AGN physics and evolution in the next decade

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AGN Science highlights

Light up and early evolution of SMBH

- progenitors: heavy vs light seeds
- re-ionization: QSOs or galaxies?
- where and how the first BH forms and grow

Onset and the evolution of the M_{BH} vs Host properties

- The role and the nature of obscuration

Perspectives for future Chandra observations in the next decade... Athena and X-ray Surveyor in the 30s

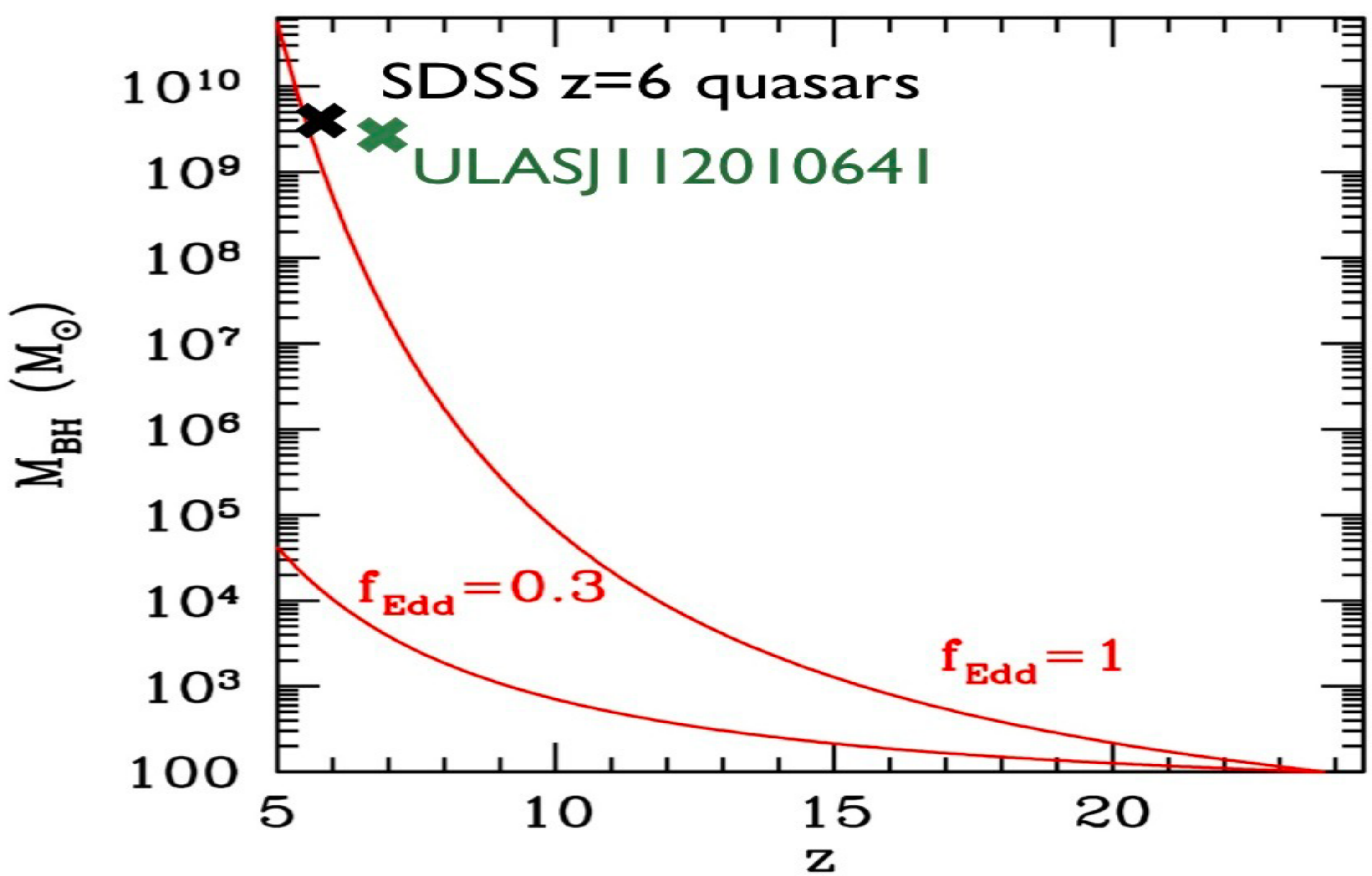
The challenge of the first Quasars

z > 6 QSO imply masses > 10^9 M_{sun} already in place when the Universe was ~ 1 Gyr old

$$M(t) = M_0 \, e^{f_{\rm Edd} \frac{t}{\tau} \frac{1-\epsilon}{\epsilon}} \quad t_{\rm acc} = 0.45 \ {\rm Gyr} \, \frac{\epsilon}{1-\epsilon} \, f_{\rm Edd}^{-1} \ln(M_{\rm fin}/M_{\rm in})$$

$M_{final}=10^9 M_\odot$
$M_{initial}=10 M_\odot$ ($10^5 M_\odot$)
$f_{EDD}=1$
$\varepsilon=0.1$
➪ t_{acc}=0.4 Gyrs (0.2 Gyrs)
If f_{EDD}=0.3 – 1.2-0.6 Gyrs

