The highest redshift X-ray selected AGN

Brusa et al., 2009, ApJ 693, 8 (XMM-COSMOS)
CIvano, Brusa et al. 2011, ApJ 741, 91 (C-COSMOS)
+ flash on new results

Importance of high-z QSO

- How and when do early BHs form and grow?

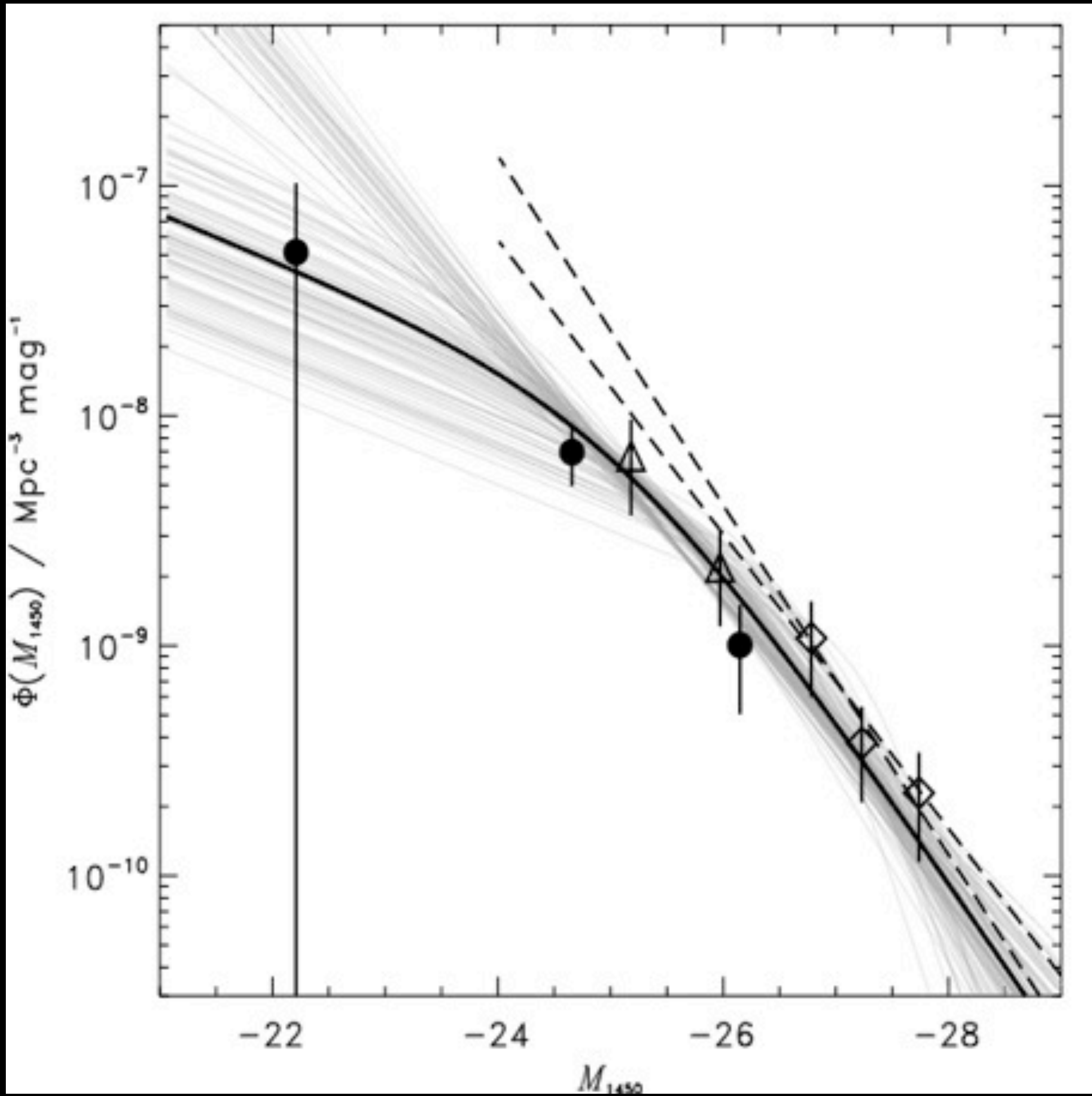
Plenty of models in hierarchical scenario (see e.g. Rees 1978 ... Begelman+10, etc.)
Formation paths from BH seeds + (Eddington limited) accretion modes
What is the high-z BH mass ***and*** luminosity function?

- What formed first, BH or galaxy?

Some evidence for larger BH per fixed stellar mass up to z~4 (see e.g. Peng+06, Merloni+10). But also suggestions for M_{BH}/M_{*}~0.1-0.3 in SMG/QSO2 at z>2 (Alexander+05)

QSOs at high-z: where do we stand

About 40 QSOs **optically selected** at z>5.7, ~15 at z>6, mostly from SDSS and CFHQZ, logL(bol)~47. **[UKIDSS/VISTA results NOT included]**



Fan+2001-06;
Willott et al. 2010
Jiang et al. 2010
z ~ 6 Luminosity Function

Mortlock et al. 2011: record holder at z=7.1

They are already "mature":
large (~3-7 x 10^9 M_{sun}) BH masses
high metallicity and dust content, not significantly different from lower-z QSO (Beelen+06, Juarez +09, Kurk +09; but see also Jiang+10)

They are accreting at $L \sim L_{edd}$
(required in order to get the BH mass in less than 1 Gyr from stellar mass seeds)
Challenge for structure formation models

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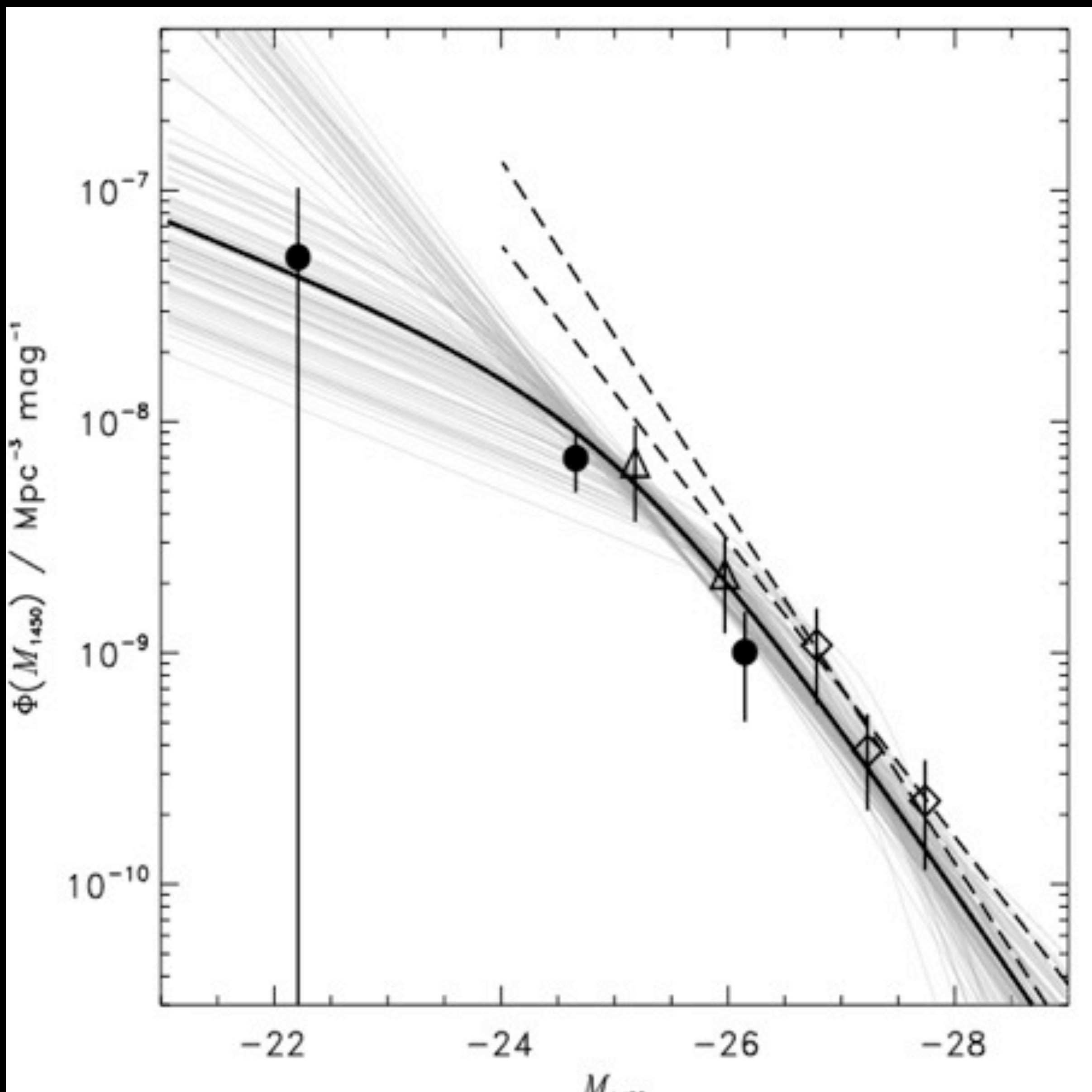

