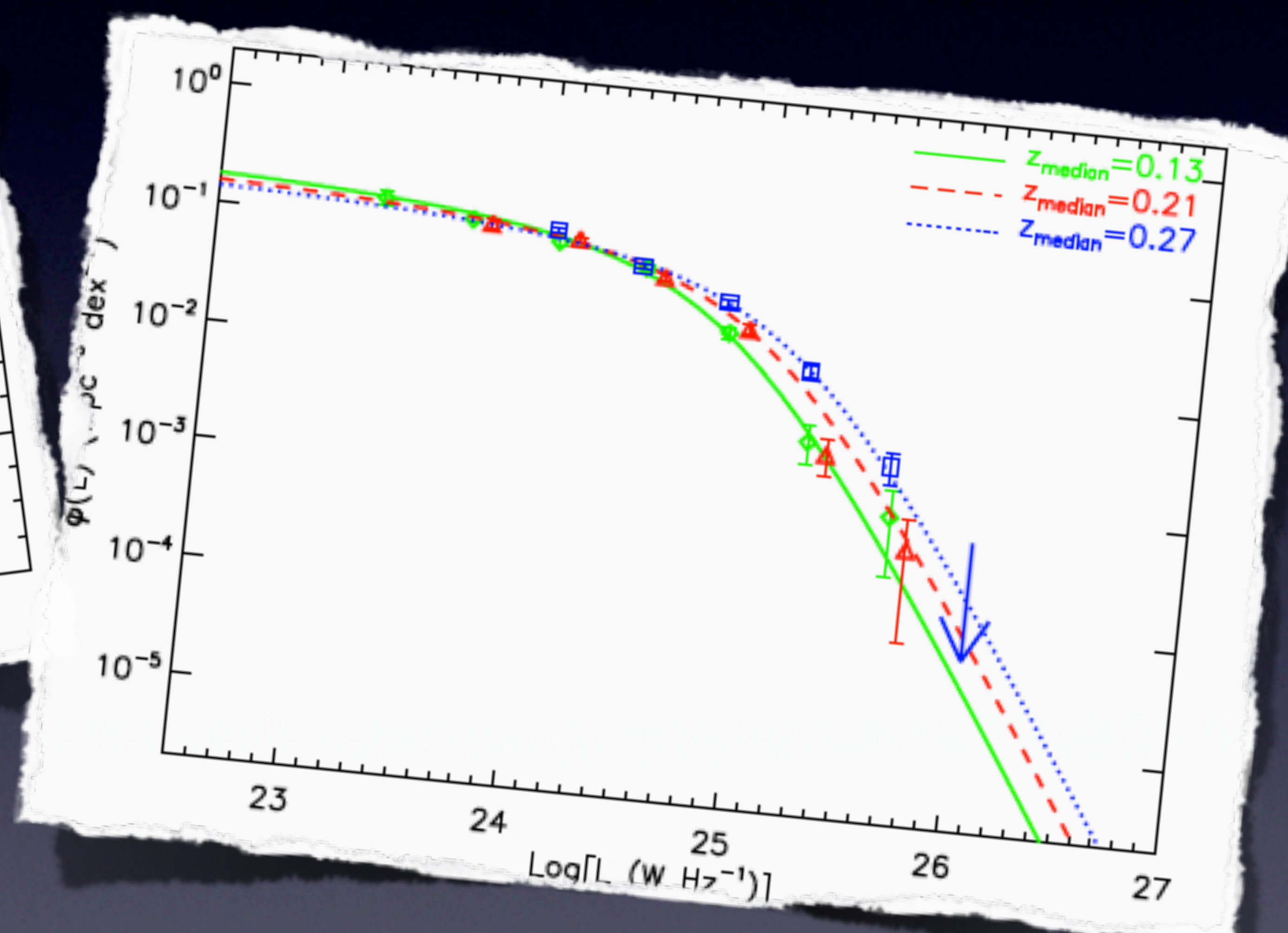
Strong z-evolution of the cluster radio LF and impact on the SZ surveys

(or, why keep flogging that dead horse?)





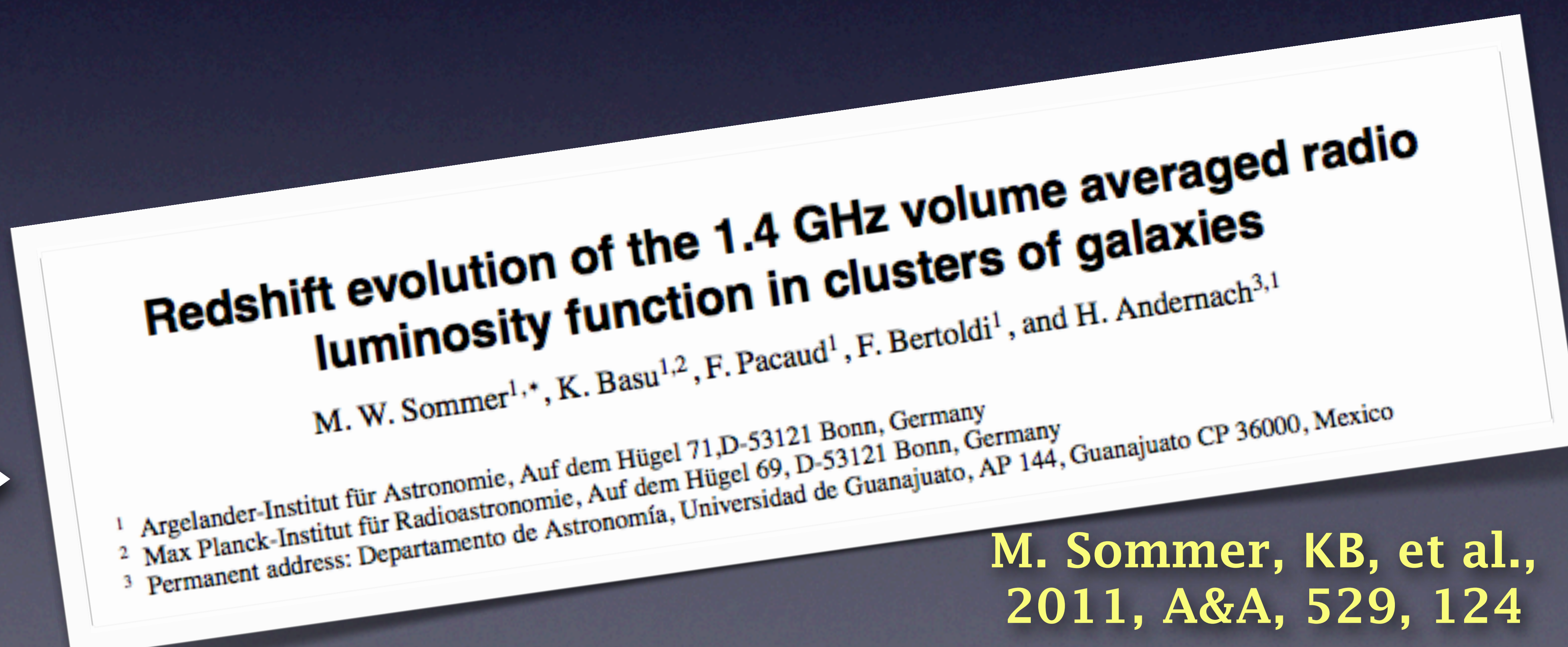
Kaustuv Basu

University of Bonn

Outline of the talk

- What we need to know about cluster radio sources to assess their impact on SZ surveys?
- What has been known so far? How do the radio luminosity function (RLF) look like?
- Where does our work fit in? What does it signify?

To get the details check this one:



Redshift evolution of the 1.4 GHz volume averaged radio luminosity function in clusters of galaxies

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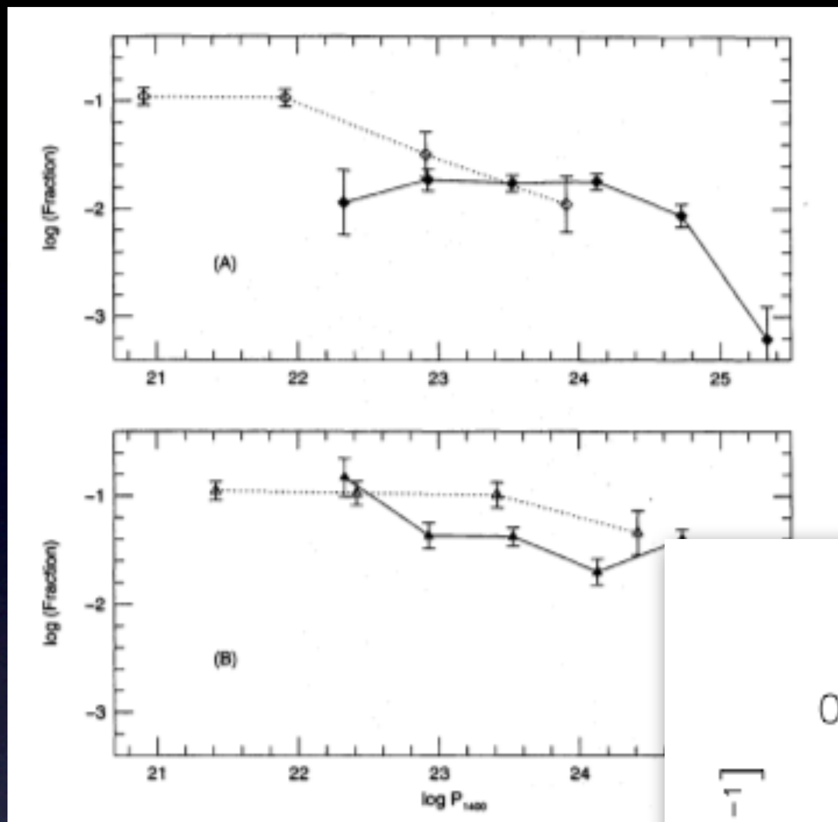
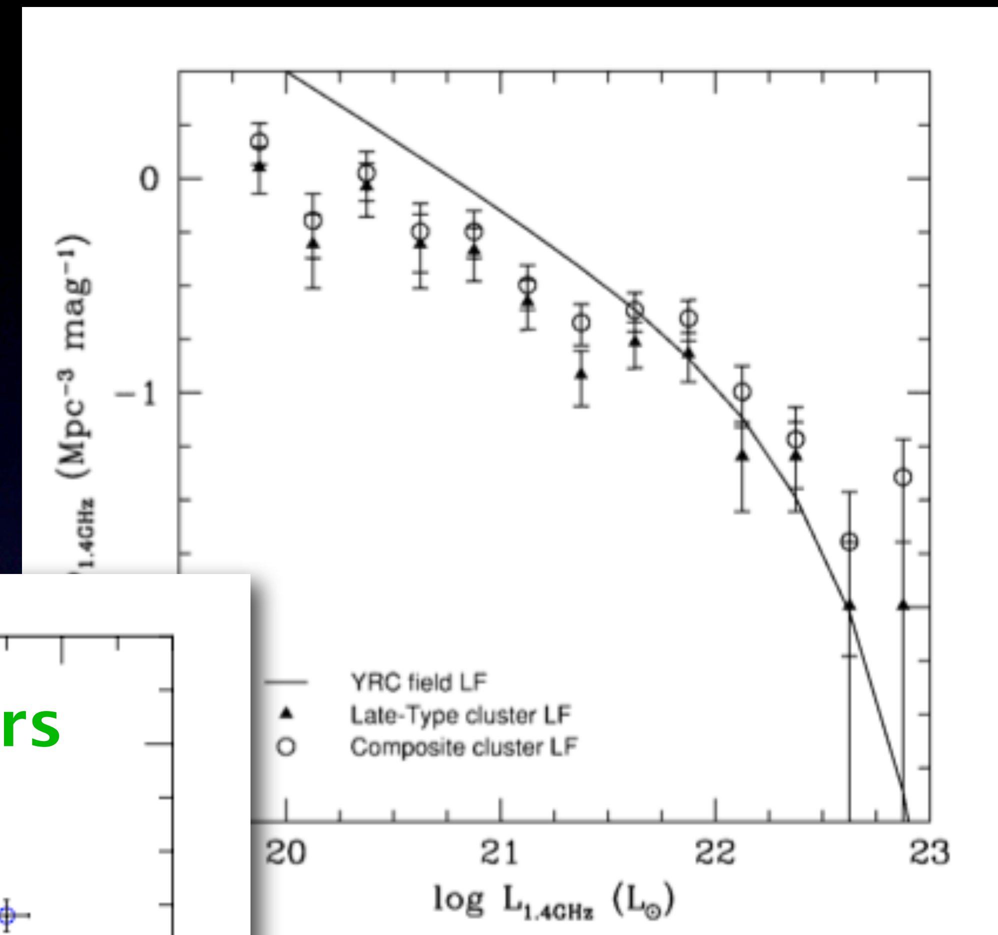
M. Sommer, KB, et al., 2011, A&A, 529, 124