$t_H(z=7)$=0.75 Gyrs
$t_H(z=6)$=0.9 Gyrs

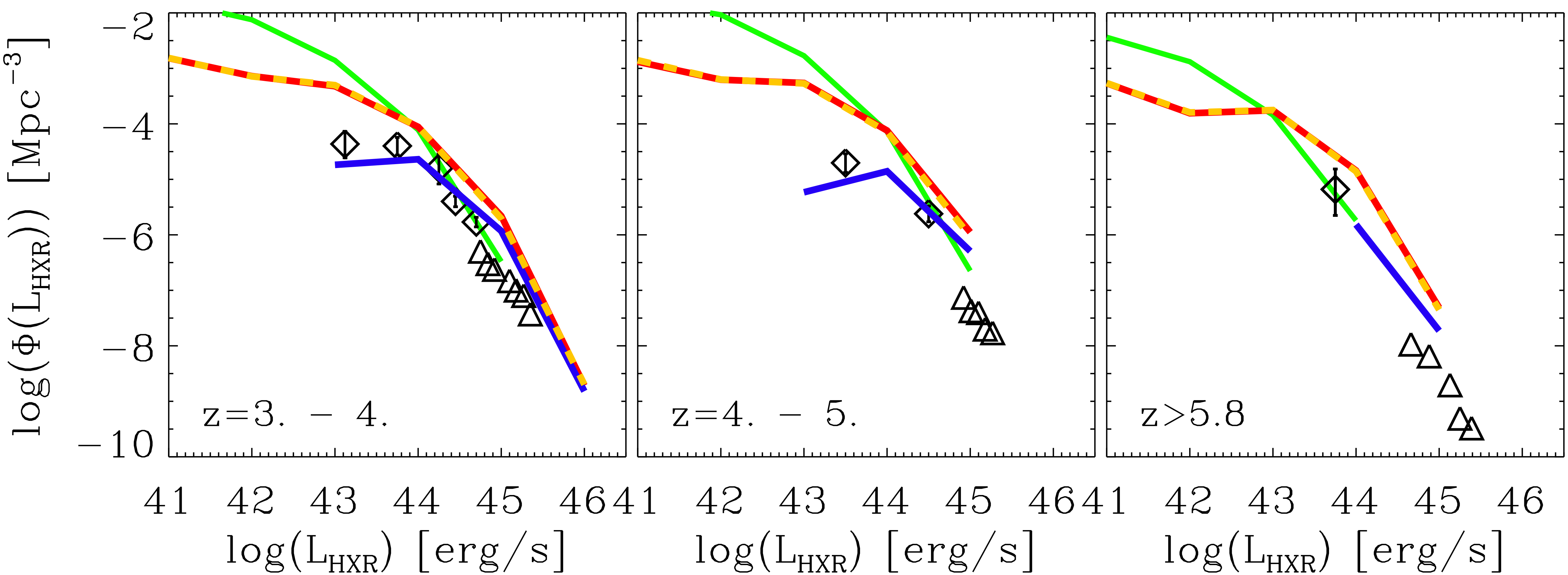


SMBH at high redshifts

Time Problem: right combination of seeds masses and accretion rates

PopIII remnants M_{BH}~100-500 M_{sun} or DCBH M_{BH}~10^3-10^6 M_{sun}

i.e. Loeb&Rasio04; Volonteri+12; Madau&Rees01; ...



Examples of high-z XLF predicted by models with light and heavy seeds

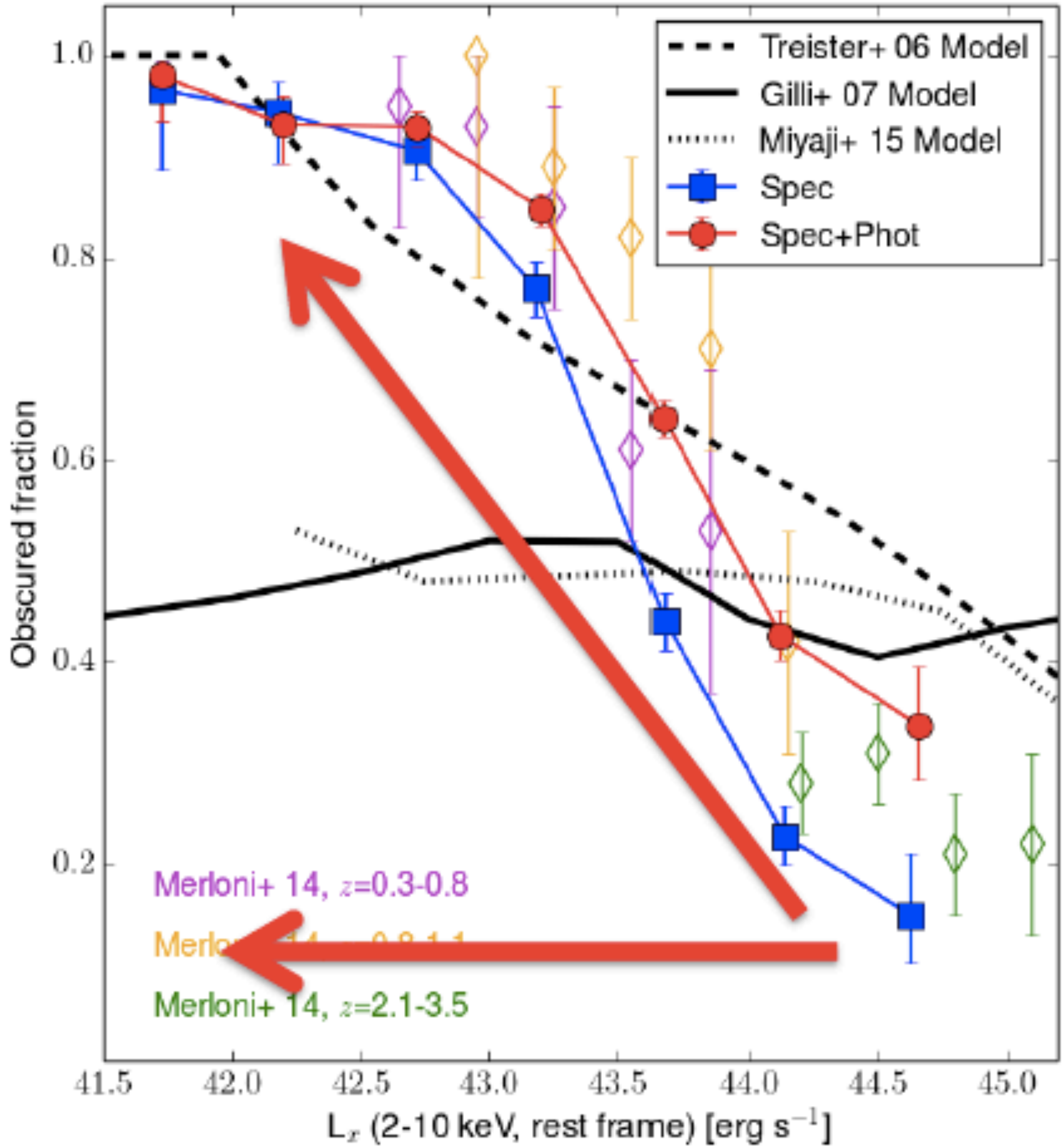
Hirschmann+12;Triangles - SDSS converted to X-ray , rhombi Fiore+12

Volonteri;Menci;Granato;Shankar;Hopkins;Di Matteo;Springel; ....