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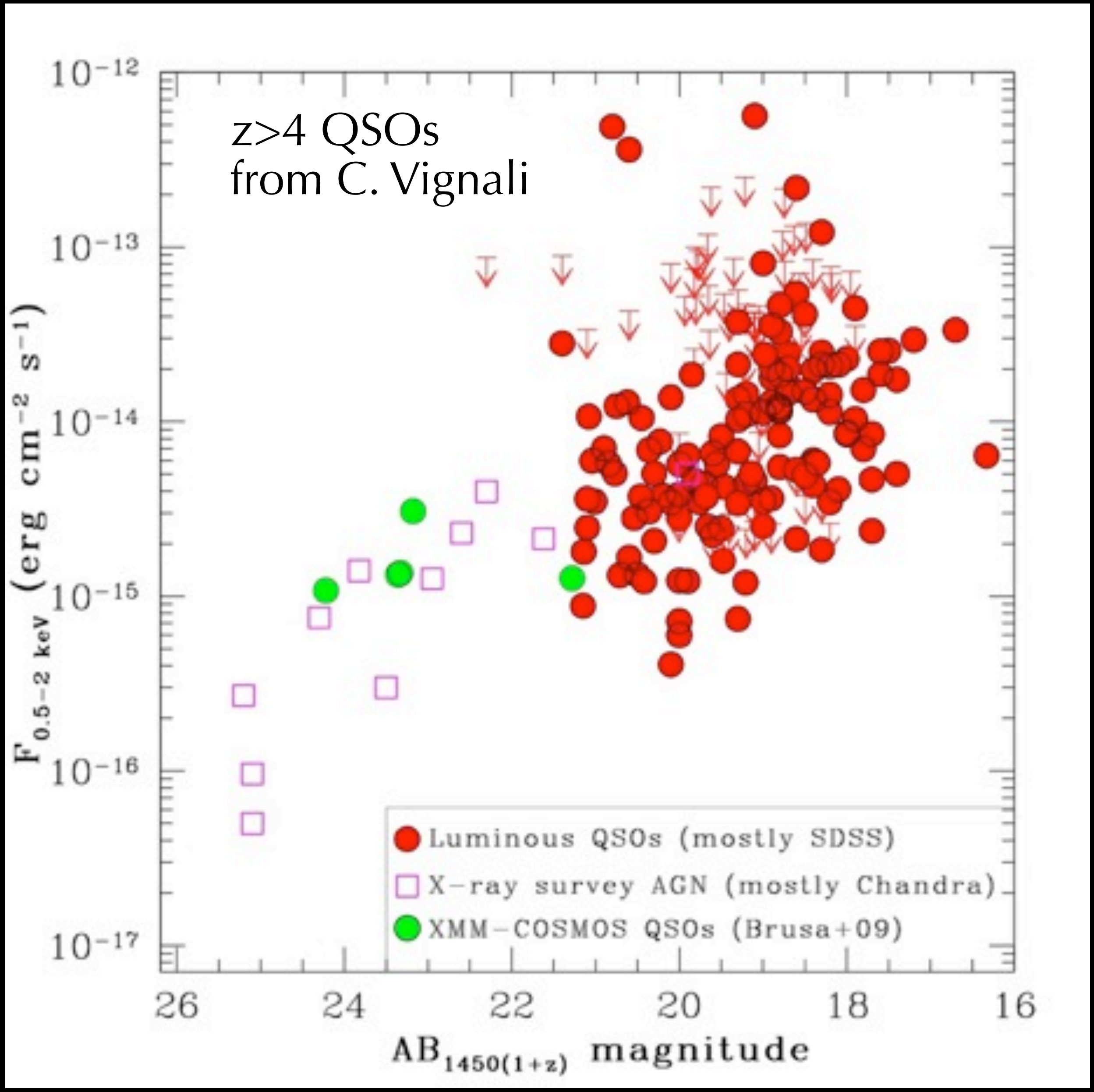
Likely not representative of the entire QSO population. There could be (many ?) more lower L and obscured AGN missed by optical selection (dust).

X-rays from high-z QSO

X-rays needed to get the LF faint end (more representative of the whole high-z pop)



2000-2010:
Chandra/XMM contribution
Follow-up of optically SDSS QSOs
(Brandt+02, Mathur+02,Vignali+03,05; Willott+03)

First complete & statistically significant samples of X-ray selected z~3-4 QSOs (Brusa+09, Aird+10)

The number of high-z AGN detected so far

	Optical	X-ray
z > 3	8000	~100
z > 4	1500	~20
z > 5	150	3-5
z > 6	~15	0

bust statistics still ***low for z>4***

Present X-ray surveys still limited by sensitivity over solid angle

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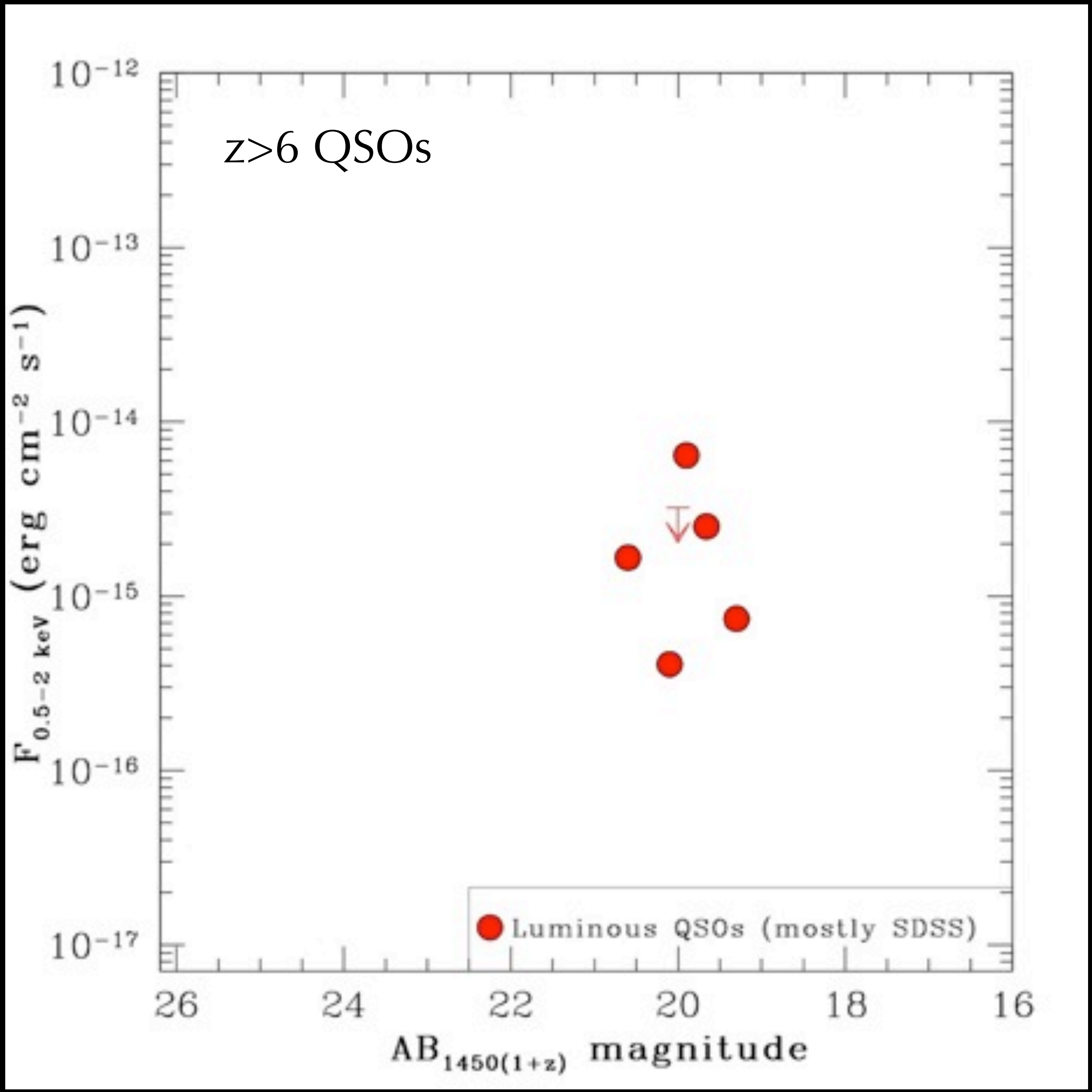

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Selection details of X-ray samples in COSMOS

(soft) X-ray samples, combine spectro-z + photoz
Brusa et al. 2009 / Civano et al. 2011

1) C-Cosmos catalog (Elvis et al. 2009, Civano et al. 2012): 1761 sources (no cut in flux limit)

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65 objects, 29 with specz>3, 36 with photoz>3

TABLE 1
SUMMARY OF THE Z>3 SAMPLE.

	Total			Spec.			Phot.			Phot.+1σ >3		
	S	H	F	S	H	F	S	H	F	S	H	F
z>3	81	14	6	29	2	0	36	10	4	16	2	2
z>4	14	1	1	6	0	0	7	1	0	1	0	1
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3) all the sources with photoz>2 have been inspected and flagged if photoz+error > 3 (16, shaded areas in the figures)

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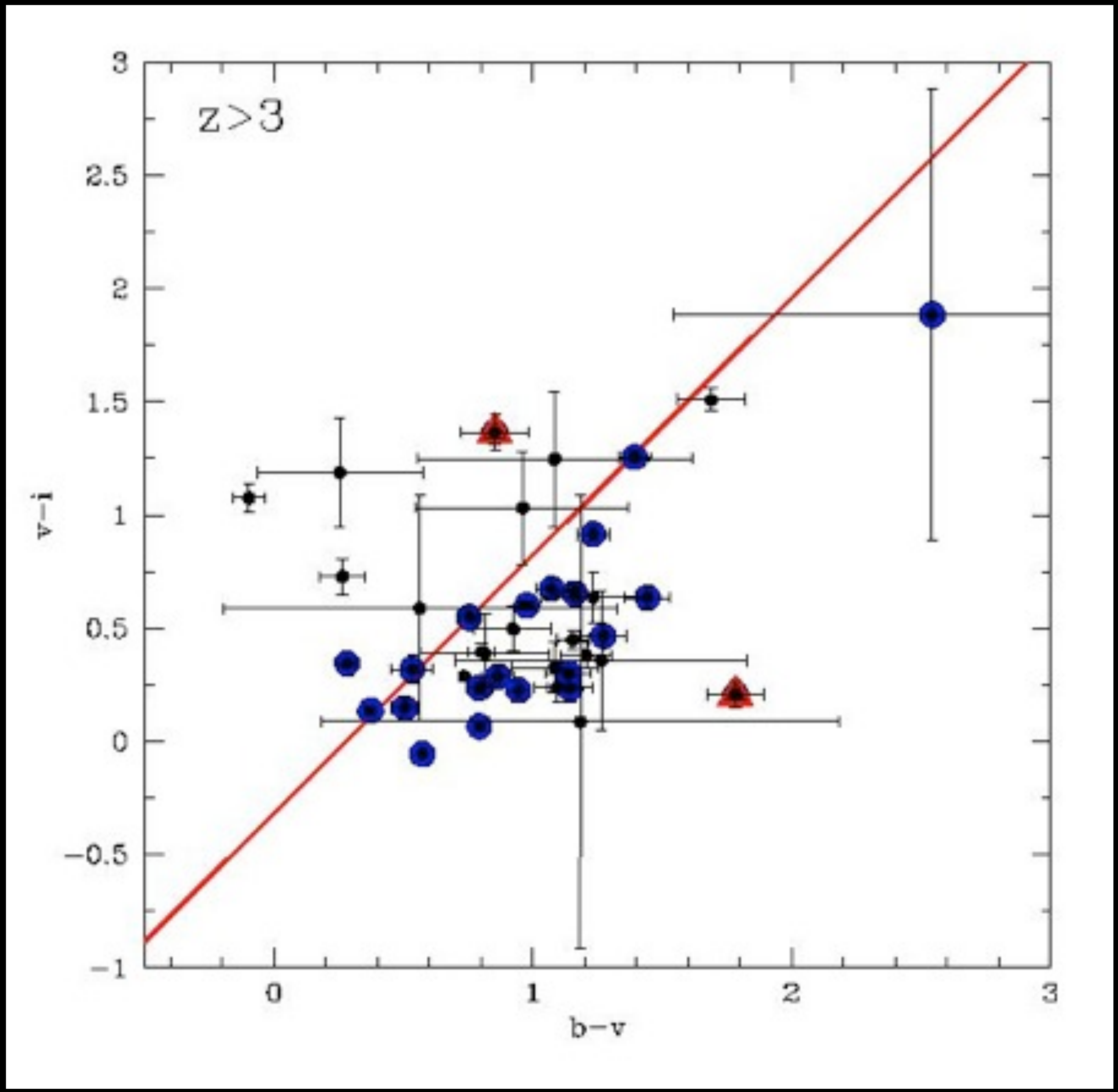
Color color selection v-I vs. b-v
(proposed, e.g. in Casey et al. 2008, Siana et al. 2007)