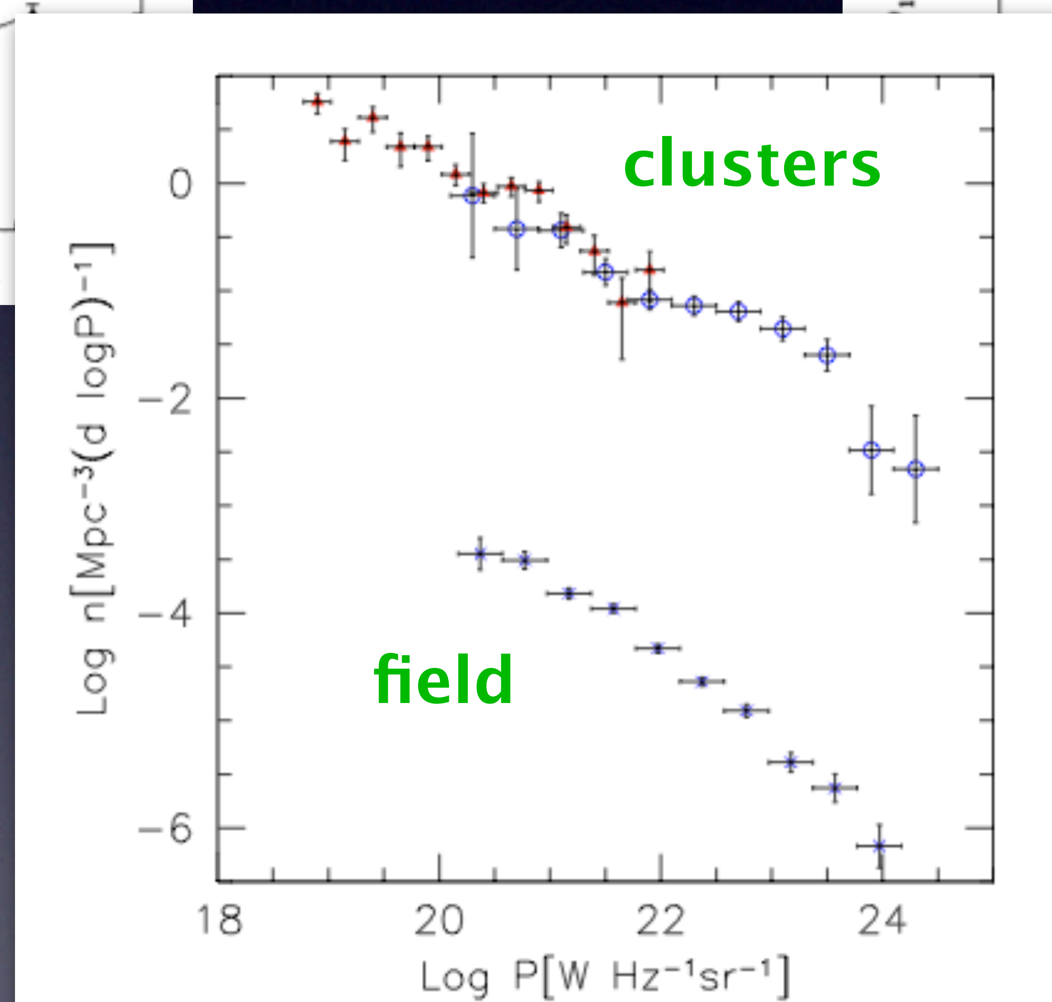
The 1.4 GHz cluster radio LF



Ledlow & Owen (1996)
~100 Abell clusters

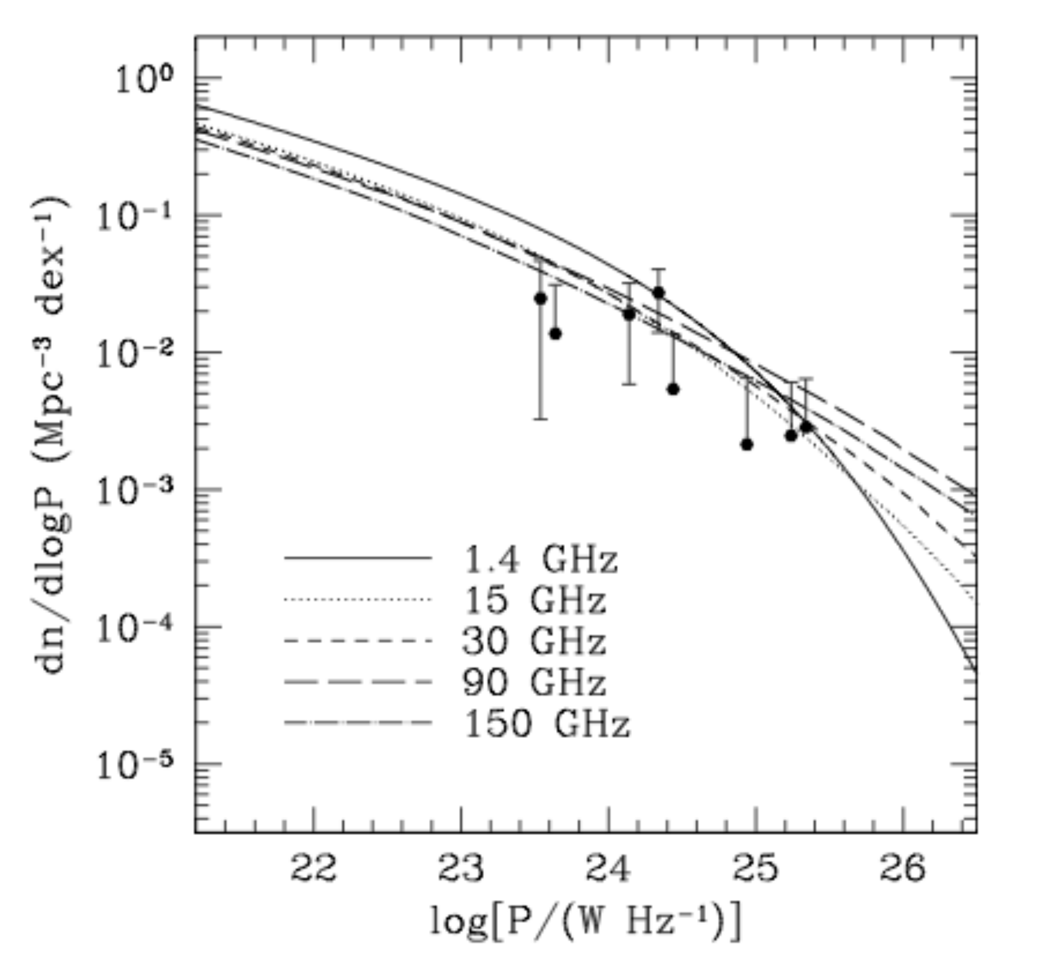


Reddy & Yun (2004)
7 nearby clusters

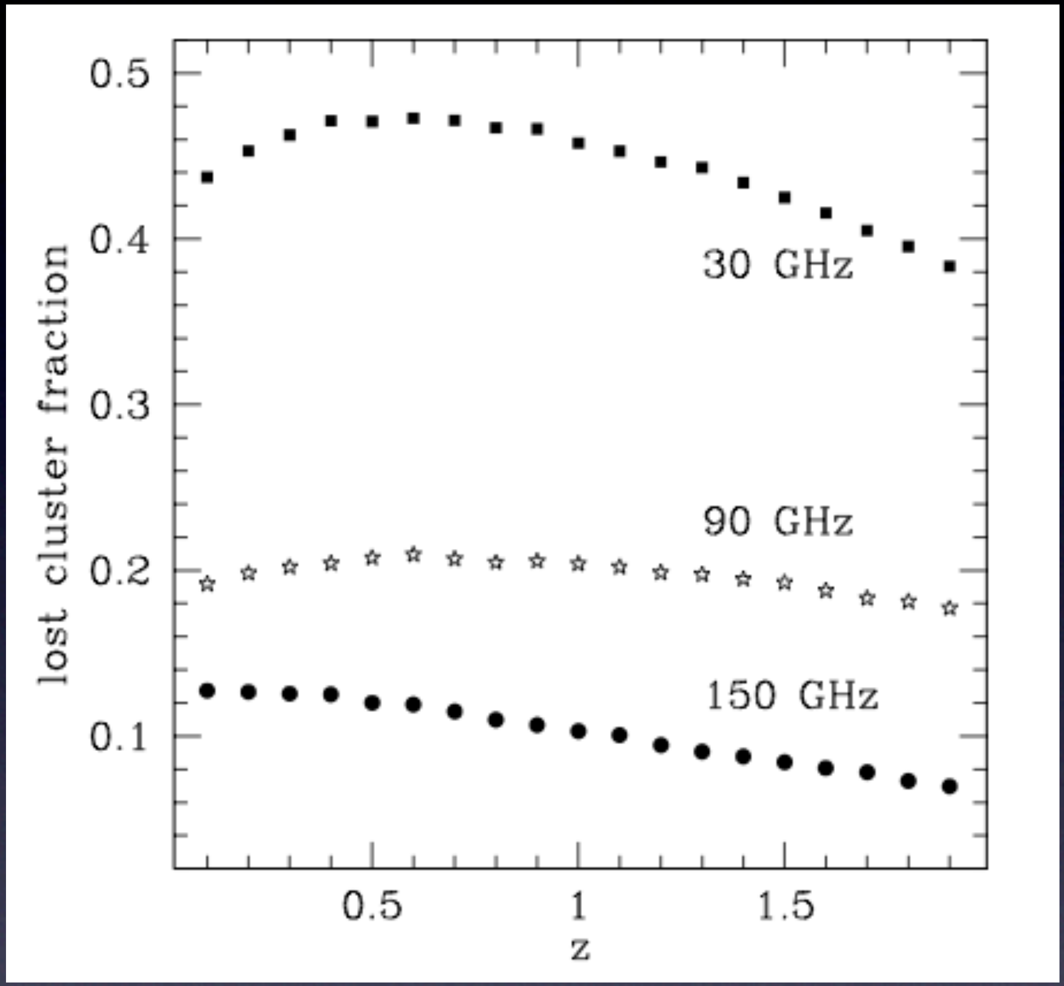


Massardi & De Zotti (2004)
~1000 Abell clusters z< ~0.4

Impact on SZ surveys



AGN radio LF at several frequencies. Data points are 30 GHz measurements (Coble et al 2006)