Need to push towards low luminosity and high-z

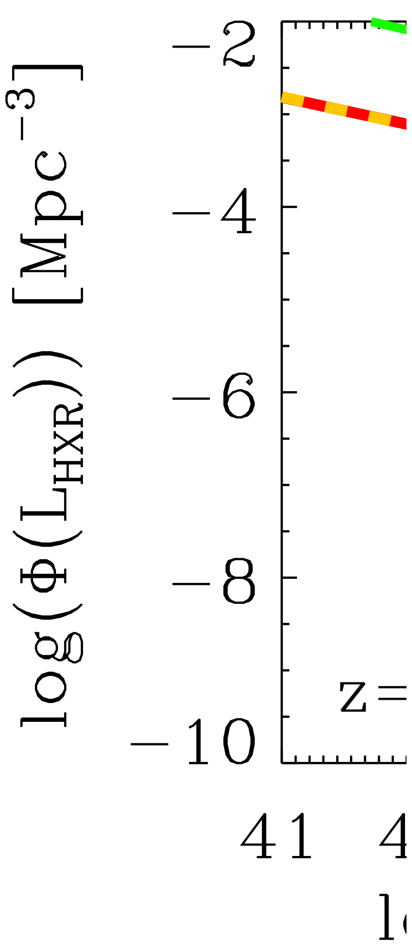
Time Probl

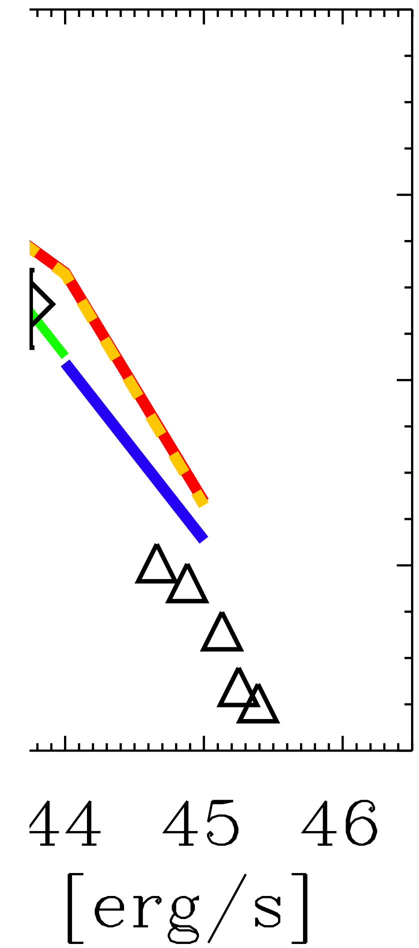
PopIII remn



retion rates

^{3}-10^{6} M$_{sun}$





Examples

heavy seeds

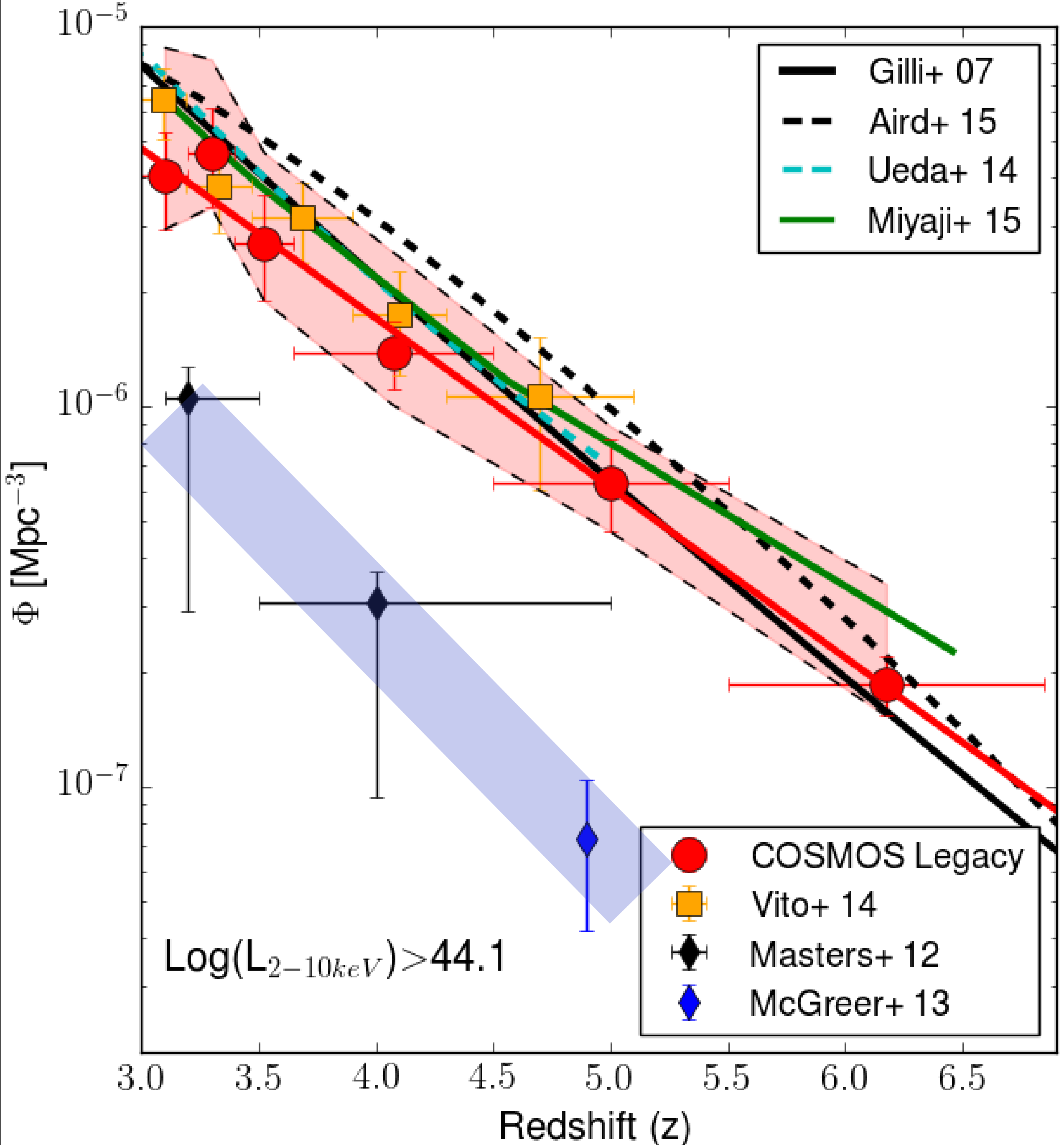
Hir

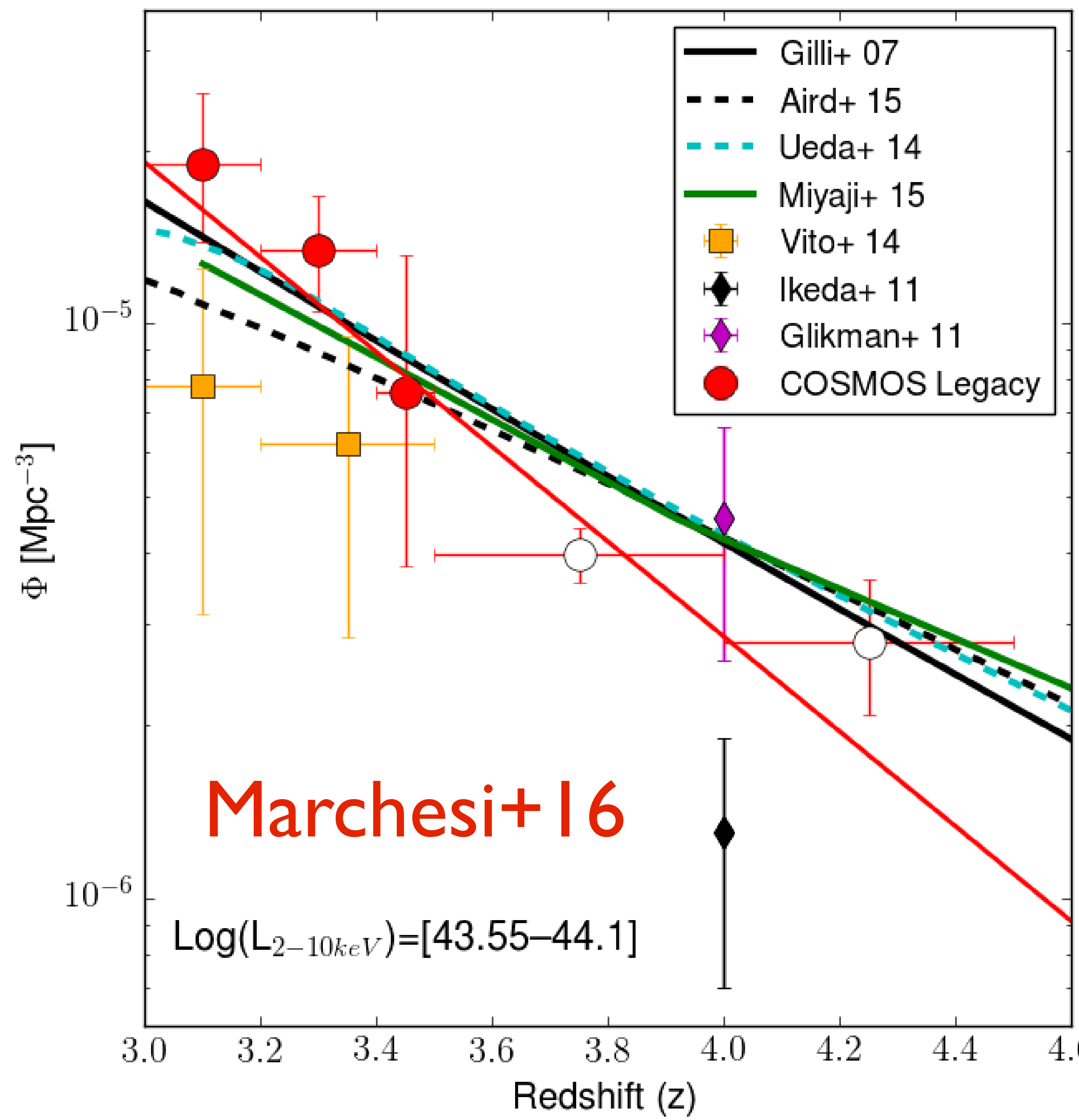
+12

Need