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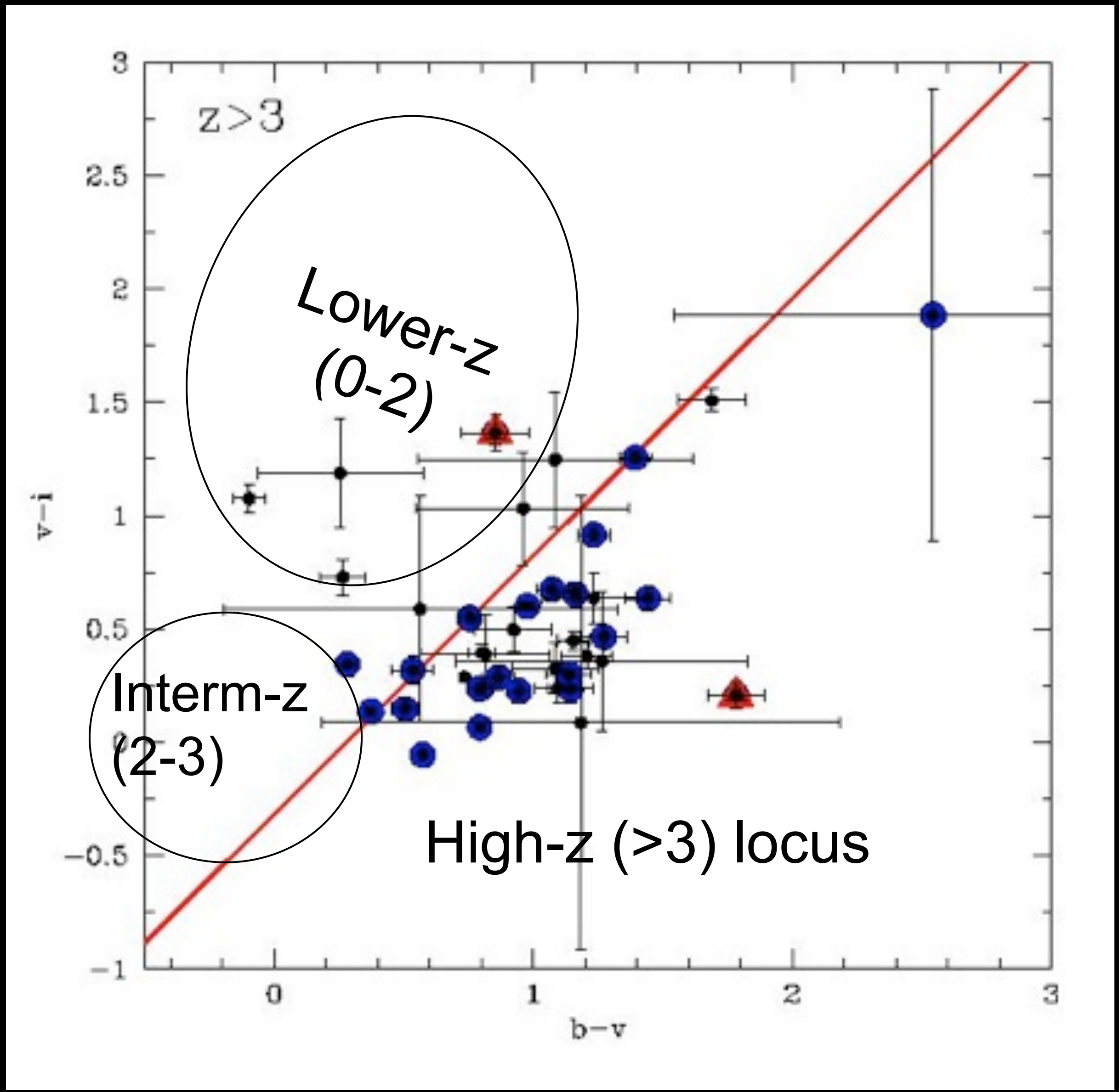

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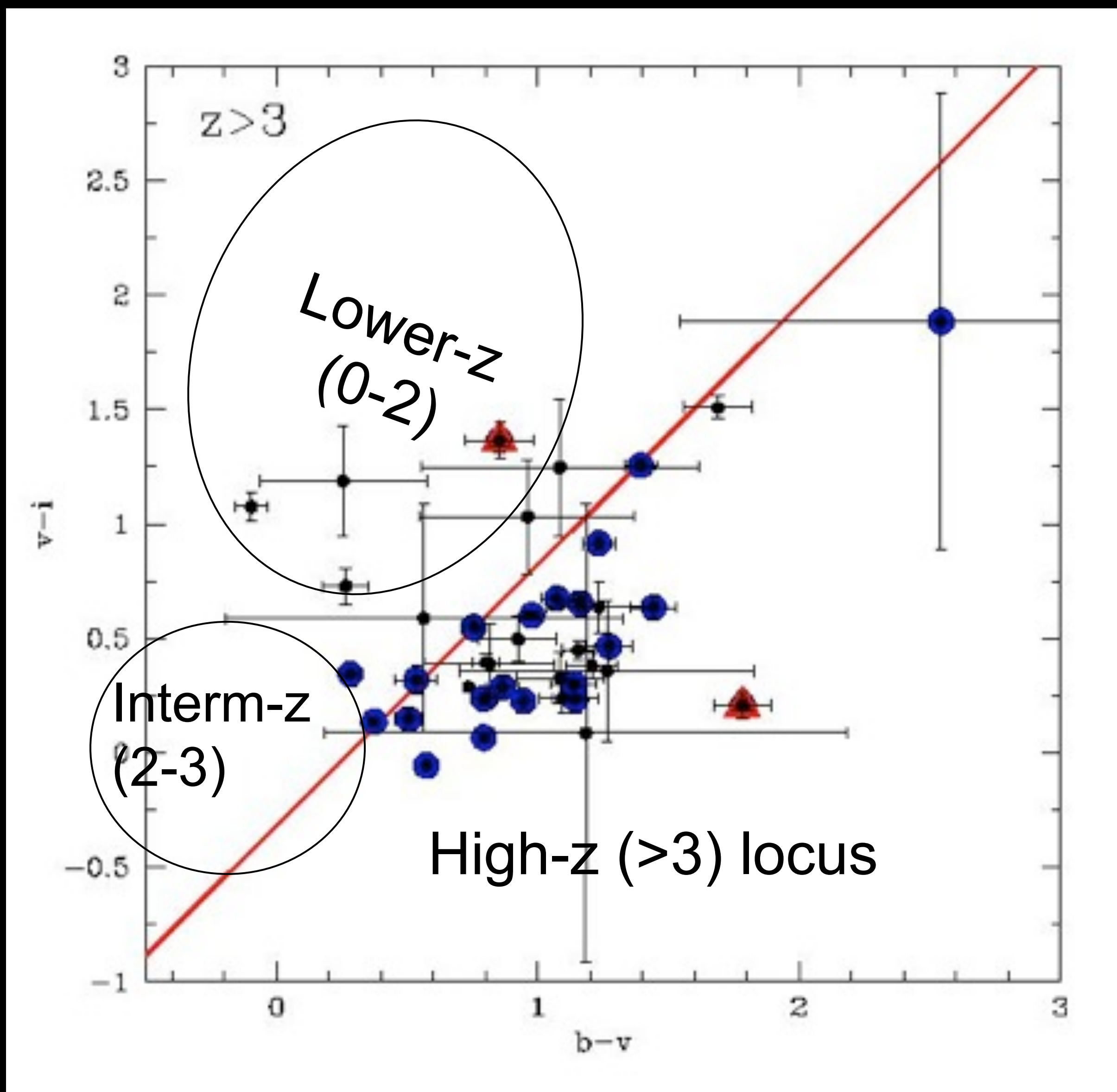