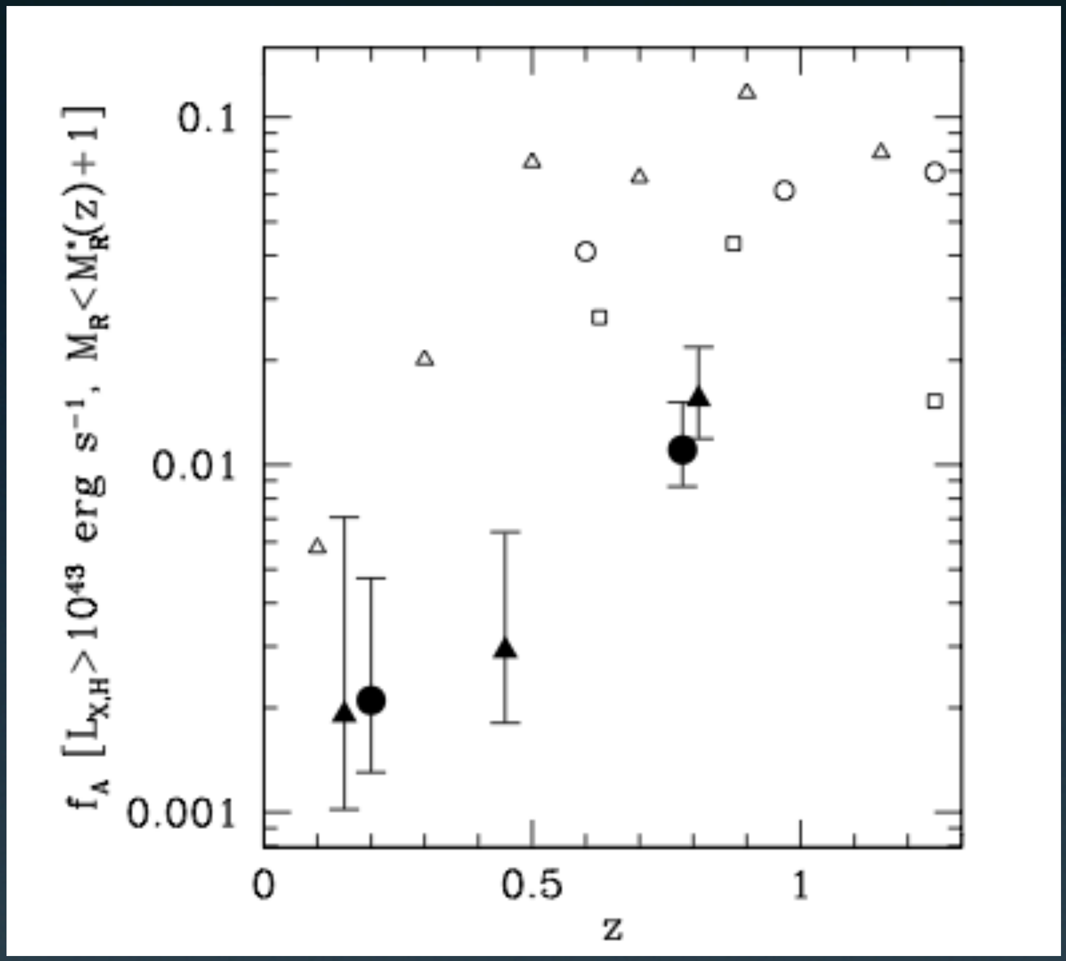


Lost cluster fraction for 2×10^{14} mass assuming $(1+z)^{2.5}$ evolution

Both figures from Lin & Mohr (2007)

Redshift evolution

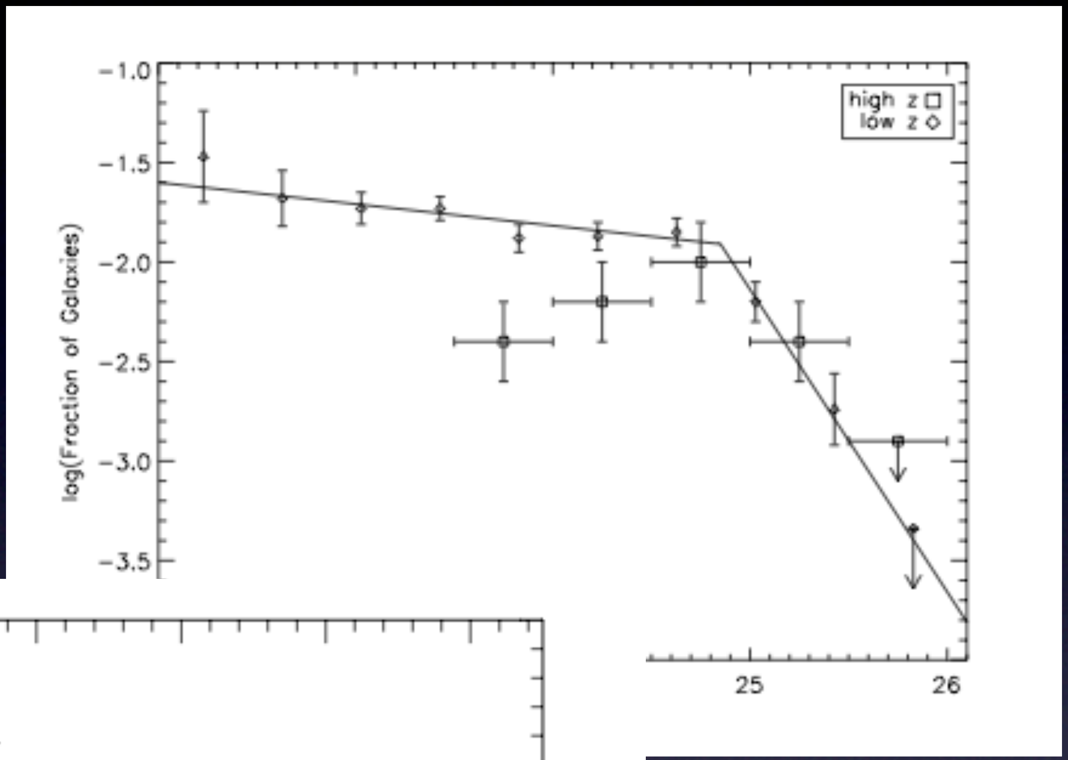
The X-ray view: ***Increase***
in the AGN fraction (talk on Monday)



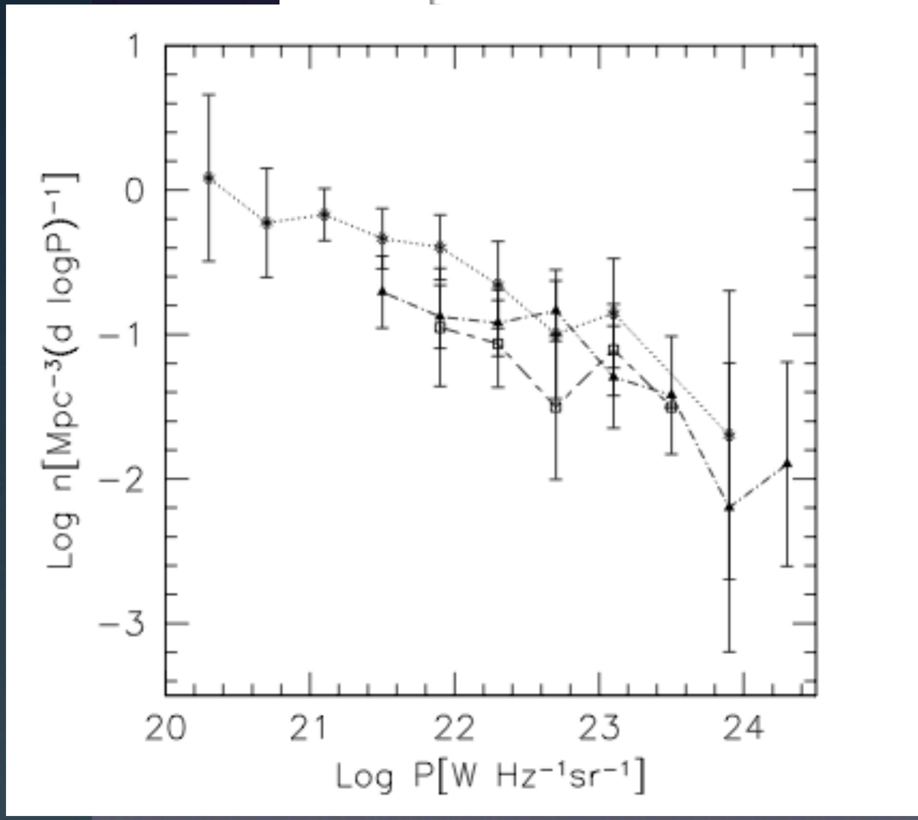
Martini et al. (2009), ...

factor ~8 increase out to z=1
but small # statistics

The radio view:

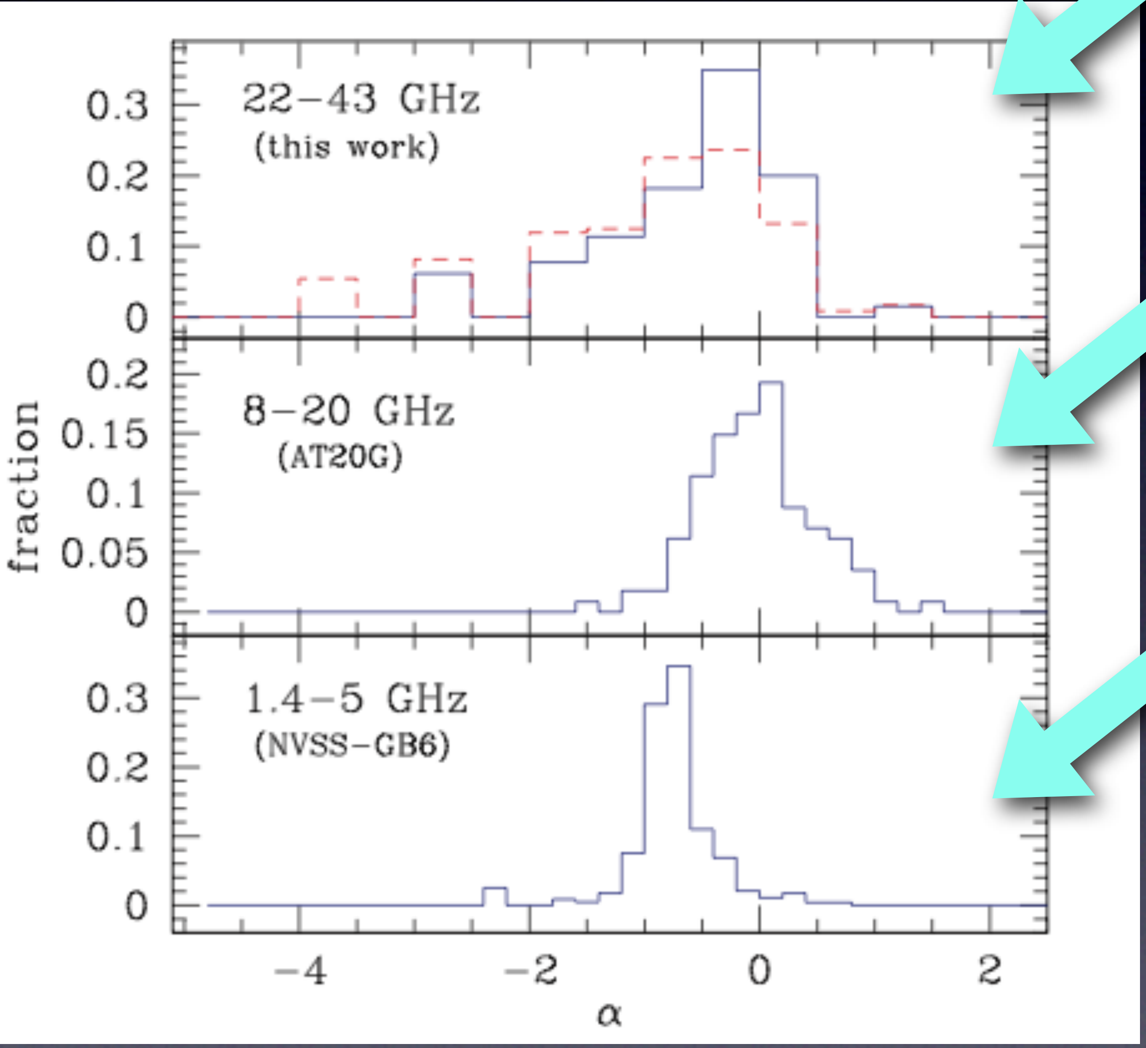


Stocke et al. 99



Massardi & De Zotti 04

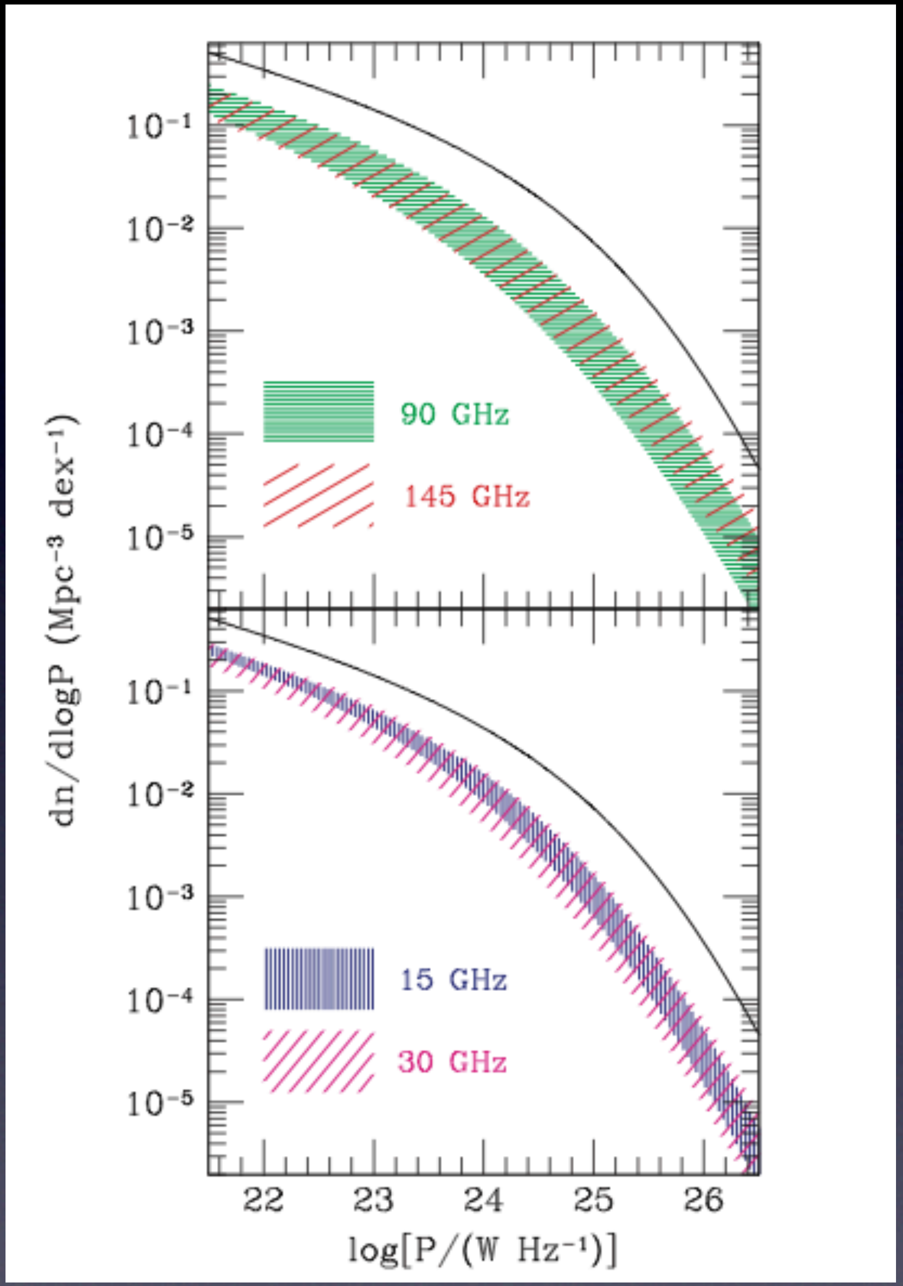
SED: The other unknown



VLA 22-43 GHz
(Lin et al. 09)

Field 8-20 GHz
AT20G survey
(Sadler et al. 06)

1.4-5 GHz SED
from NVSS and
GB6 surveys



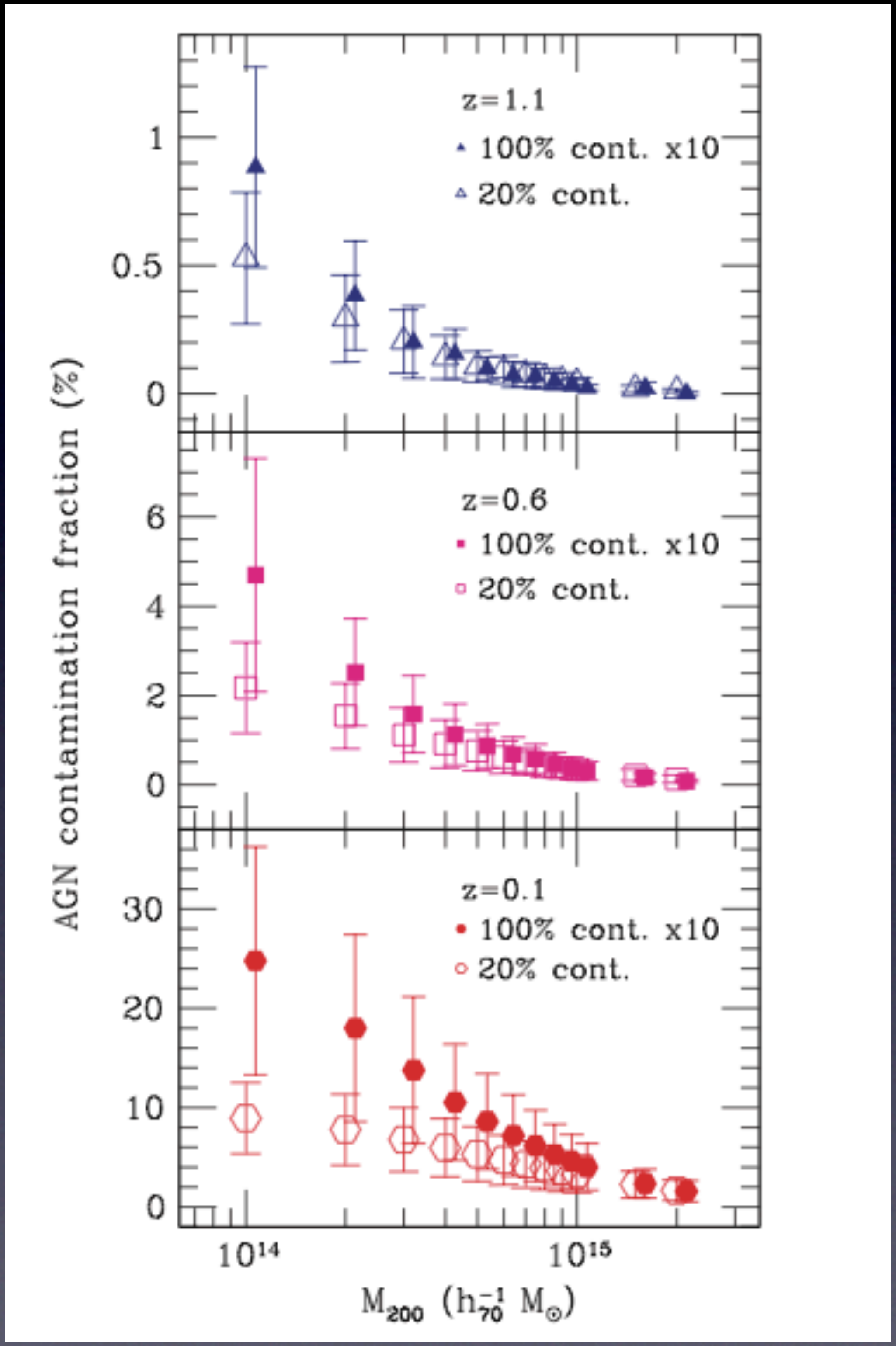
Frequency scaling of the radio LF at z=0 (Lin et al. 2009)

SZ contamination "revised"

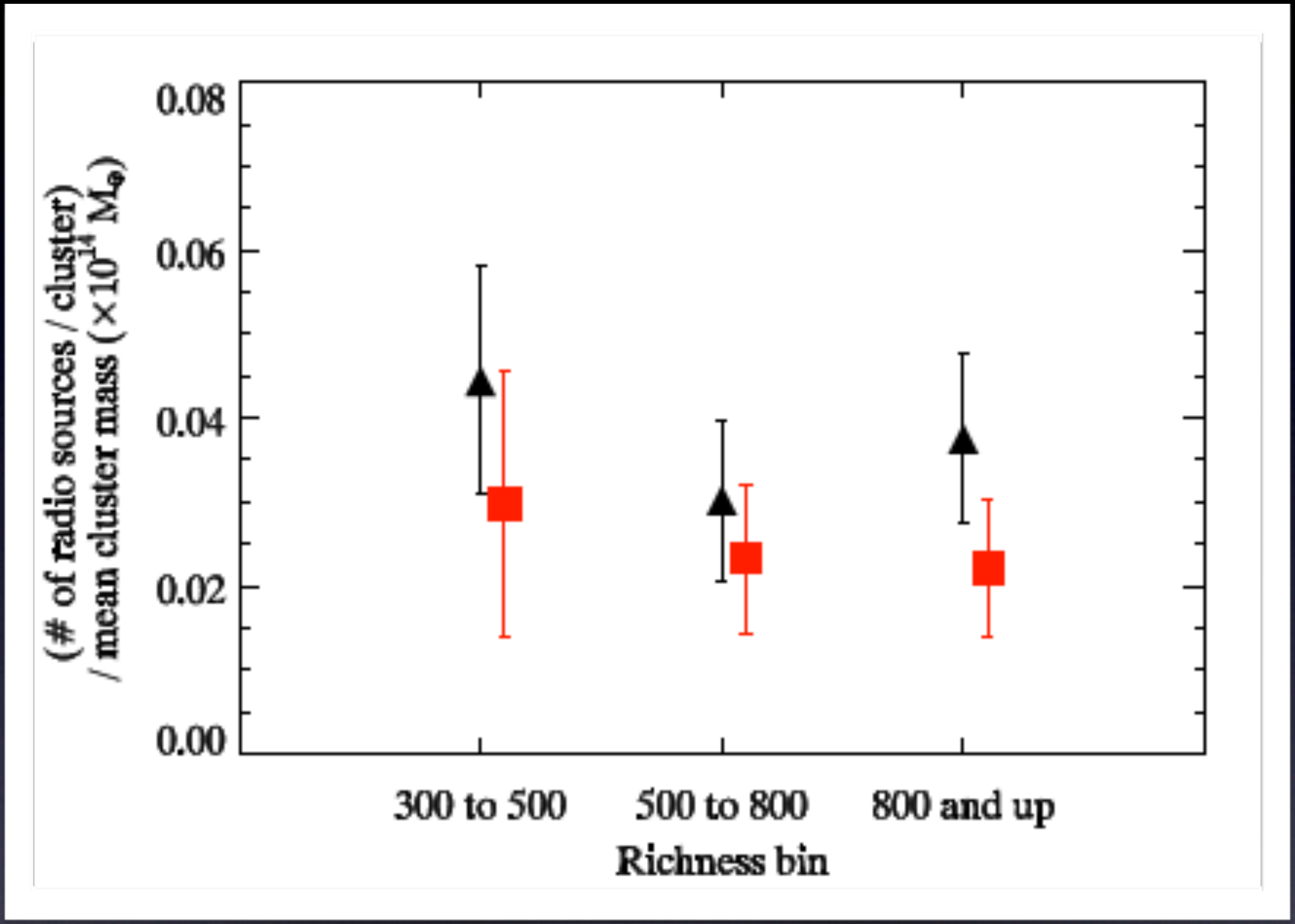
The updated analysis of Lin et al. (2009) used a pure density evolution of the form:

$\varphi(z) \sim \varphi(0)\,(1+z)^{\Upsilon}$

with $\Upsilon=1$
which is much milder than than what was assumed in Lin & Mohr (2007)



SZ contamination “revised”