gh-z

Evolution at z > 3



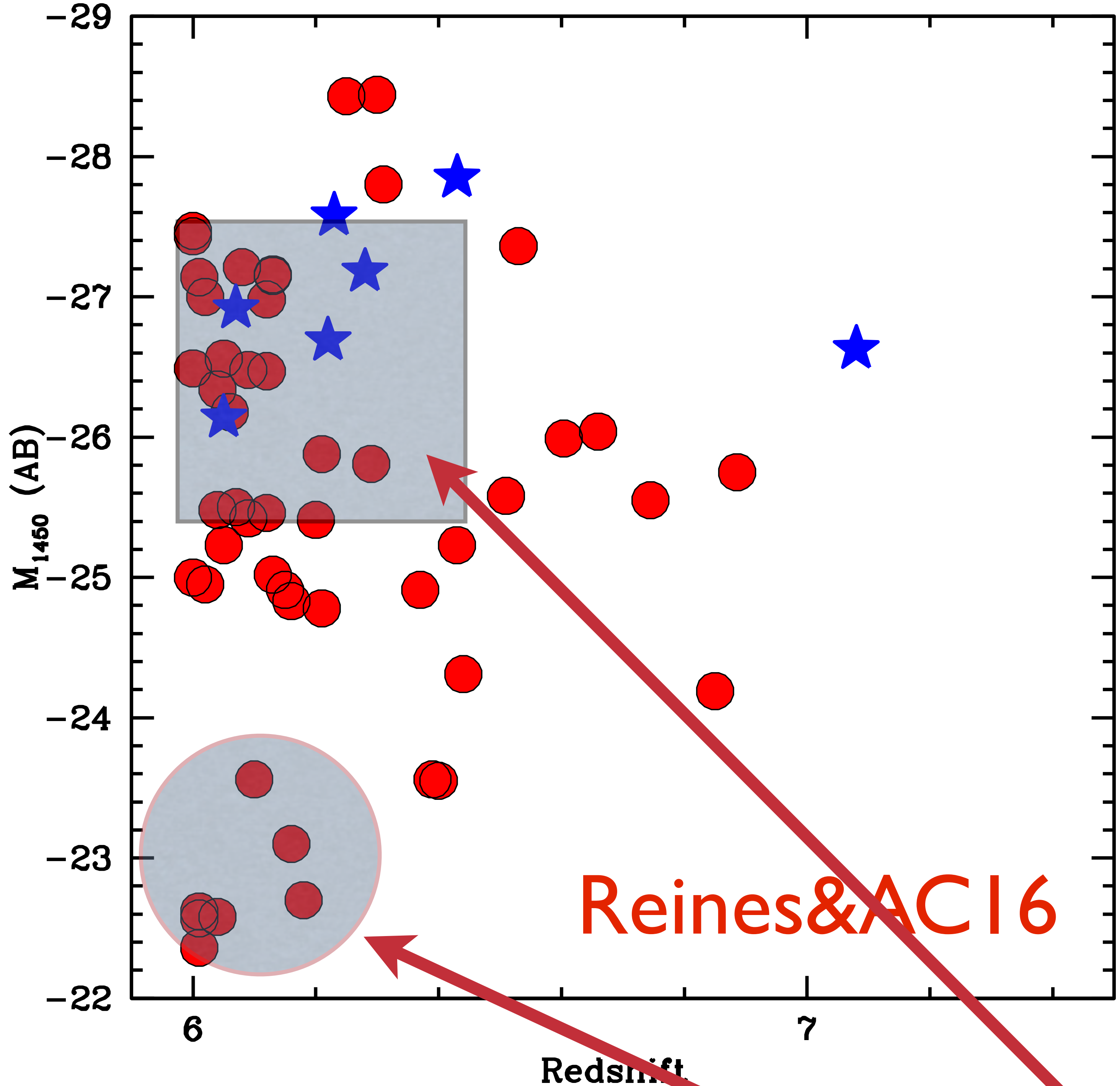


Strong decline @ z>3 and log L_x >44 $\phi \propto (1+z)^{-6}$

Hints of a similar beahviour at log L_x < 44 ???

Brusa+09,Civano+11,Hiroi+12;Vito+14,Kalfountzou+14 Georgakakis+15, Ueda+14,Miyaji+15,Aird+15, Ikeda+11;Glikman+11,Masters+12, ...