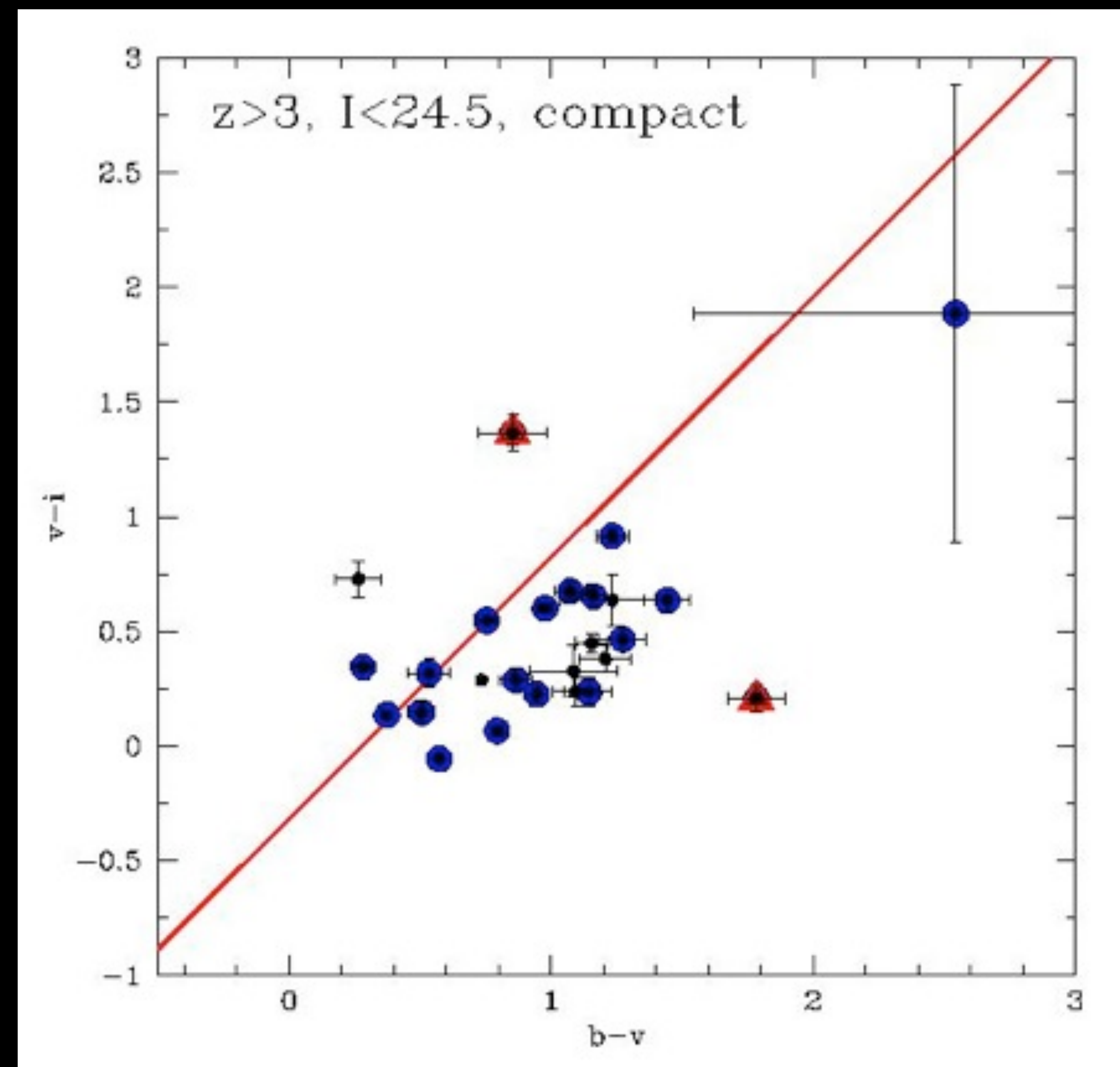

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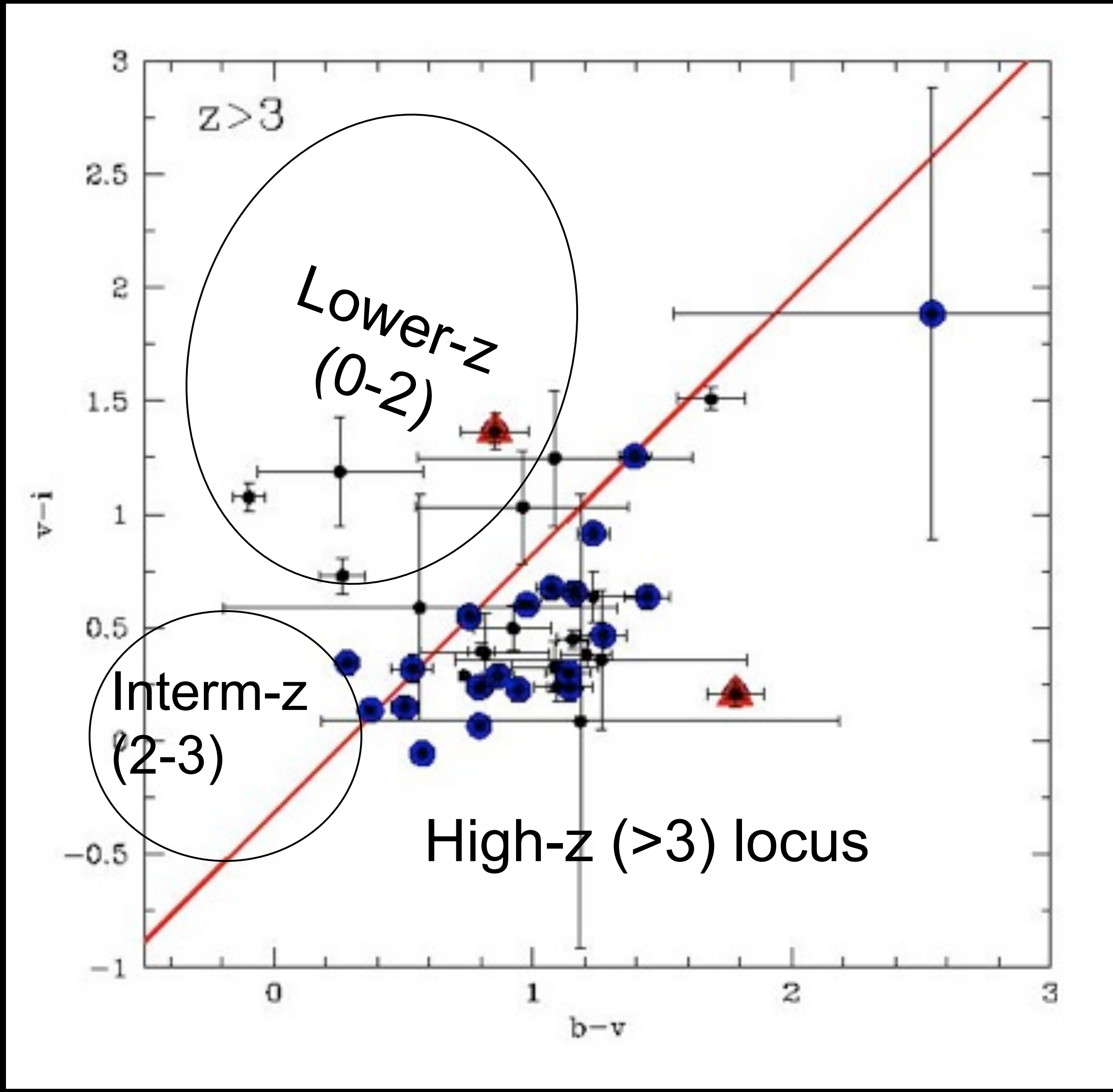

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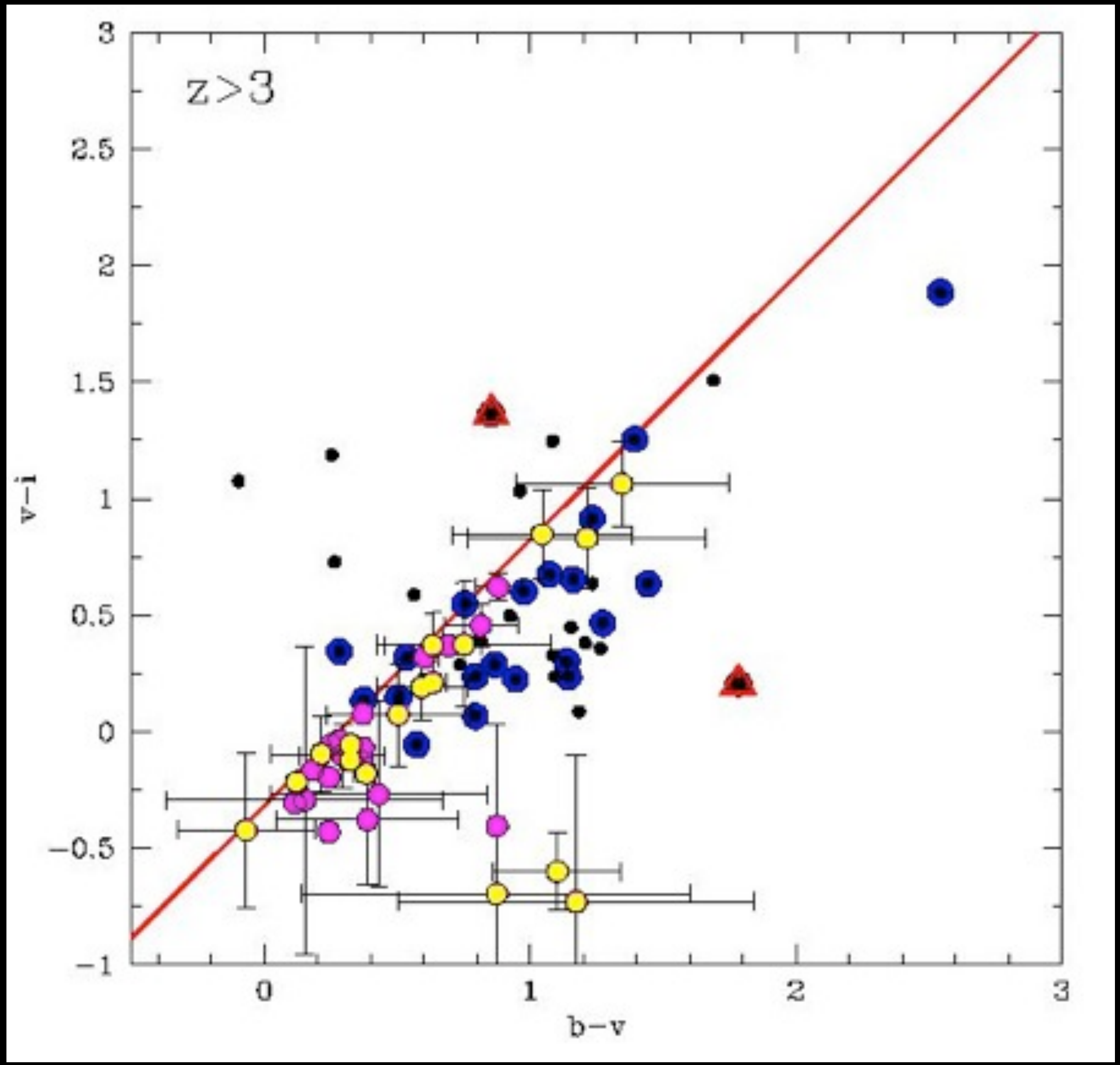


~40 (magenta/yellow) contaminants

high-redshift universe: source counts

data from COSMOS survey

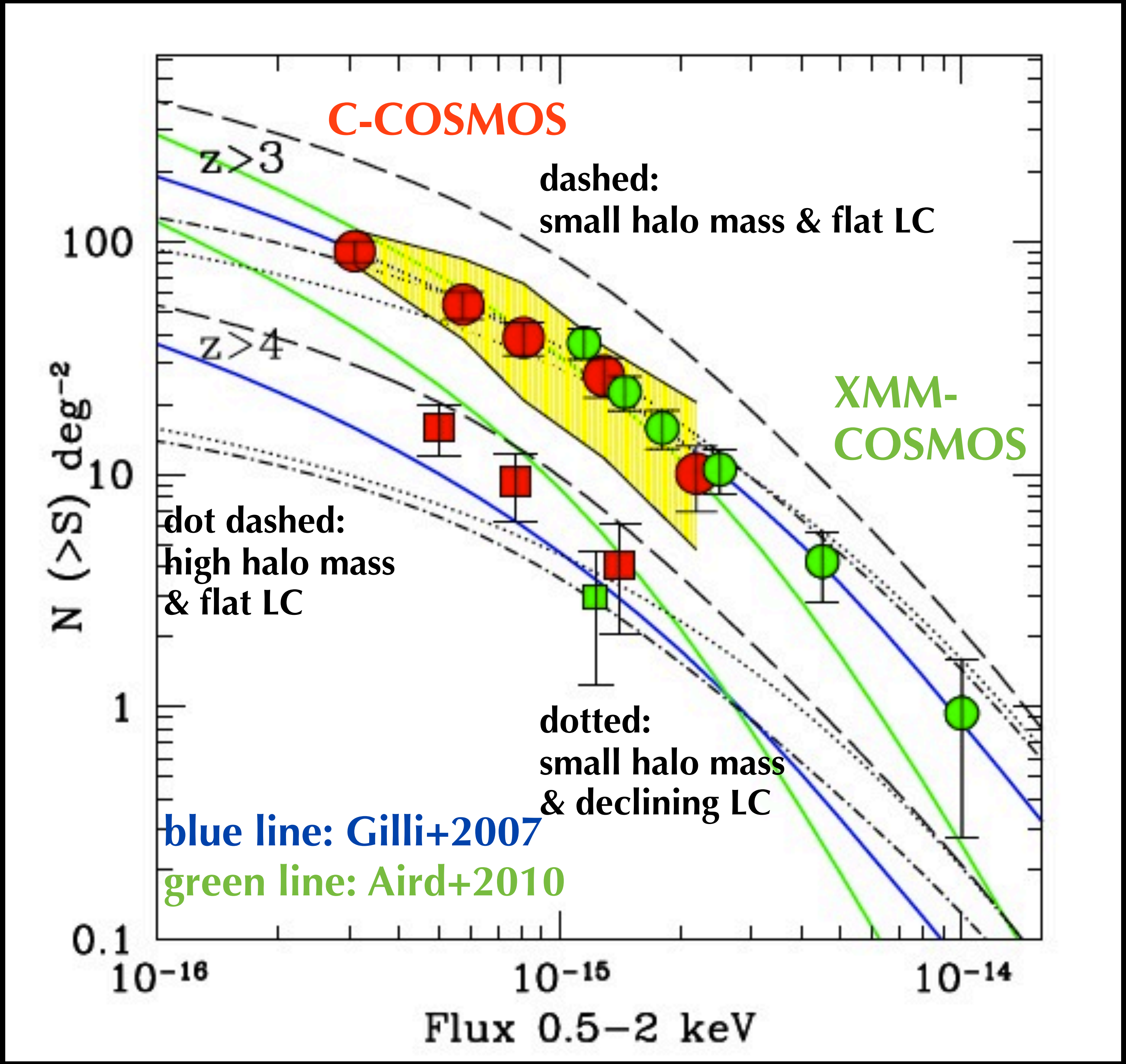
Brusa et al. 2009 (XMM),
Civano, MB+11 (Chandra)