Gralla, Gladders, Yee & Barrientos, 2011

618 RCS1 clusters

cross-correlated with
FIRST 1.4 GHz data

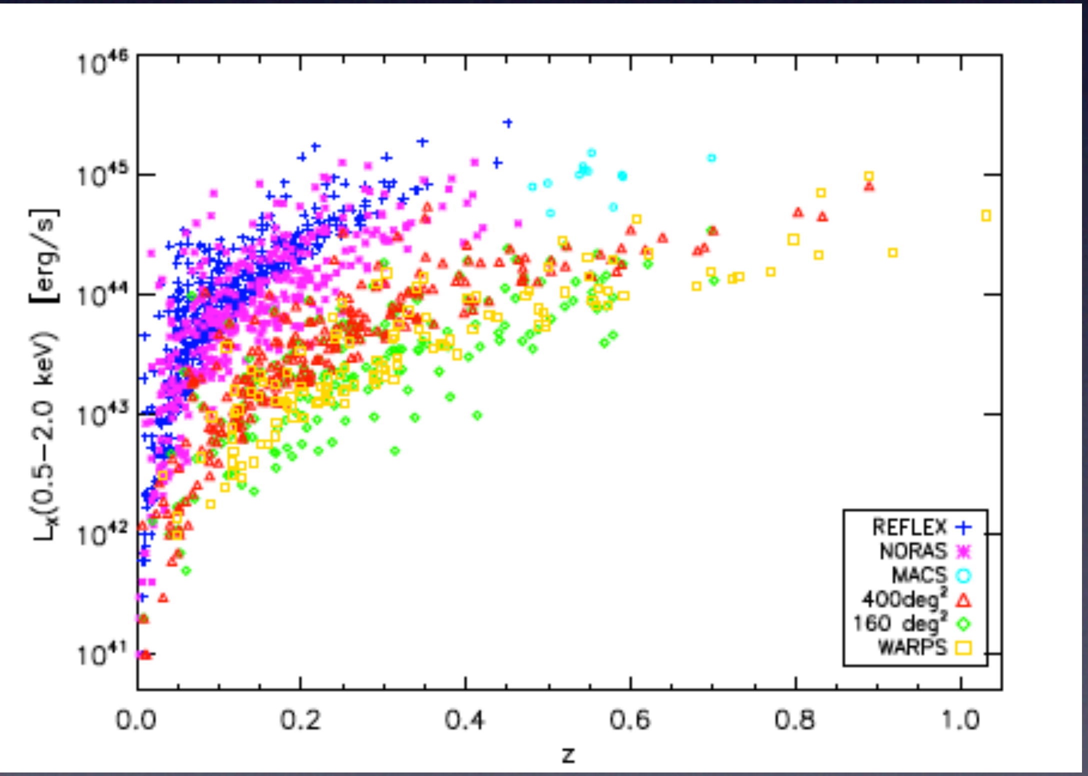
Redshift bins:

0.35 < z < 0.65 (black triangles)
0.65 < z < 0.95 (red squares)

Cluster sample

Main sample	maxBCG	X-ray	
clusters in main sample	13823	1177	
clusters with sufficient separation	12846	1121	
Sub-sample		high-z	low-z
Redshift range	$0.1 \leq z \leq 0.3$	$0.1 \leq z \leq 1.26$	$0.05 < z < 0.12$
Clusters within redshift range	12846	690	292
Clusters with $M > 5 \times 10^{13} M_{\odot}$	12522	674	275
clusters with NVSS coverage[a]	12475	596	218
clusters with FIRST coverage[a]	11812	273	75

Cross-correlate against radio catalogs

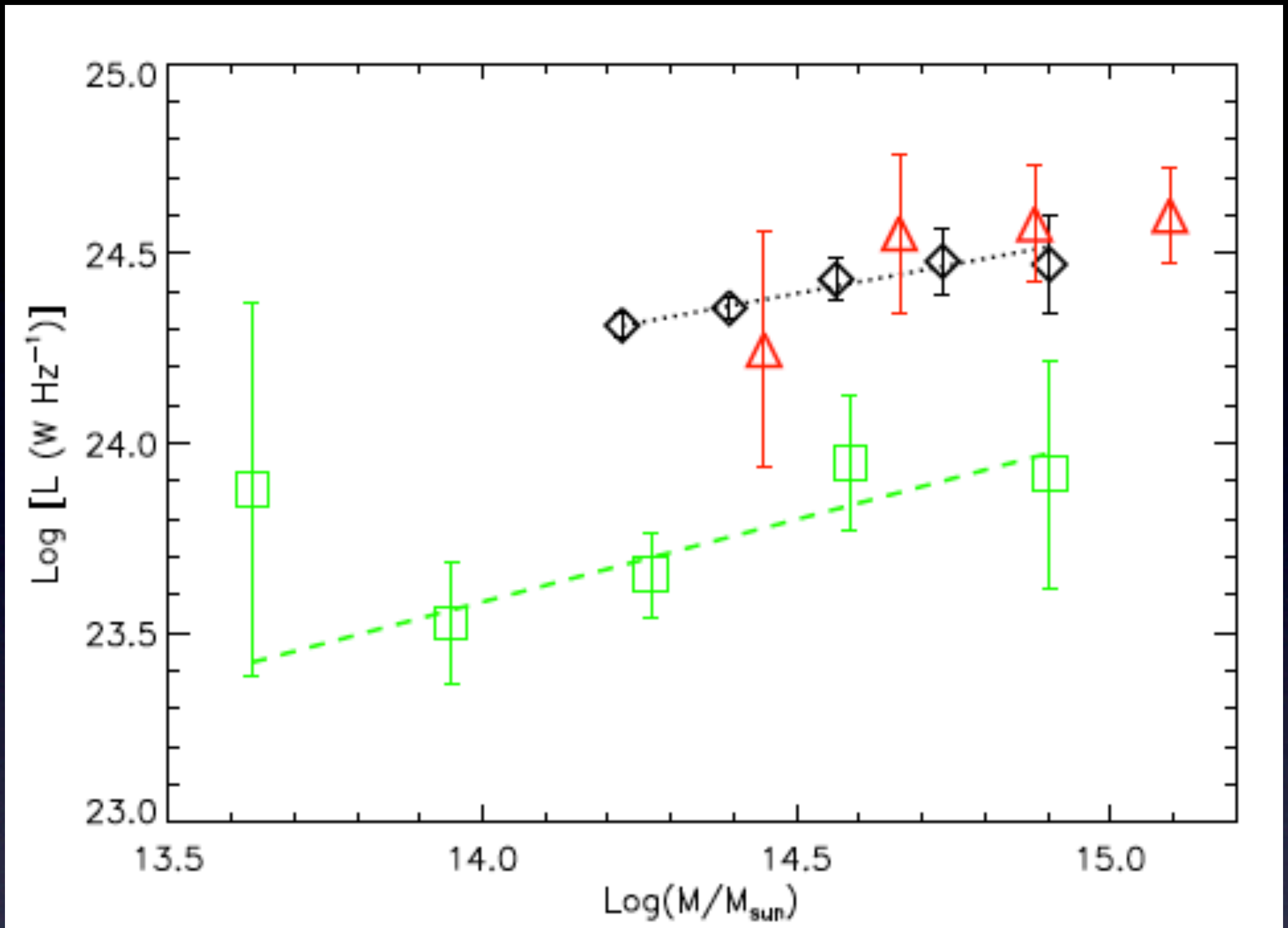


The X-ray "meta"-sample

Properties of the FIRST and NVSS radio continuum surveys

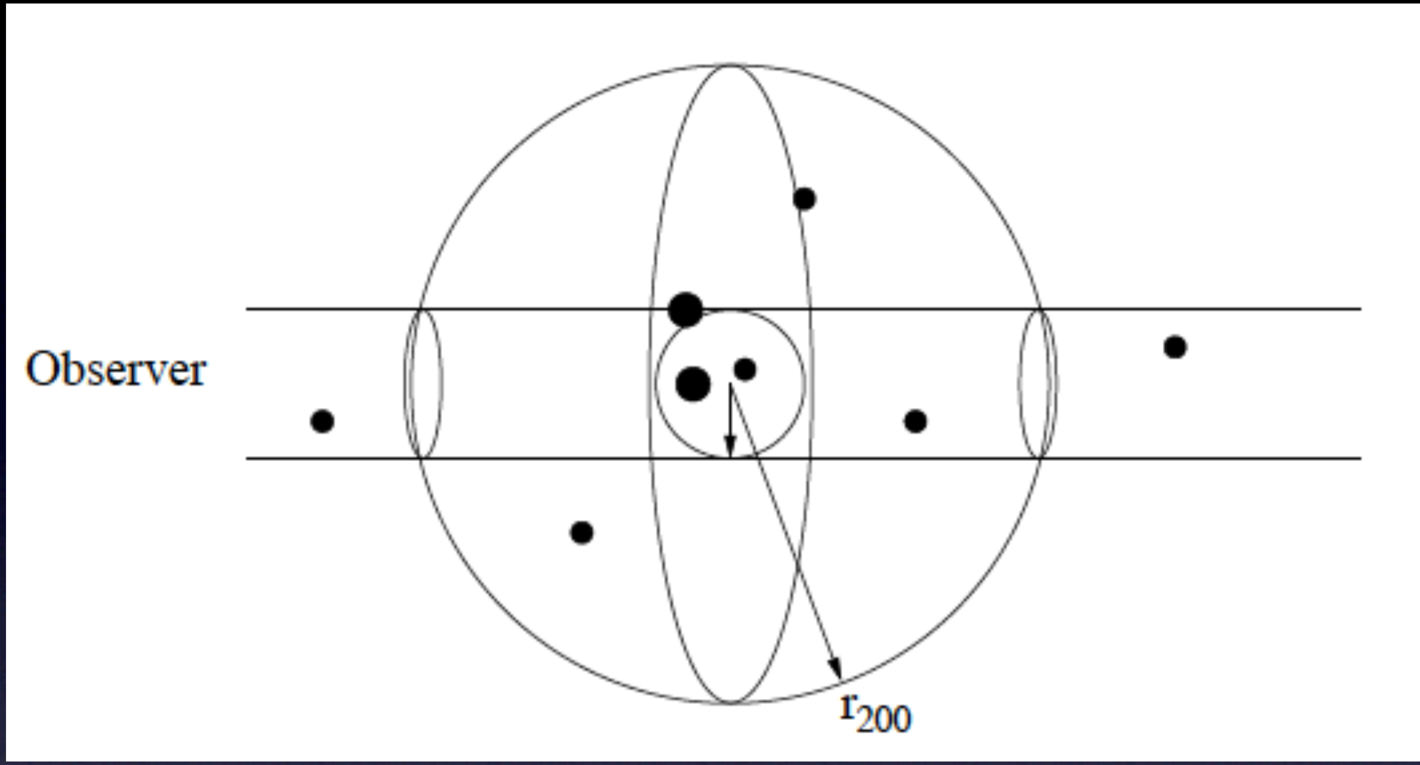
	FIRST	NVSS
effective resolution	5″	45″
completeness limit	1 mJy [a]	~2.5 mJy
positional uncertainty[b]	< 0.5″	< 1″
positional uncertainty[c]	1″	~7″
sources per square degree	~90	~45

Radio luminosity of the BCGs



- Luminosity of the brightest source inside 50 kpc from center
- Similar weak correlation found by Lin & Mohr (2004), Croft et al. (2007), Haarsma et al. (2010) and others
- Deciphering redshift evolution is problematic because clusters can have multiple BCG or other non-BCG radio sources. Also there is a large scatter in the BCG radio luminosity, and <u>accounting for extended radio structure is difficult (need checking by eye!)</u>