z > 6



Blue Stars
X-ray detected

Red circles
Opt-NIR only

Calura+14;Venemenas+13,15; Banados+14; Carnall+15; Kashikawa+15Wu+15;Reed+15

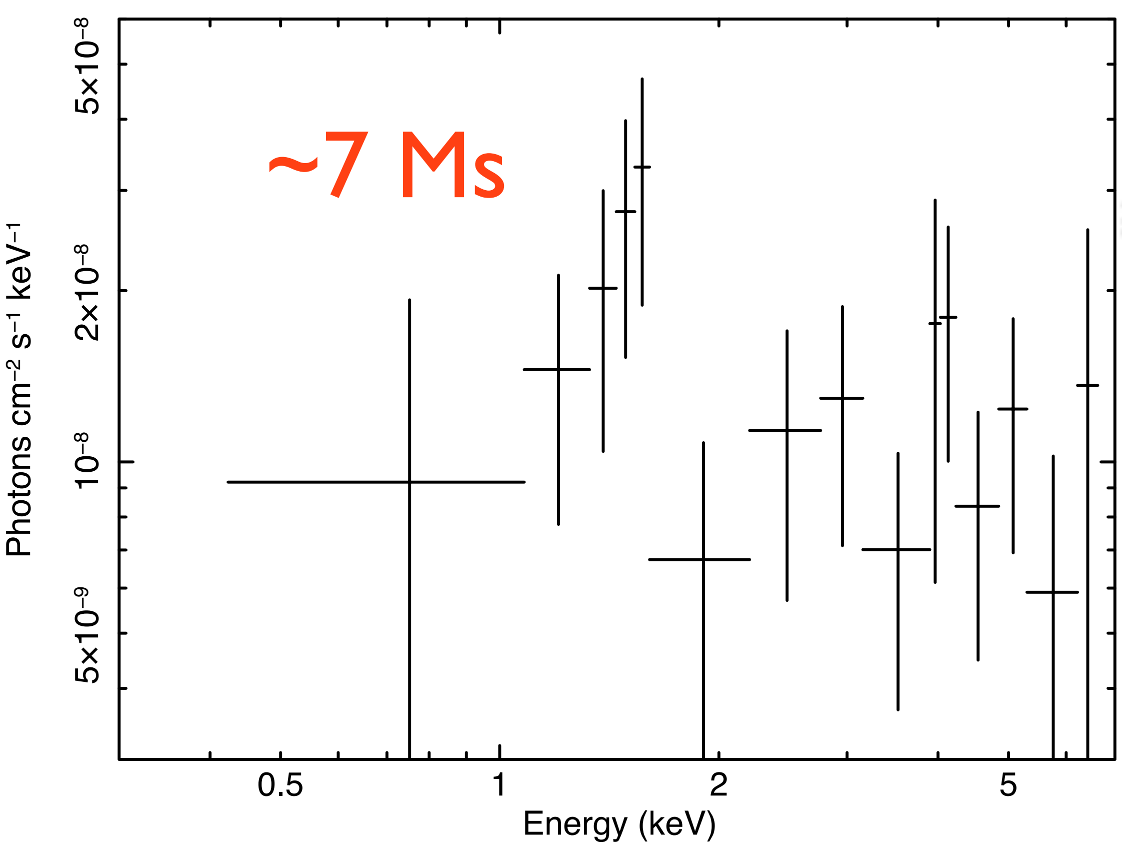
Matsuoka+16 HSC@Subaru probe low Luminosities

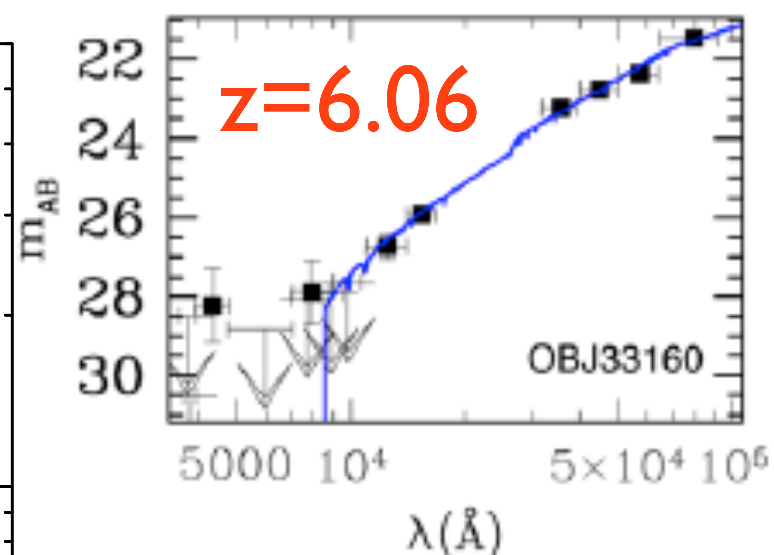
16 new QSO @z > 6 from PanStarss Banados+16

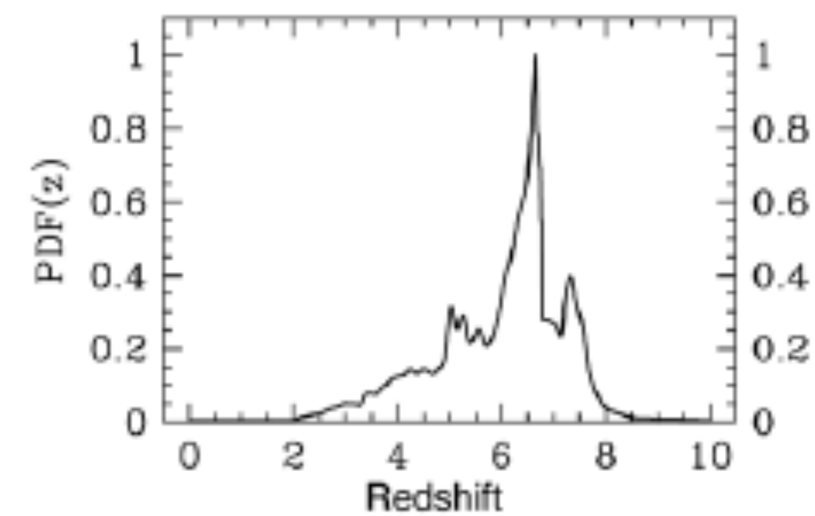
Beyond detection 1

Search for X-ray emitting sources using optical NIR priors and photo-z from Candels (i.e. Dahlen+13;Giallongo+15)

Two z > 6 X-ray sources are consistent with the theoretical spectrum expected by Direct Collapse Black Holes (Pacucci+16)
Extremely red colors and obscured-Compton thick X-ray spectrum