selection based on spectro-z and photoz
(from Salvato+09 & in prep)
~80 objects, 50% specz

in C-COSMOS
14 at z>4 (6 spectro-z)
4 at z>5 (2 spectro-z)
1 at z>6 (photoz)

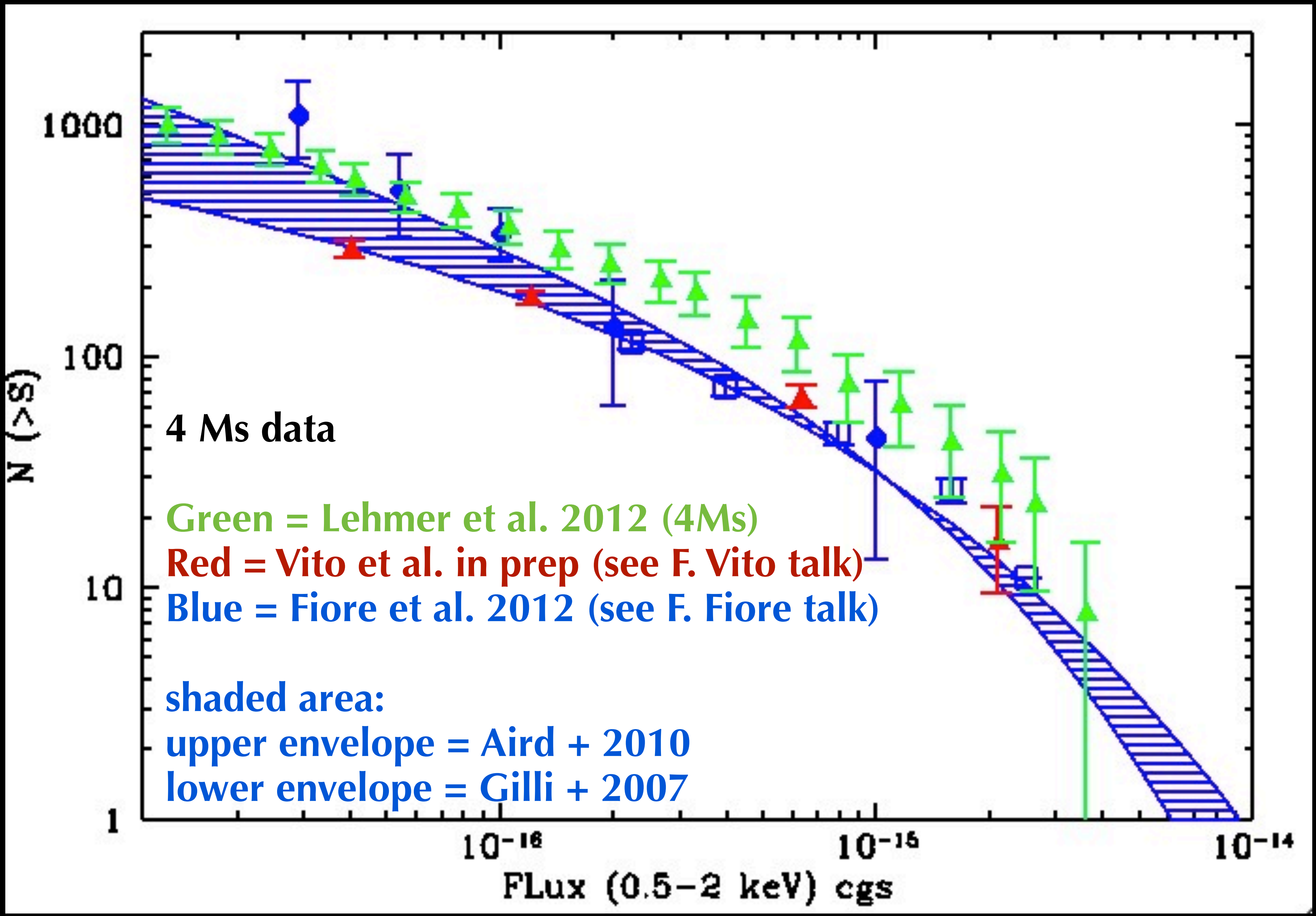
predictions
XRB models: from **Gilli+2007**
(with a decline in the space density)
Aird+2010 LF

SAM models: from Shankar+2010 & in prep
different curves --> different AGN lightcurves and minimum halo mass
degeneracy within the two parameters, z dependence?

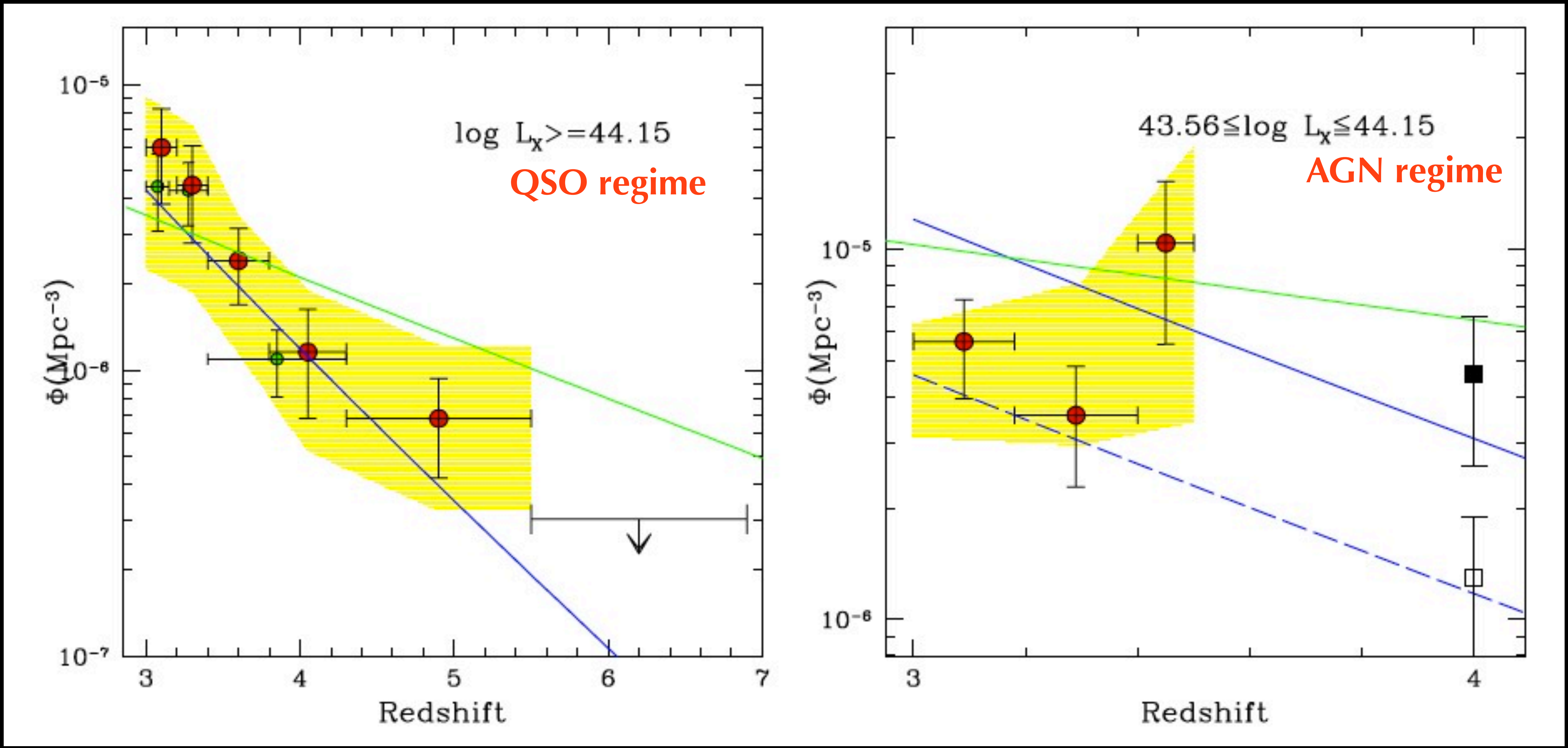


See F. Shankar talk

high-redshift universe: source counts (new data)