Computing the luminosity function

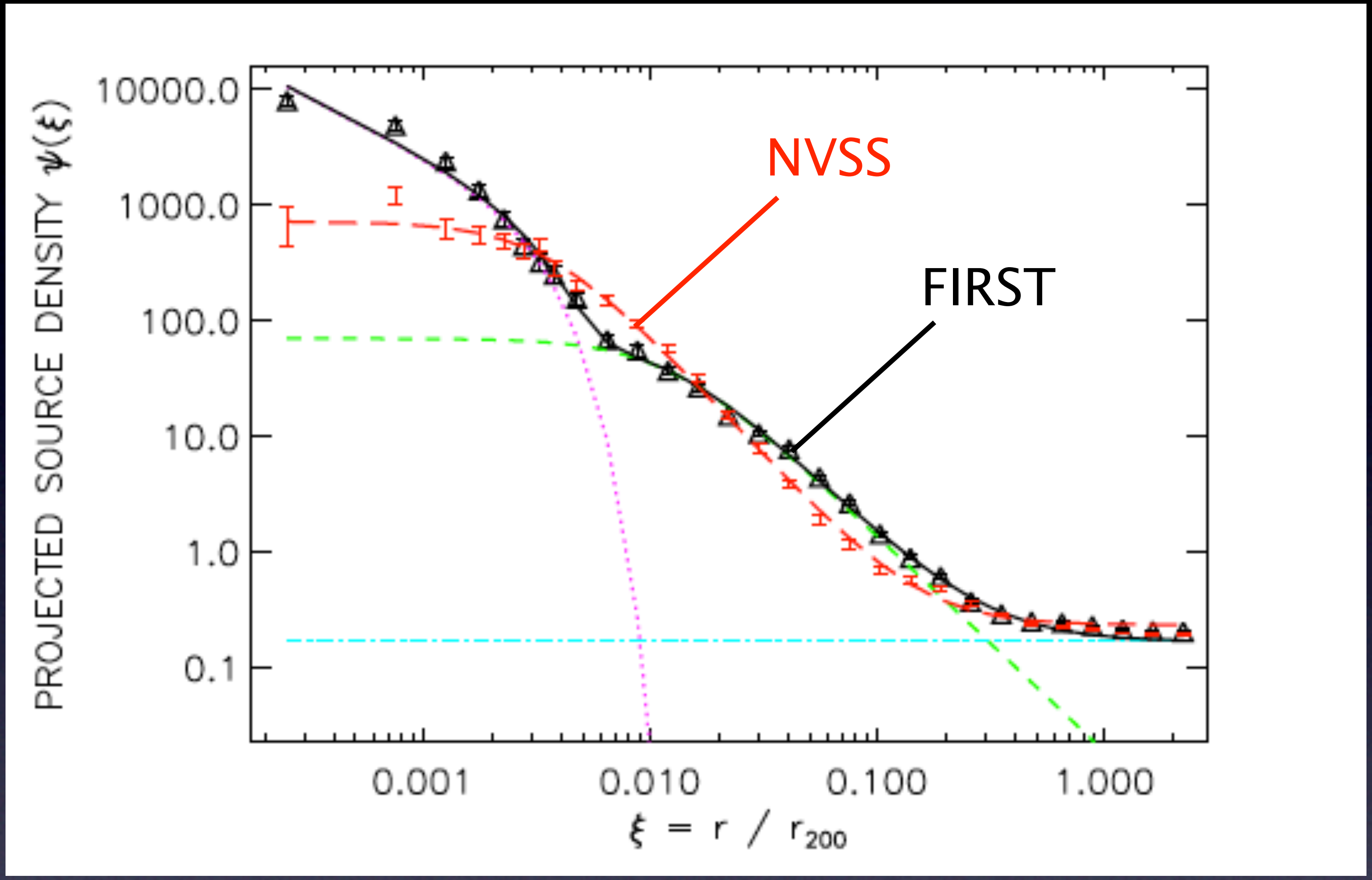


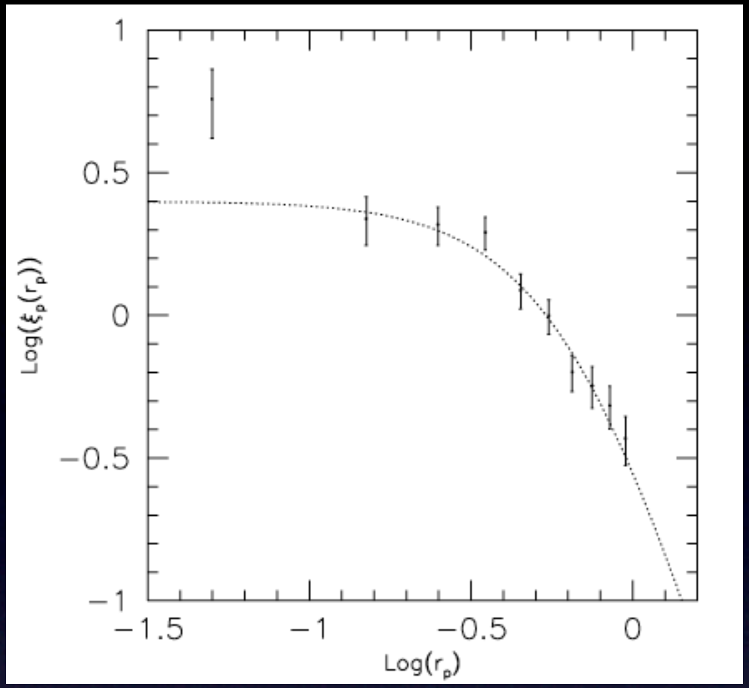
- Using a *radial distribution*, sources are de-projected in a sphere of radius r_{200}

- The luminosity function is simply the number of sources in a luminosity bin per unit cluster volume

- Source confusion is taken into account by artificially degrading the resolution (in radio catalogs) at lower redshift

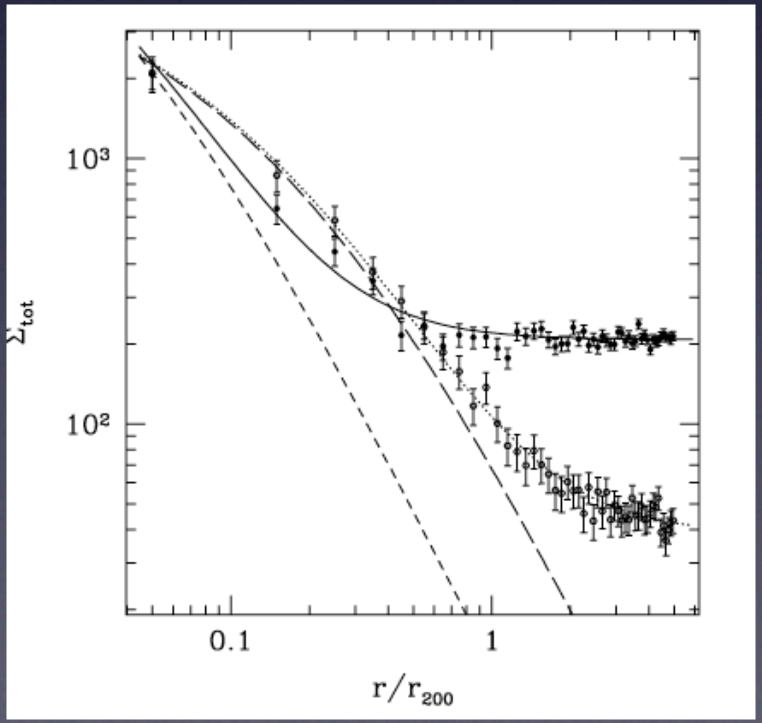
Radial source distribution





Massardi & De Zotti (2004)

Lin & Mohr (2007)

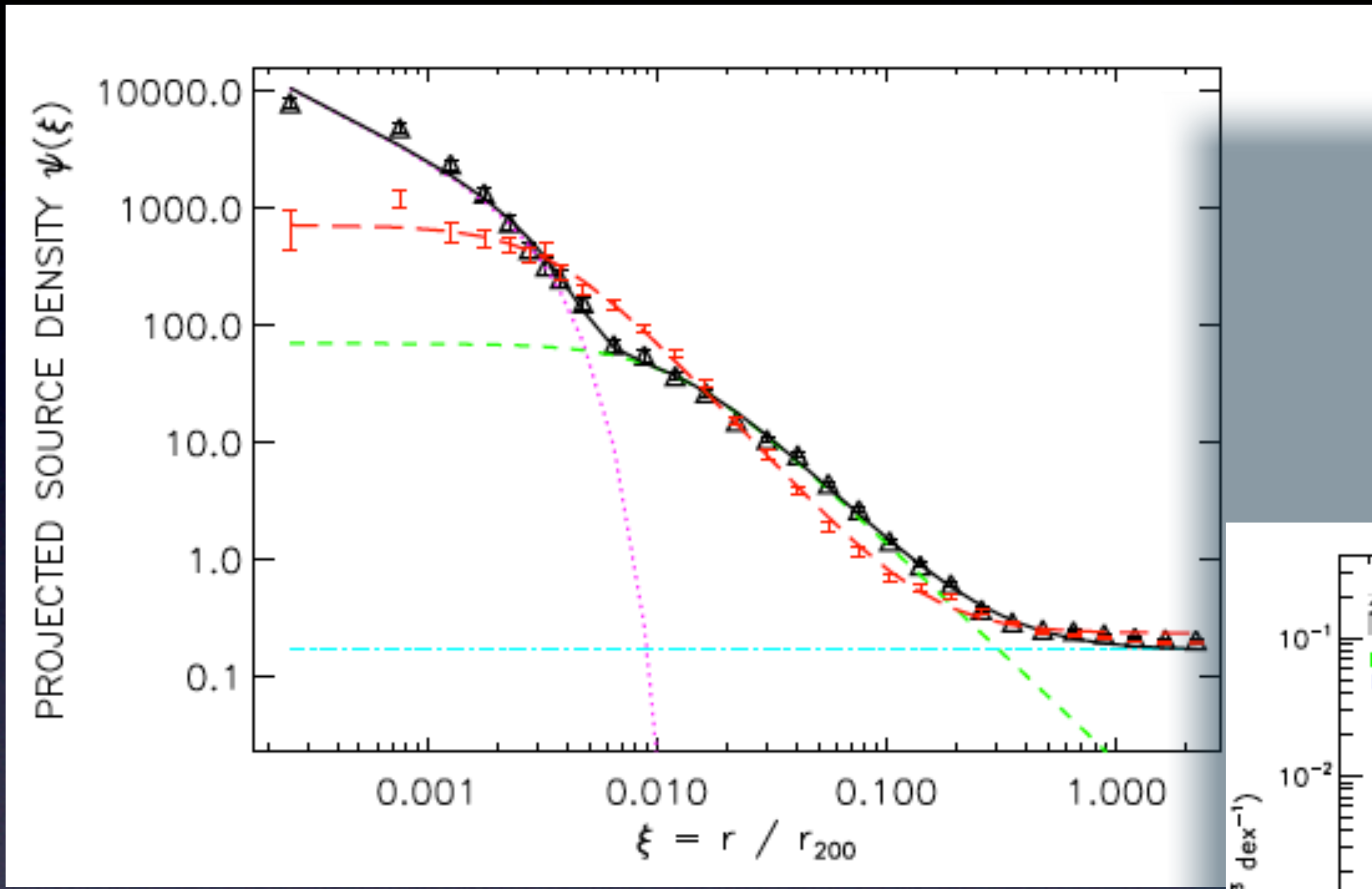


➡ Inner component modeled by a Gaussian, resulting from pointing offset/extended morphology

➡ Outer component fitted with a β-model, corresponding to the distribution of radio sources