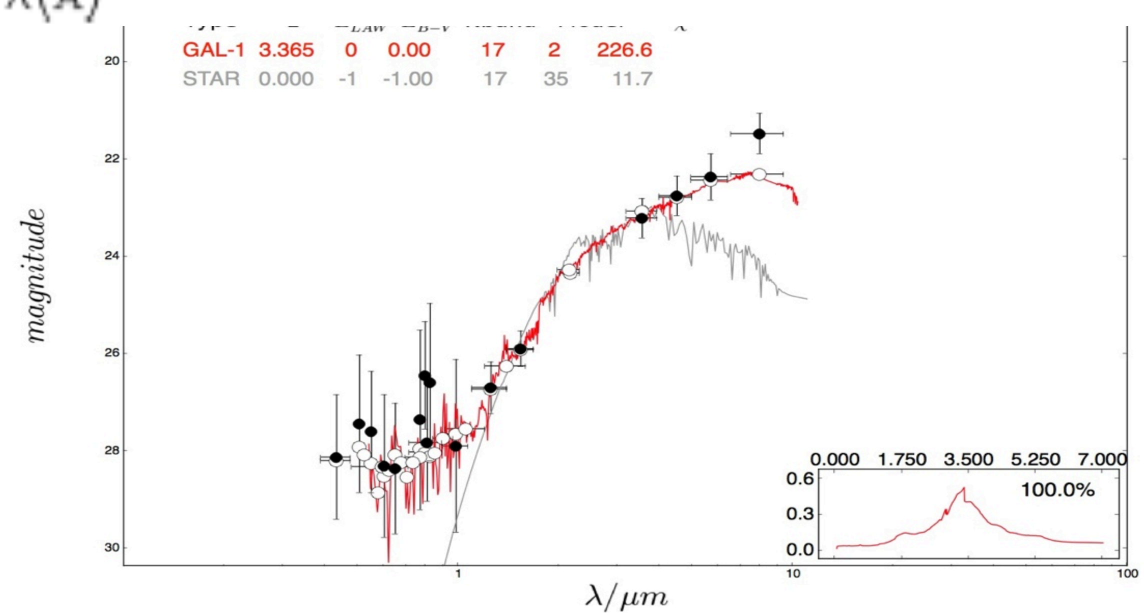






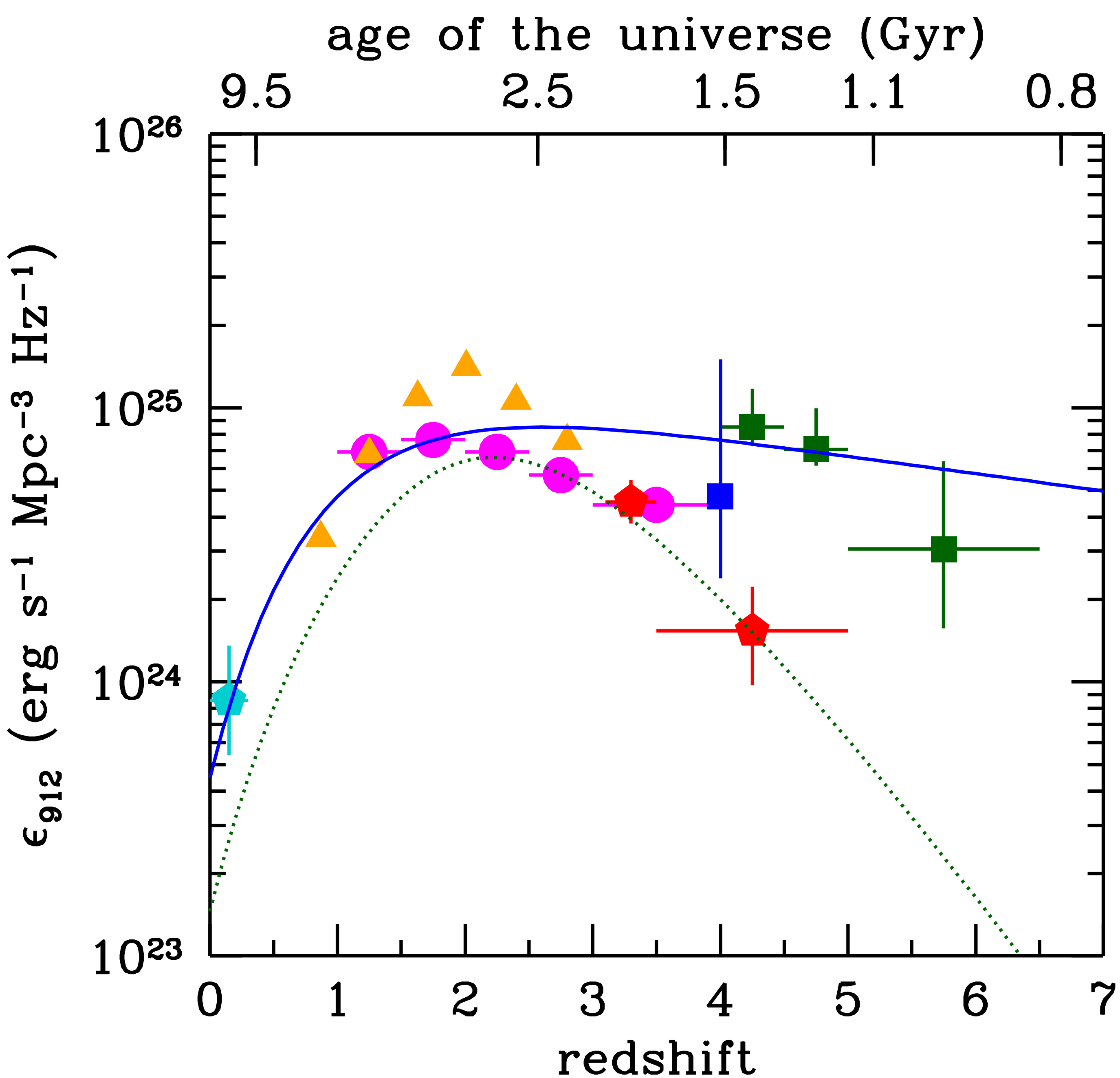
CR7 in COSMOS X-ray undetected
Sobral+15

Hsu+14
z=3.36



Beyond detection II

Candels catalogue + adaptive X-ray detection: 22 faint AGN candidates are identified in CDFS (Giallongo+15)



AGN comoving ionizing emissivity

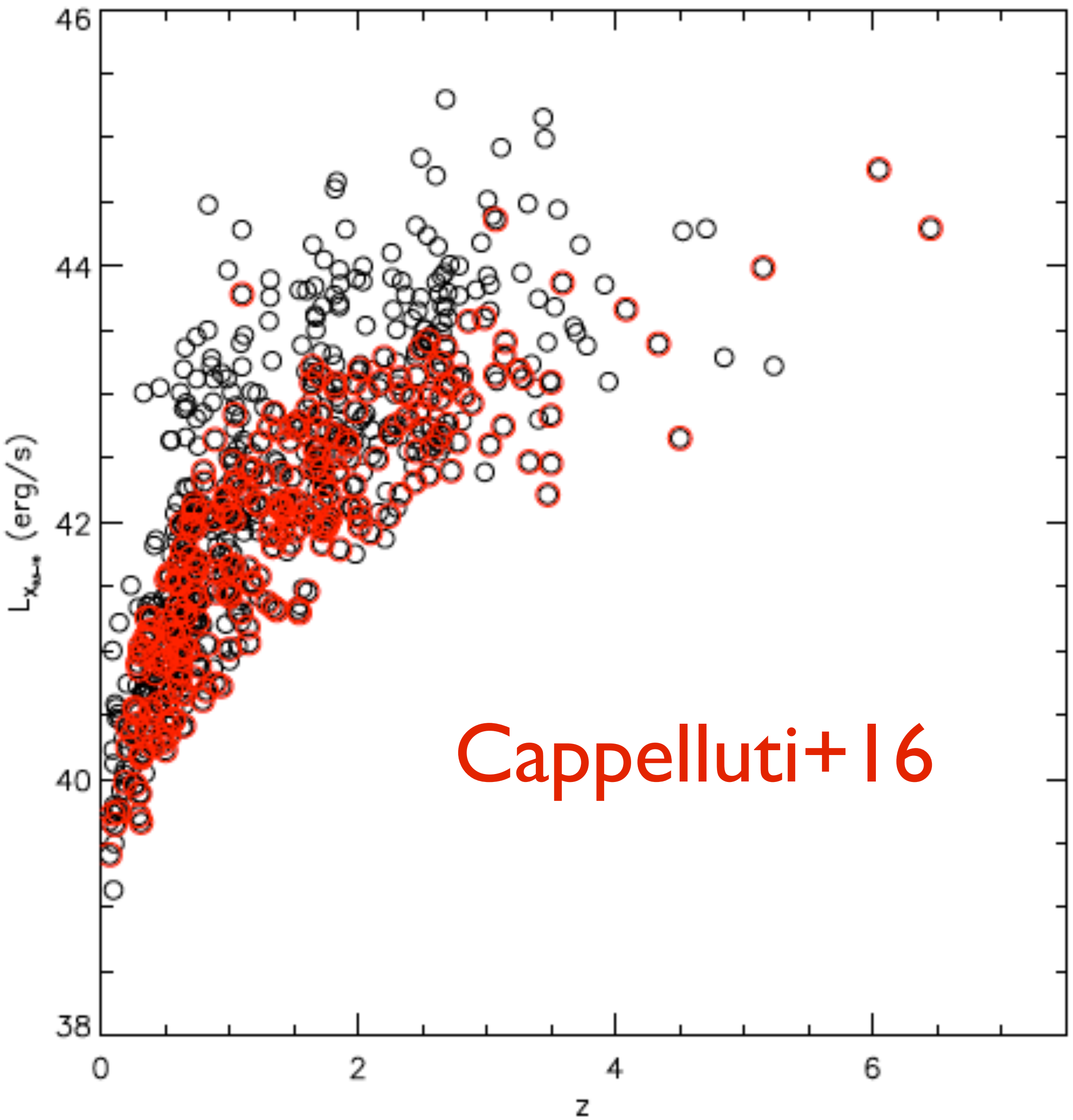
Glikman+11, Bongiorno+07
Masters+12, Giallongo+15