high-redshift universe: space density



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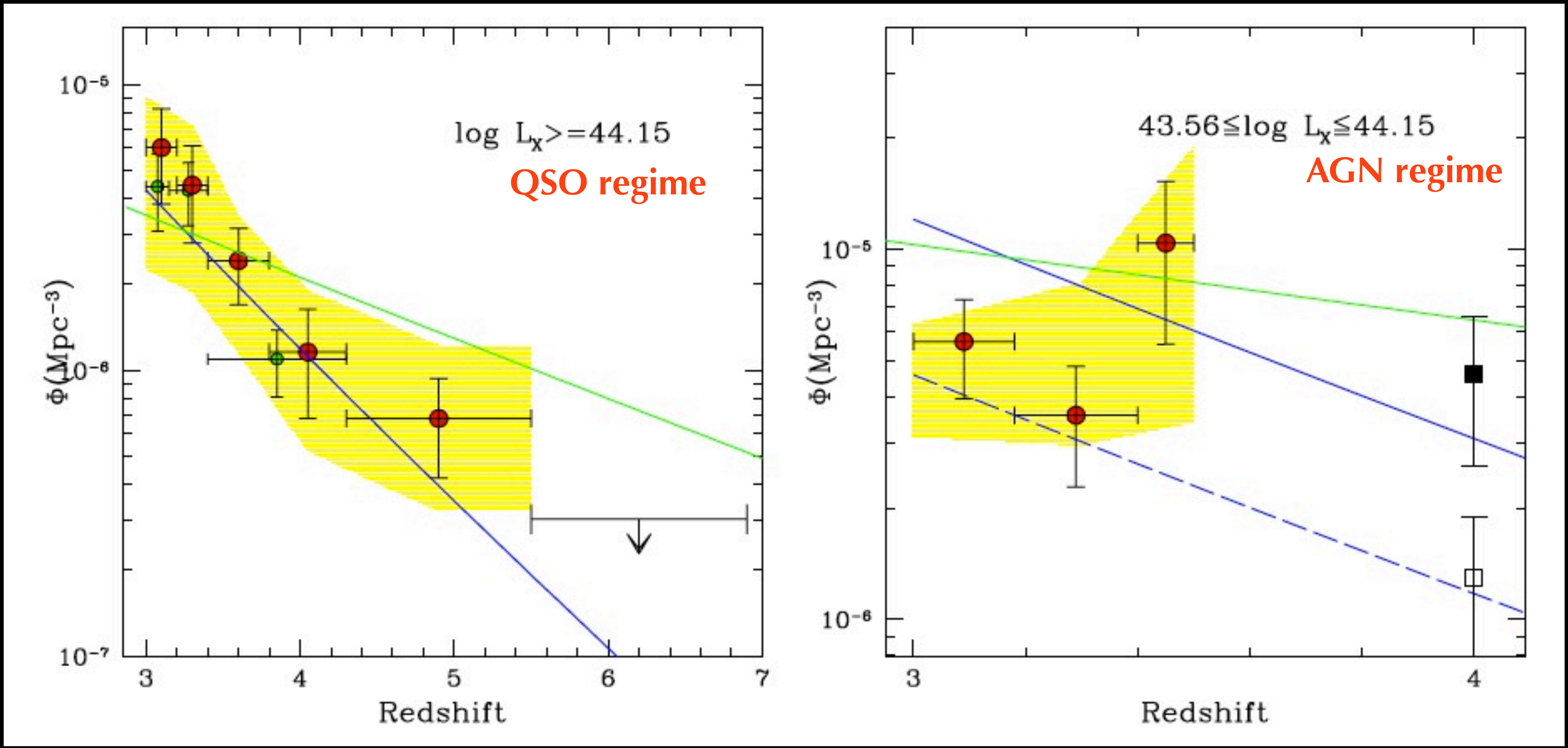
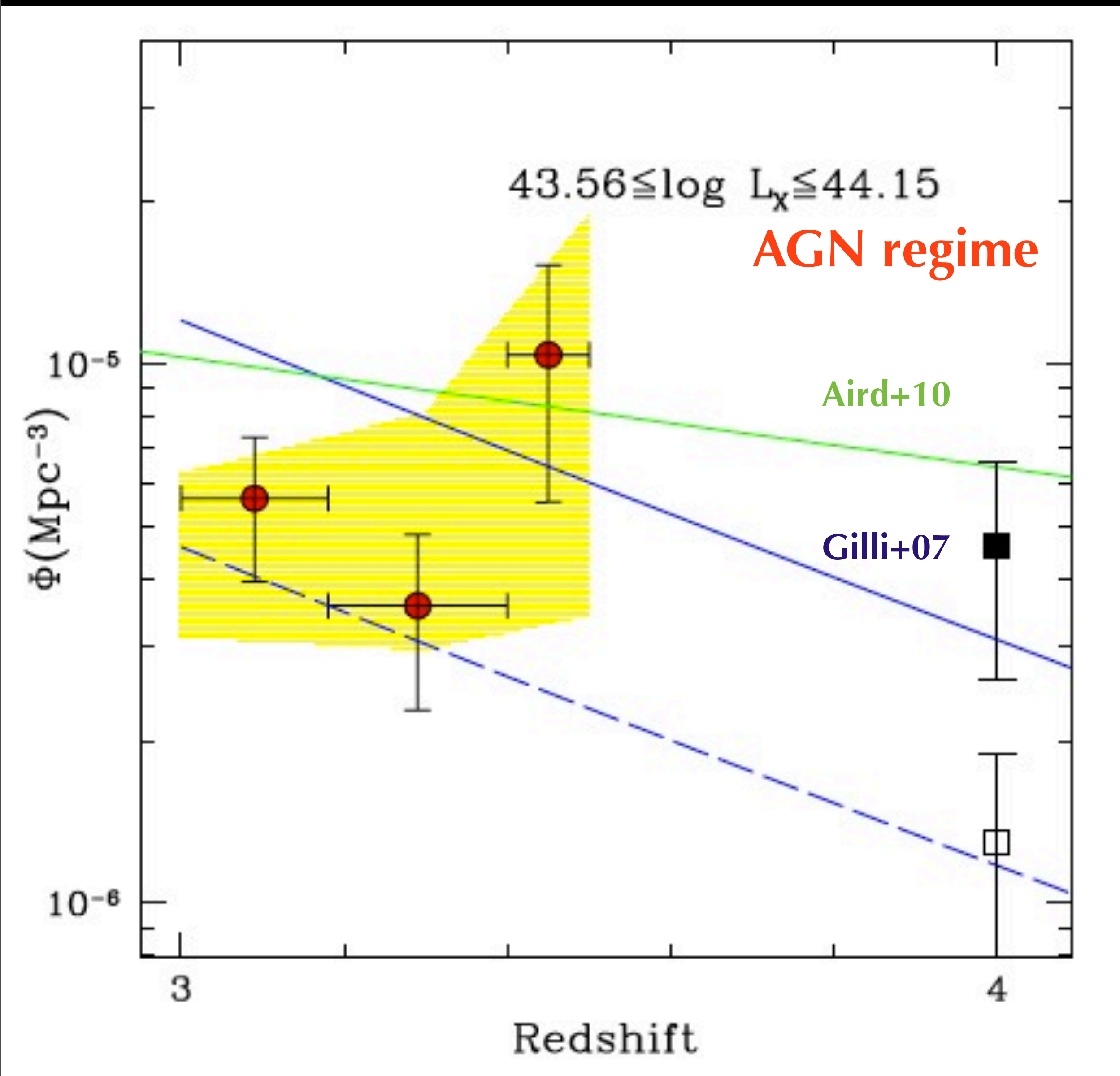
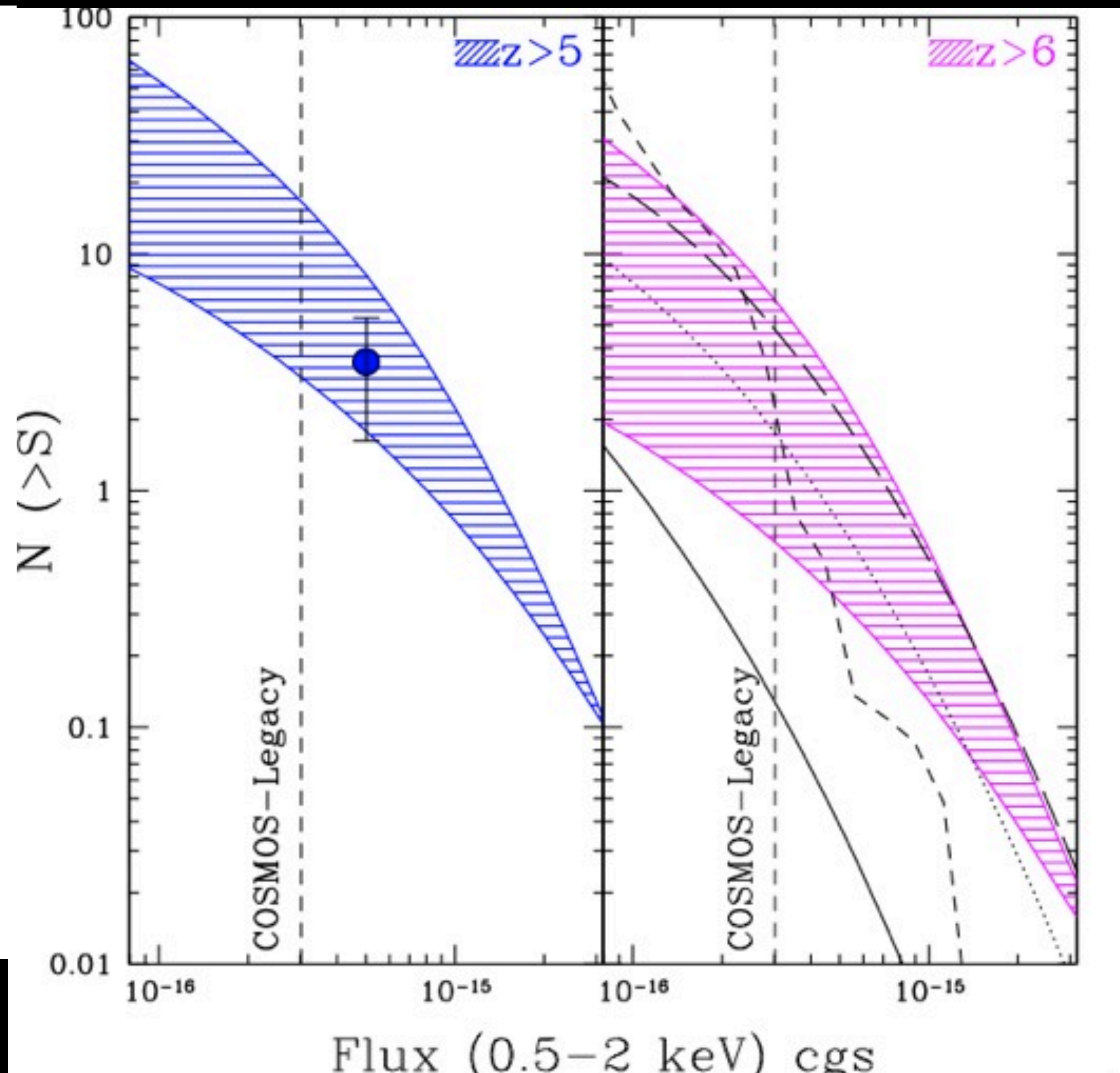