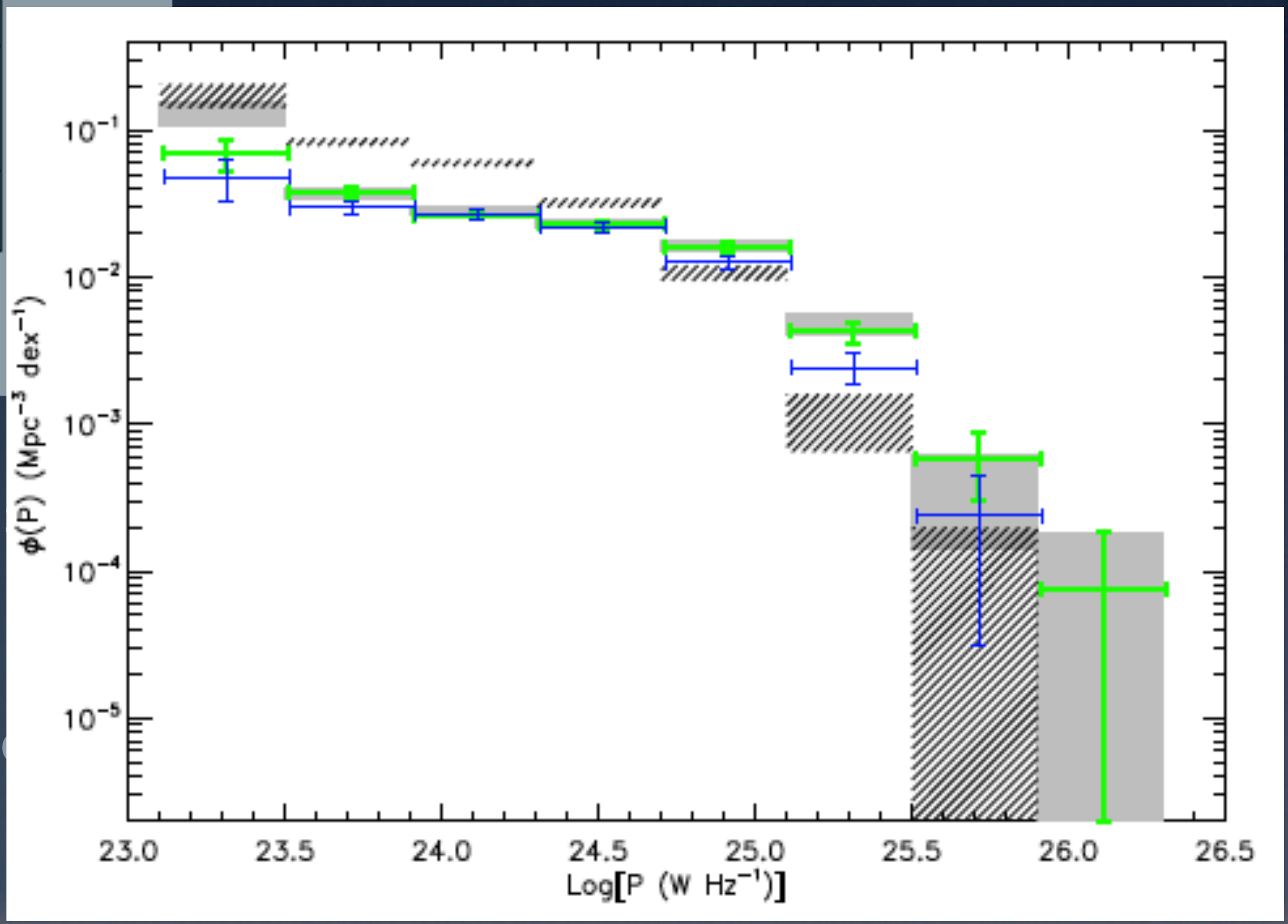
➡ The flat component is the field population

Radial source distribution



Boxes: FIRST and NVSS uncorrected

Error bars: After degrading to a common resolution



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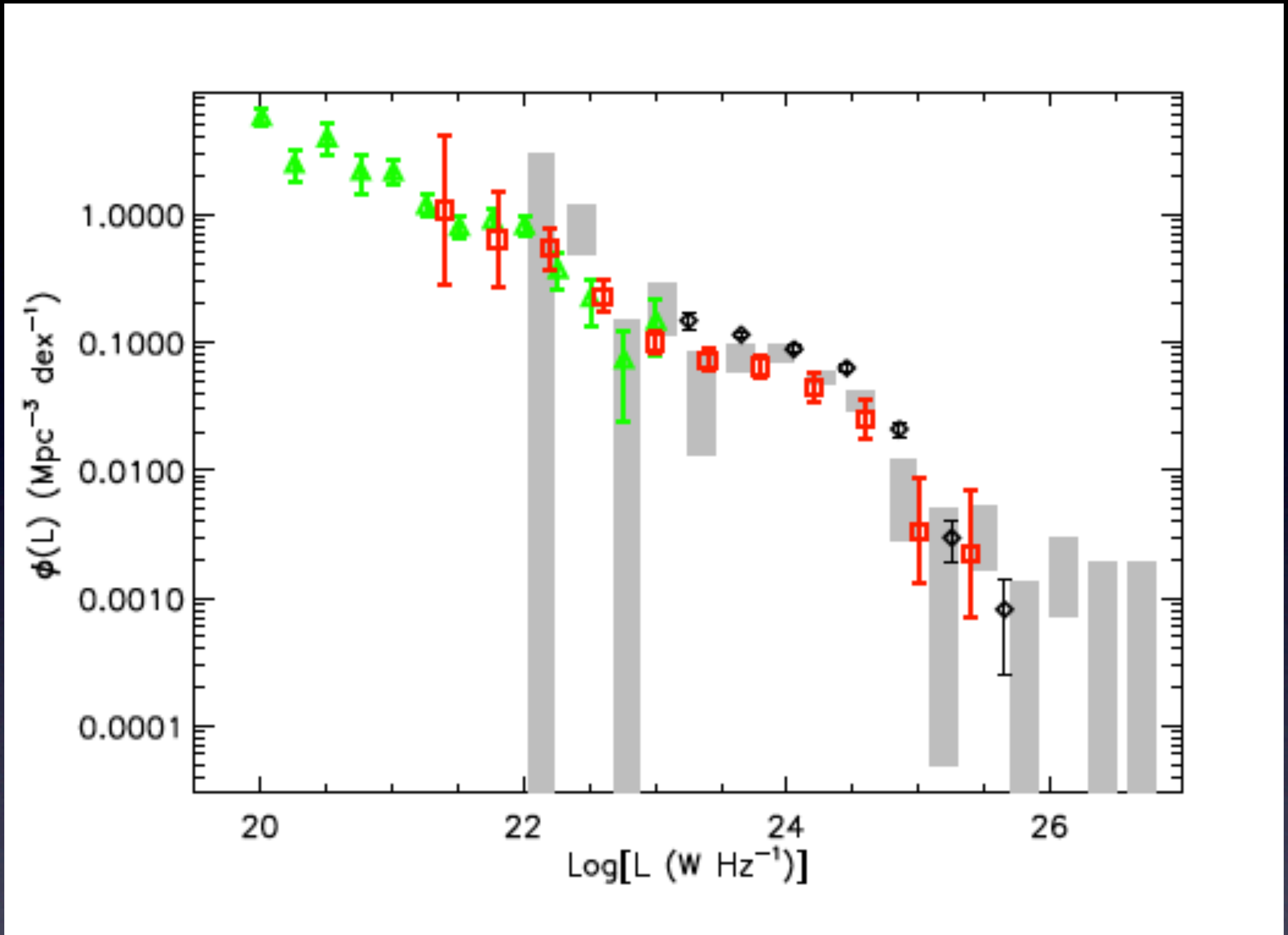
Radio luminosity function



Result from a low-redshift (0.1 < z < 0.17) maxBCG sub-sample is compared with Lin & Mohr (2007) Massardi & De Zotti (2004) and Reddy & Yun (2004).

Modeling *z* and *M* dependence

Fit the luminosity function with a hyperbolic fitting function
Condon et al (2002, ..), Lin and Mohr (2007)

$$\log \phi = y - \left(b^2 + \left(\frac{\log L - x}{w} \right)^2 \right)^{1/2} - 1.5 \log L.$$

and assume that the shape of the luminosity function does not change with redshift

$$\phi(L, z) \ = \ g(z)\, \phi\, [L f(z), z \approx 0]\,,$$

$$L = L_0 \left(\frac{1+z}{1+z_0} \right)^{\alpha_L},$$

← Luminosity scaling

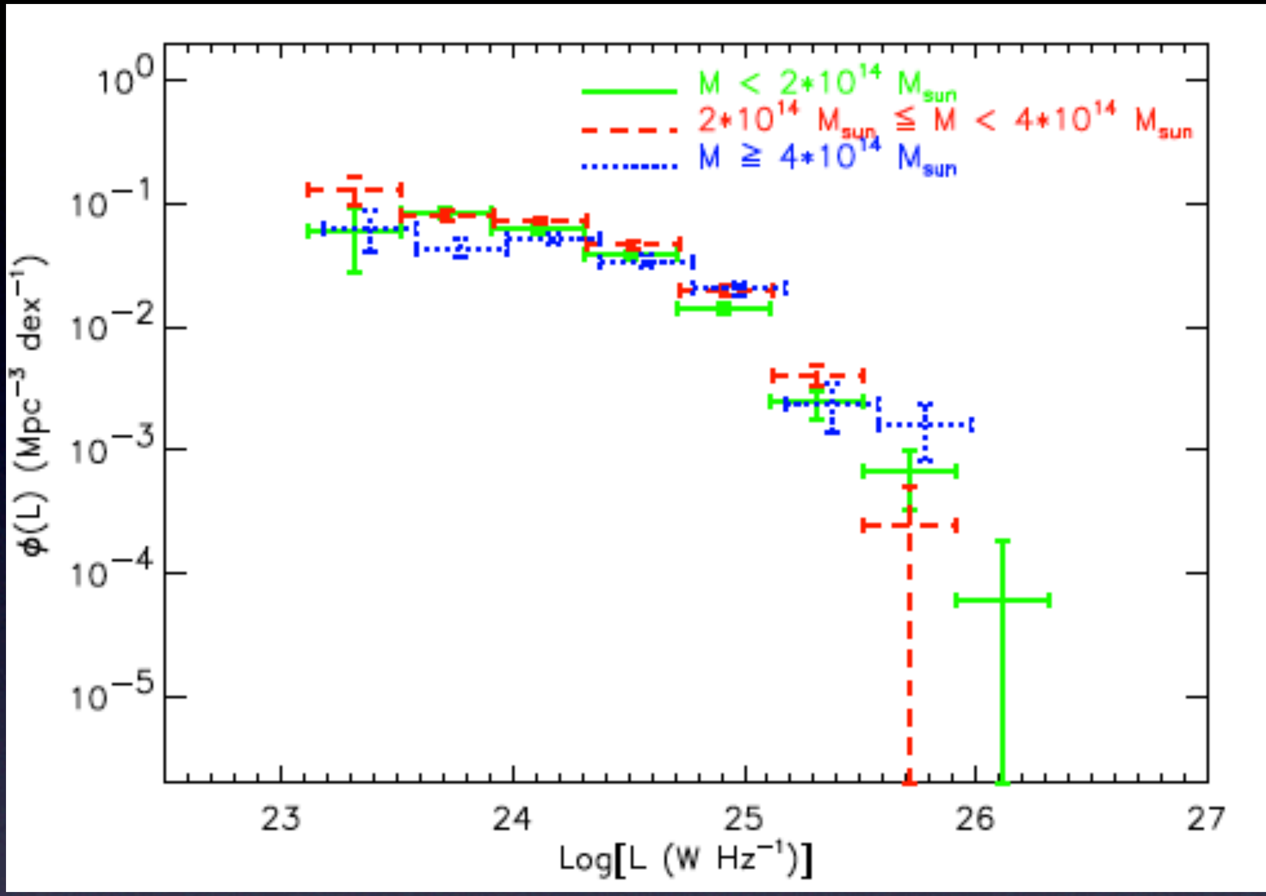
$$\phi = \phi_0 \left(\frac{1+z}{1+z_0} \right)^{\alpha_\phi},$$