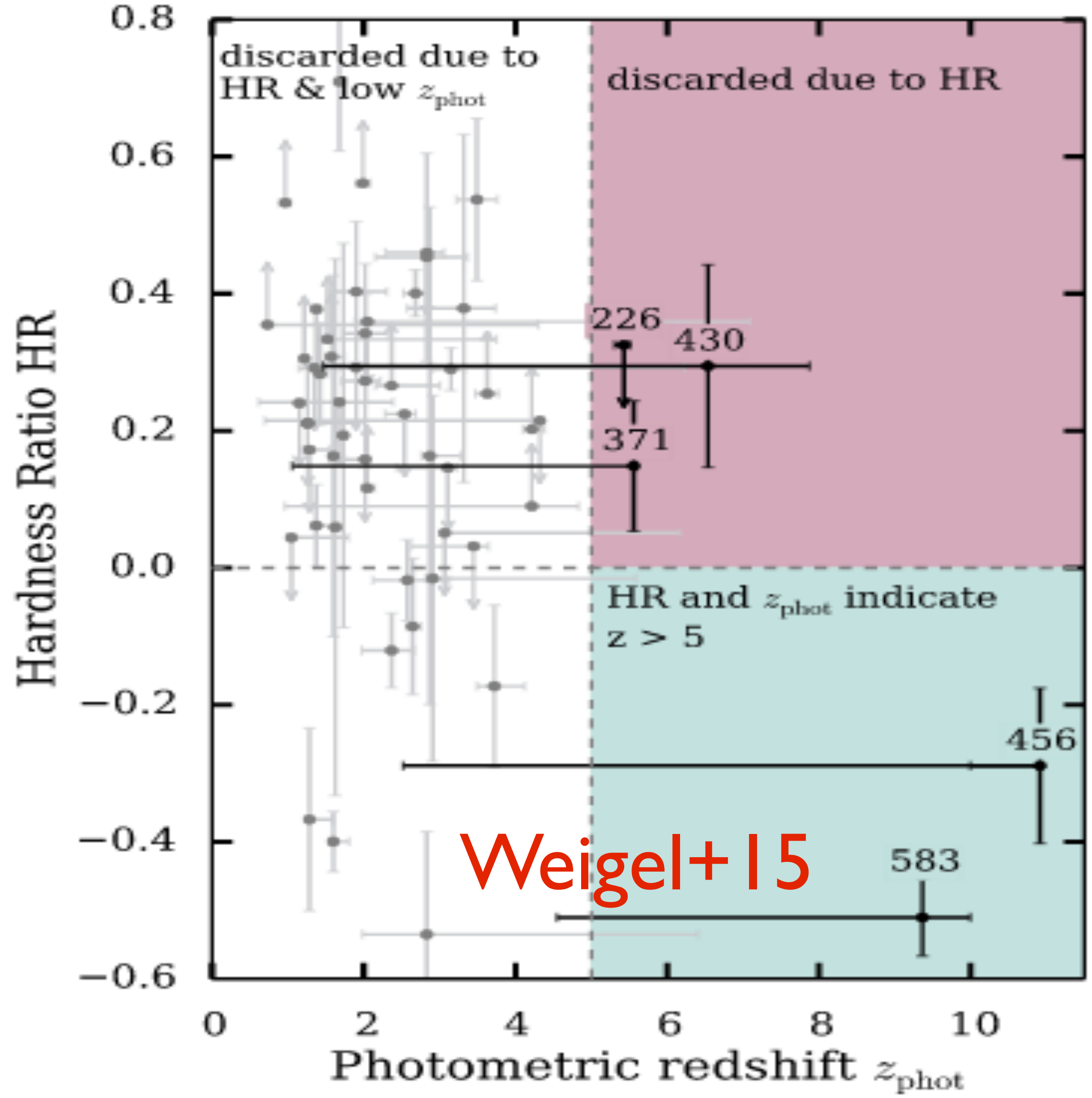
Blue line Madau&Haardt15

Green dotted Hopkins+07

AGN may be responsible of the bulk of re-ionization without violating the soft XRB limits (i.e. Madau&Haardt15)