Civano et al. 2011

low-L AGN

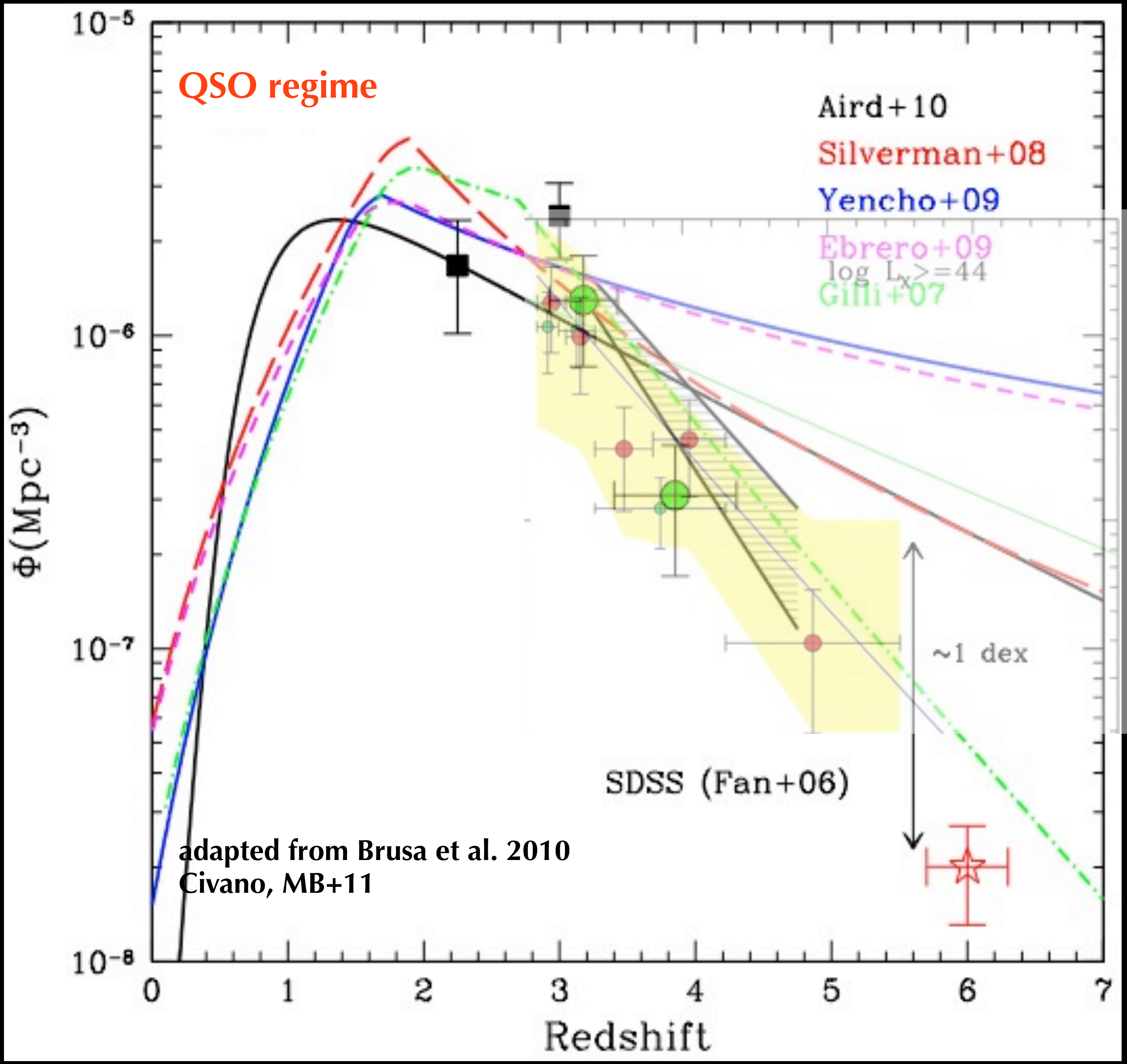




z=3-6 range sampled only at the break Lx

lower-L objects within the reach of Chandra large programs (Visionary) and in next generation telescopes...
(ATHENA, WFXT.....)

high-L QSO



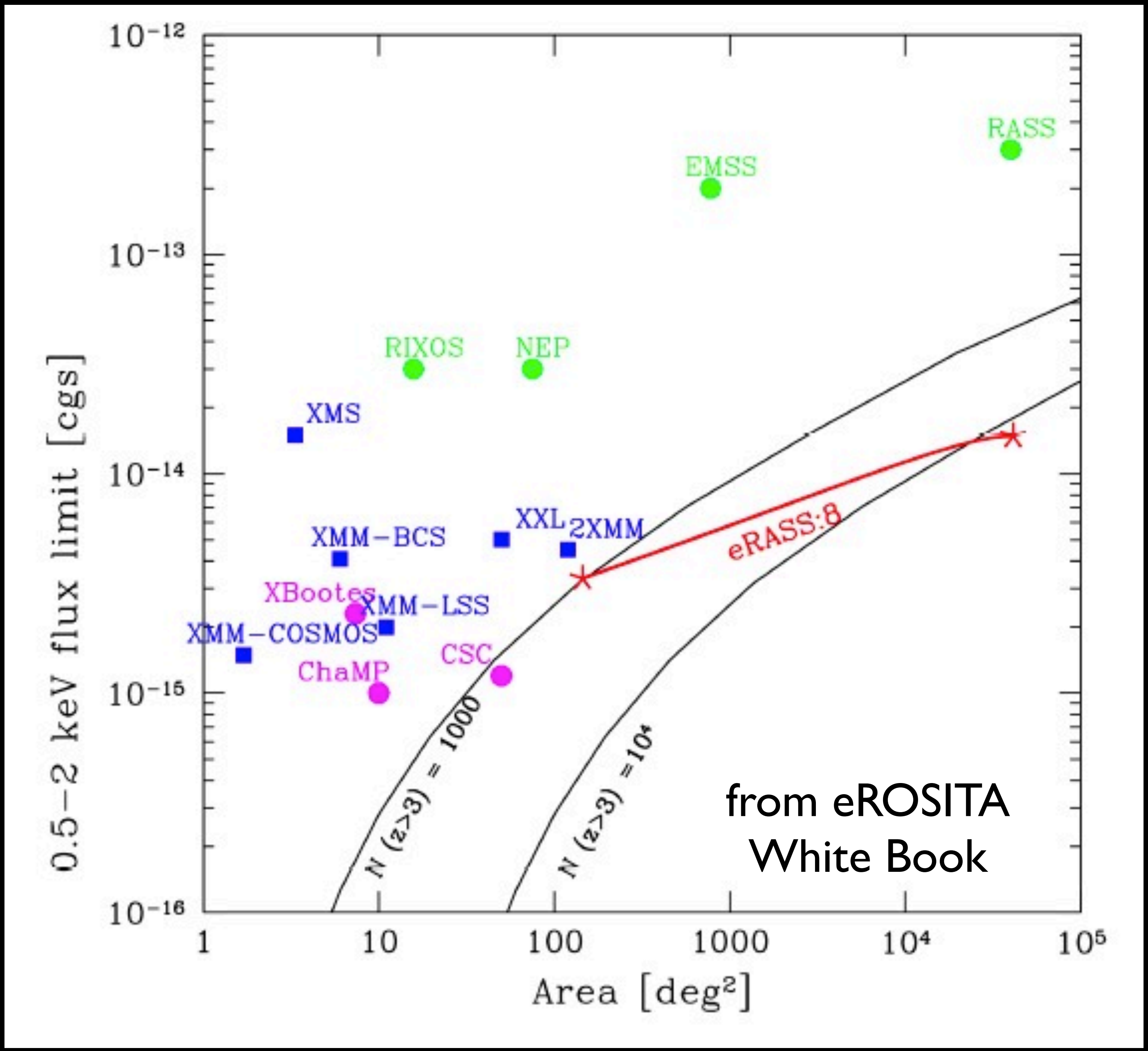
z>6: completely uncharted territory
predictions/extrapolations for high-z Universe very uncertain, even by > 1 order of mag

NOT a single (confirmed) data point!
(not even at the highest luminosities, e.g. Lx>45)

eROSITA will provide the first statistically significant sample of z>6 QSOs at Lx>45.5

~30 in the all-sky at **logLx>3e45** erg/s

number of high-z QSOs in eROSITA



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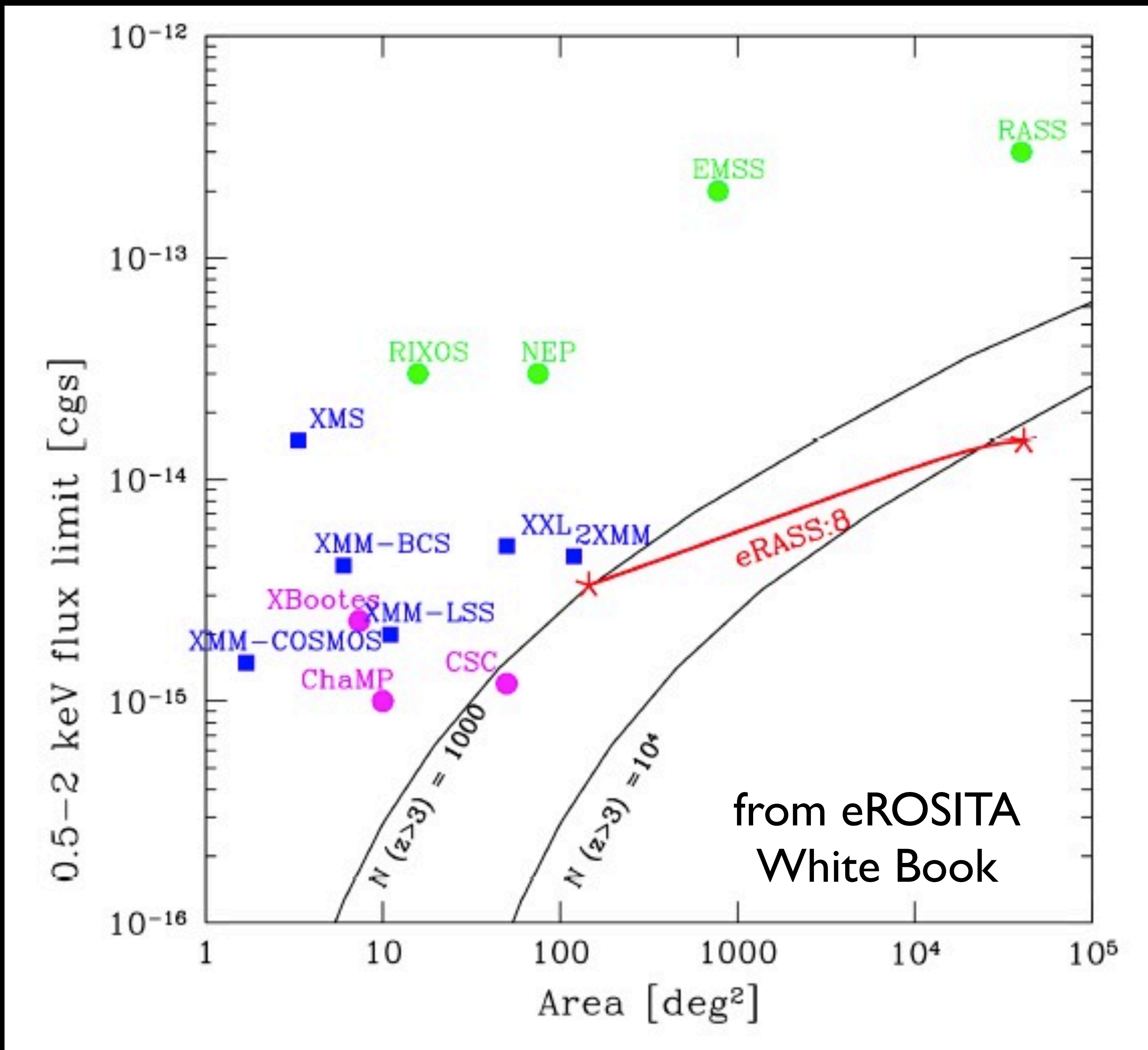


Identification of z>3 and z>6 QSOs among the few million eROSITA AGN is not trivial at all!

other lambda information is mandatory, but X-ray detection is the **fingerprint of accretion!**

- optical/IR color-color plots
- color-magnitudes diagrams
- “rough” photo-z from multiλ coverage
- follow-up with and/or cross-corr with ALMA, LOFAR, JWST samples
- quick follow-up with GROND !

see R. Gilli talk

(long way to go...)