← no. density scaling

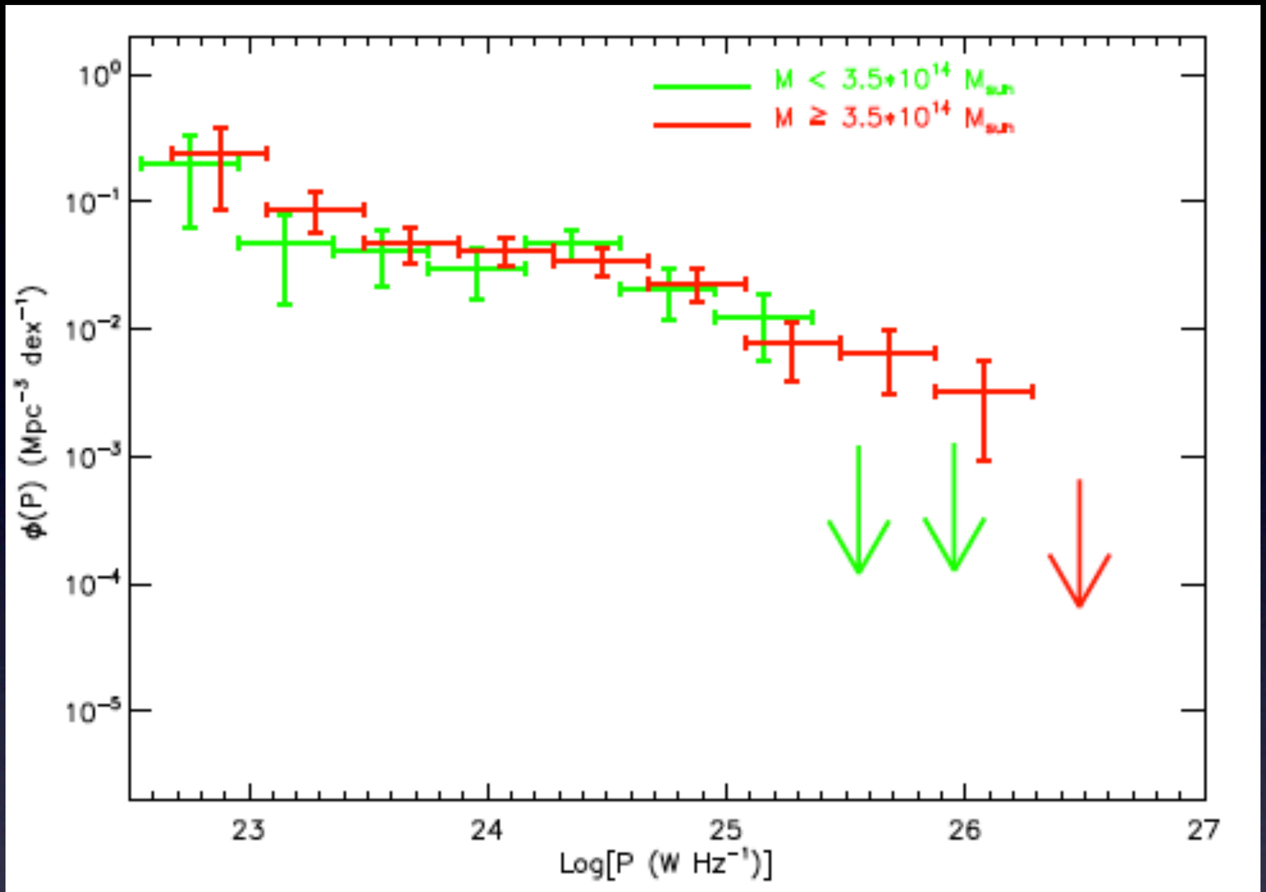
Similarly for mass dependence

$$L \sim (M_{200})^{\gamma_L};$$
$$\phi \sim (M_{200})^{\gamma_\phi}.$$

Mass dependence



optical sample



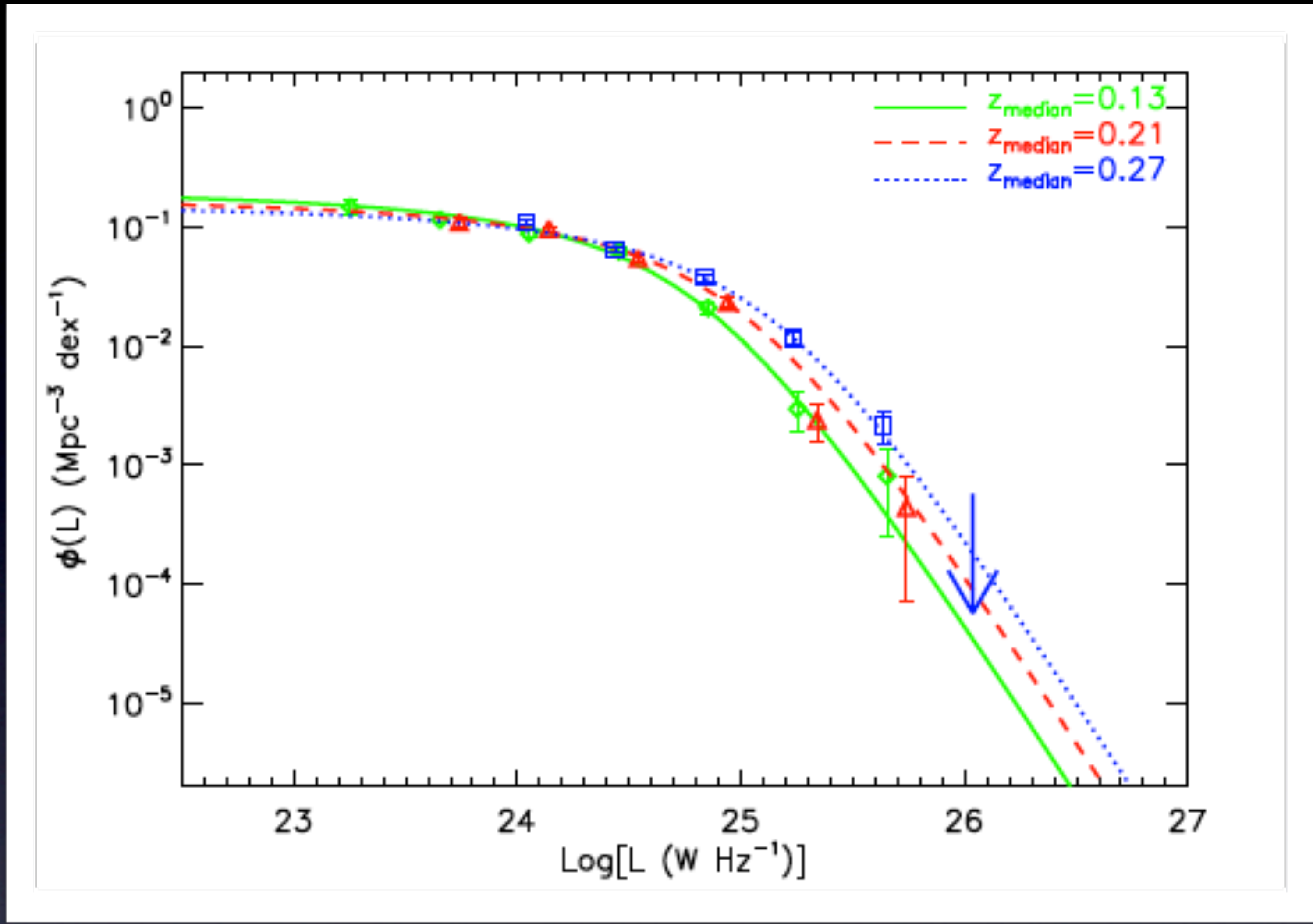
X-ray sample

✦ No conclusive evidence of mass dependence in the radio LF (although consistent with more luminous sources to be in more massive clusters)

✦ The mass effect possibly got offset by having more low-mass systems (smaller volume) and having no starburst population

Redshift evolution

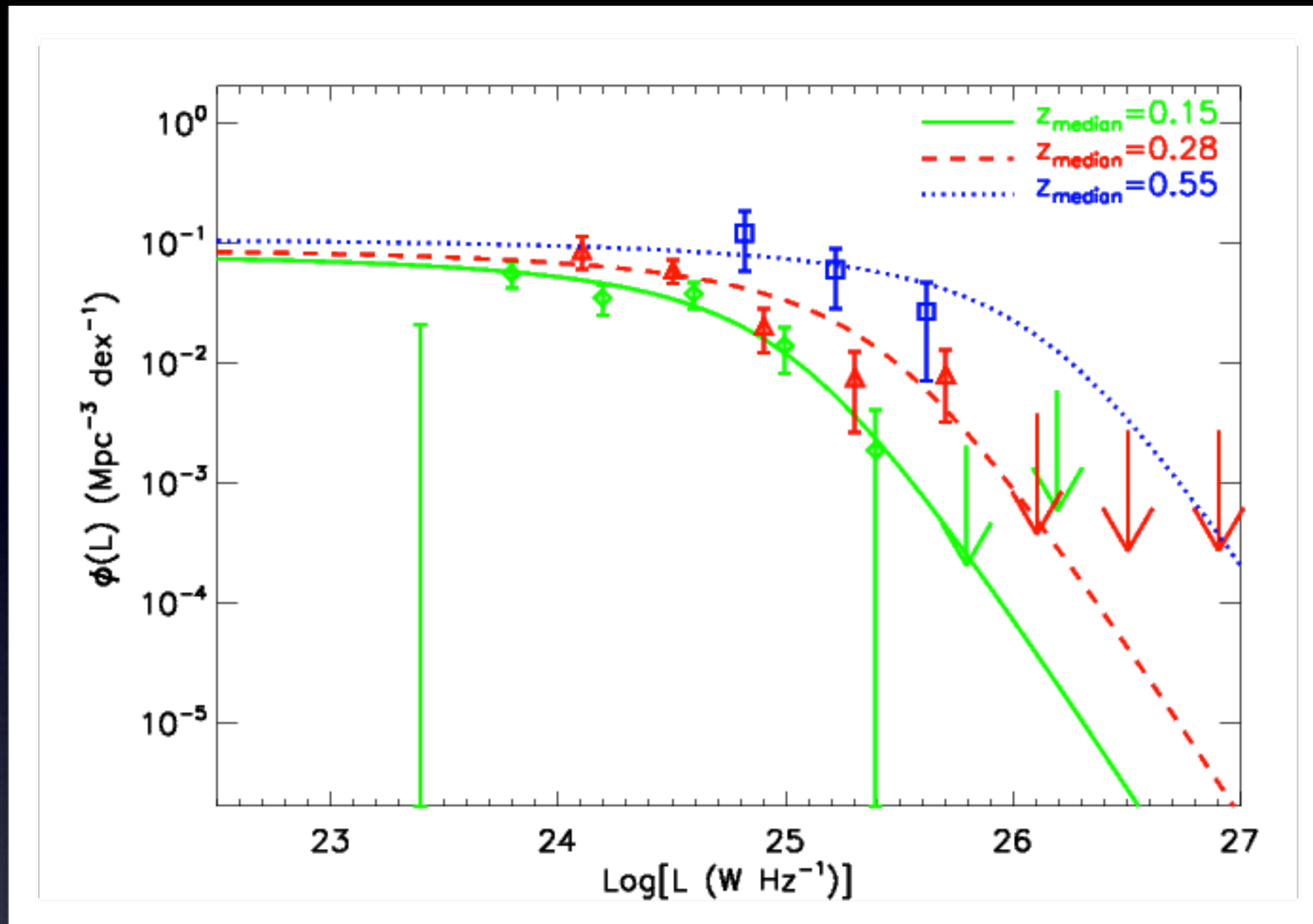
OPTICAL SAMPLE



Cluster sample	Source catalog	Priors	y	b	x	w	α_ϕ	α_L	$\chi^2_{\rm red}$
maxBCG	FIRST		36.38±1.02	1.05±0.73	24.53±0.18	0.66±0.13	−2.46±1.58	6.20±1.76	1.07
maxBCG	FIRST	$\alpha_\phi = 0$	36.34±0.92	0.91±0.81	24.87±0.14	0.72±0.21	(0.0)	3.99±1.24	1.19
maxBCG	FIRST	$\alpha_L = 0$	36.74±0.89	1.01±0.55	25.11±0.11	0.71±0.19	1.03±1.14	(0.0)	2.25
X-ray	FIRST	(a)	36.19±0.19	(1.05)	(24.53)	(0.66)	0.76±1.86	8.12±2.67	0.94
X-ray	FIRST	(a); $\alpha_\phi = 0$	36.26±0.10	(1.05)	(24.53)	(0.66)	(0.0)	8.19±2.66	0.89
X-ray	FIRST	(a); $\alpha_L = 0$	35.89±0.18	(1.05)	(24.53)	(0.66)	9.40±1.85	(0.0)	10.48

Redshift evolution

X-RAY SAMPLE



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To conclude:

You can argue the result, or you can prove it wrong, but you cannot ignore!

- **We find a strong redshift evolution for the cluster radio luminosity function, with more than ten-fold increase in the AGN luminosity at z=1**
  - ➡ are we measuring the wrong thing?
  - ➡ are we affected by weird selection bias?
- **If not, then we have non-trivial impact on the SZ cluster selection function at high-z (steep SEDs can still save the day)**