Stacking results (1)

signal from z>6 samples (WFC3, dropouts etc.)

"Positive" result

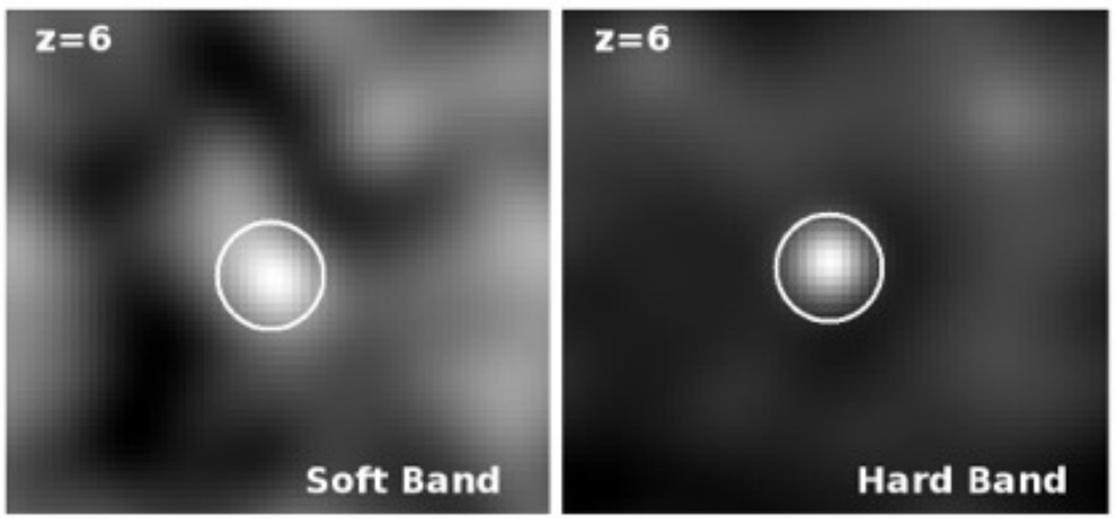


Figure 4 | Stacked *Chandra* images for the z=6 galaxy sample in the soft (*left panel*) and hard (*right panel*) X-ray bands. The detections are significant at the 5 and 6.8 -σ levels respectively. Each image is $30'' \times 30''$. The *white circle* at the center of each image has a radius of $3''$. Images were adaptively smoothed using a minimum scale of 3 pixels, a maximum scale of 5 pixels and minimum and maximum significances of 3 and 6 respectively.

Treister+2011

"Negative" result

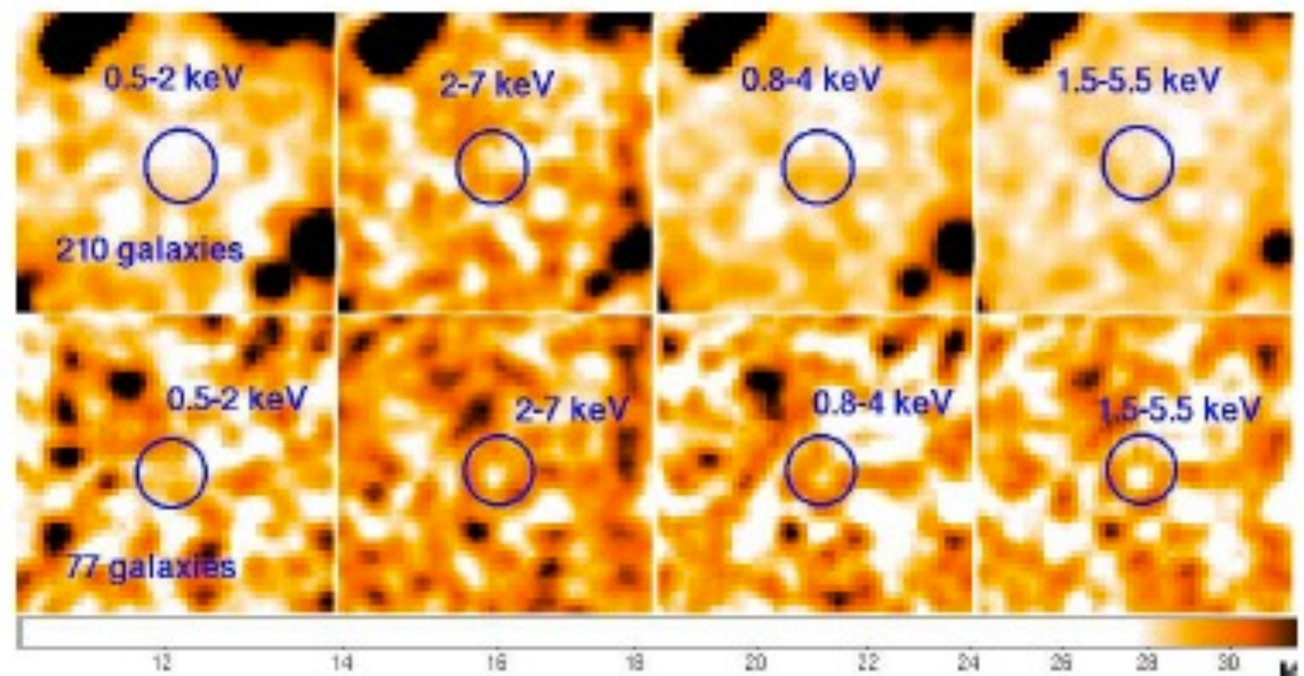
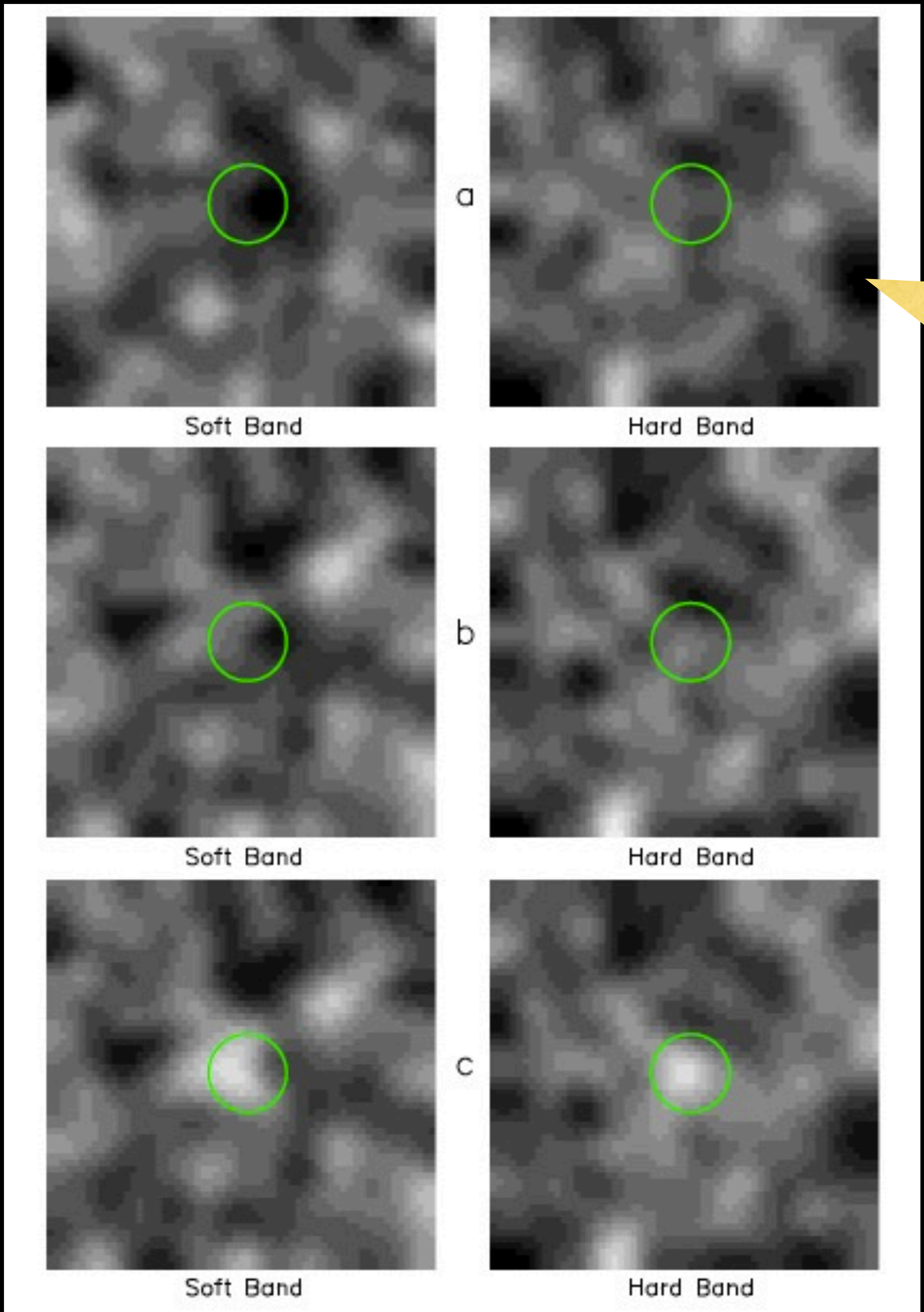


FIG. 1: Stacks of Chandra images at the position of 210 and 77 Bouwens et al. [3] candidate $z\sim 6-7$ galaxies in four energy bands: 0.5-2 keV, 2-7 keV, 0.8-4 keV and 1.5-5.5 keV.

Fiore+2012b

a factor ~3 lower than Treister (upper limit)

Stacking results (2)



Willott et al. 2011
reproducing Treister results

background subtraction / no sigma clipping

sigma clipping in source+bkg
(consistent with Fiore+2012b)

sigma clipping only in the bkg

Summary

- High-fluxes / High-L regime
Well constrained up to z~4

Need same statistics (few tens) up to z~6 --> Wide area X-ray surveys (eROSITA!)
comparison with SDSS / BOSS/ eBOSS QSO give insight in obscuration

- Low-fluxes / low-L regime
Predictions "wildly" different

sensitivity & small PSF needed
XVP today is only viable tool...

- Stacking perspectives
huge.... but to be "tuned" (smaller energies bands? Iron line search? larger samples?)