Beyond detection III

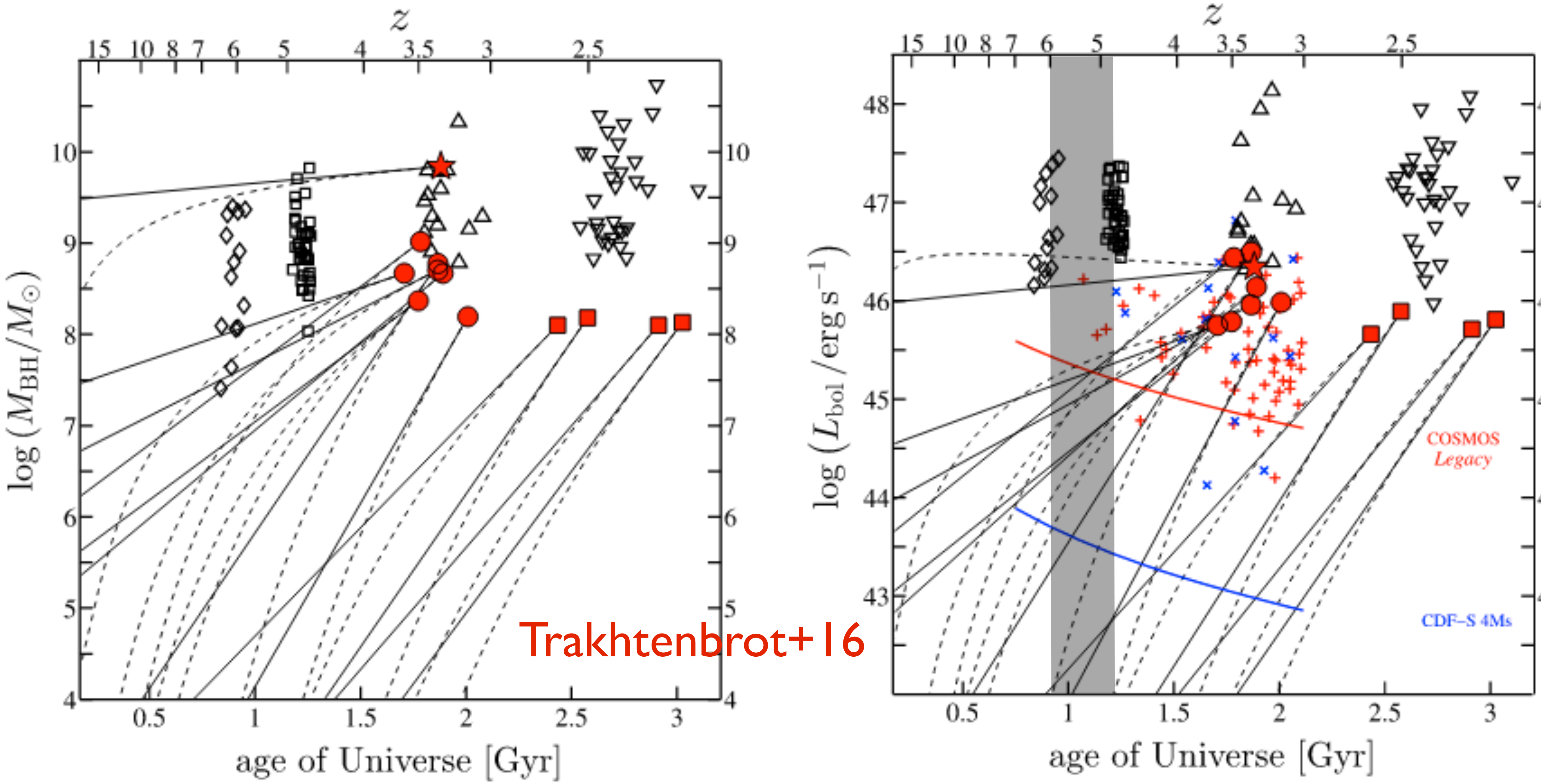




The number of high-z AGN may be significantly lower

detection algorithm; counterpart association; photo-z code robustness, etc etc

Lessons from z ~ 3.3



Tracks of M_{BH} and L_{BOL} traced back to z~20 assuming simple prescriptions for accretion efficiency and Eddington rate.

Need Massive BH at very high-z to reproduce observed/measured masses

Relatively luminous quasars at z~5-7 are within the limits of current surveys but not detected (1 in Stripe 82 La Massa+16) OBSCURATION ?? - Lower efficiency?? ...

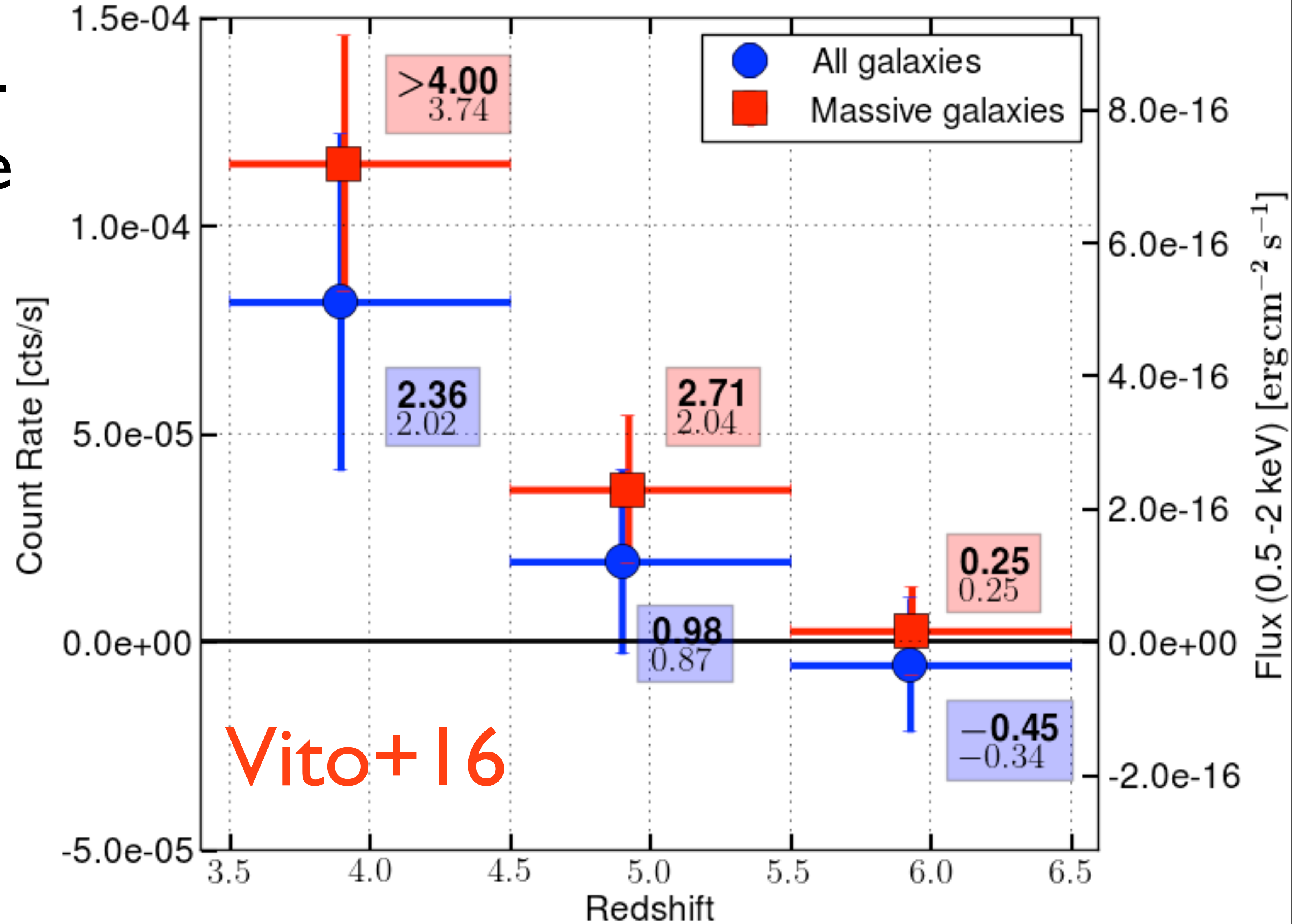
Beyond detection: Stacking

z bin	mass sample	N	$\langle z^w \rangle$	Effective Exposure
$3.5 \leq z < 4.5$	all	1393	3.90	8.16×10^9s ~260 yr
$3.5 \leq z < 4.5$	massive	662	3.91	3.86×10^9s ~120 yr
$4.5 \leq z < 5.5$	all	453	4.90	2.65×10^9s ~85 yr
$4.5 \leq z < 5.5$	massive	217	4.92	1.26×10^9s ~40 yr
$5.5 \leq z < 6.5$	all	230	5.93	1.35×10^9s ~43 yr
$5.5 \leq z < 6.5$	massive	111	5.93	0.65×10^9s ~20 yr

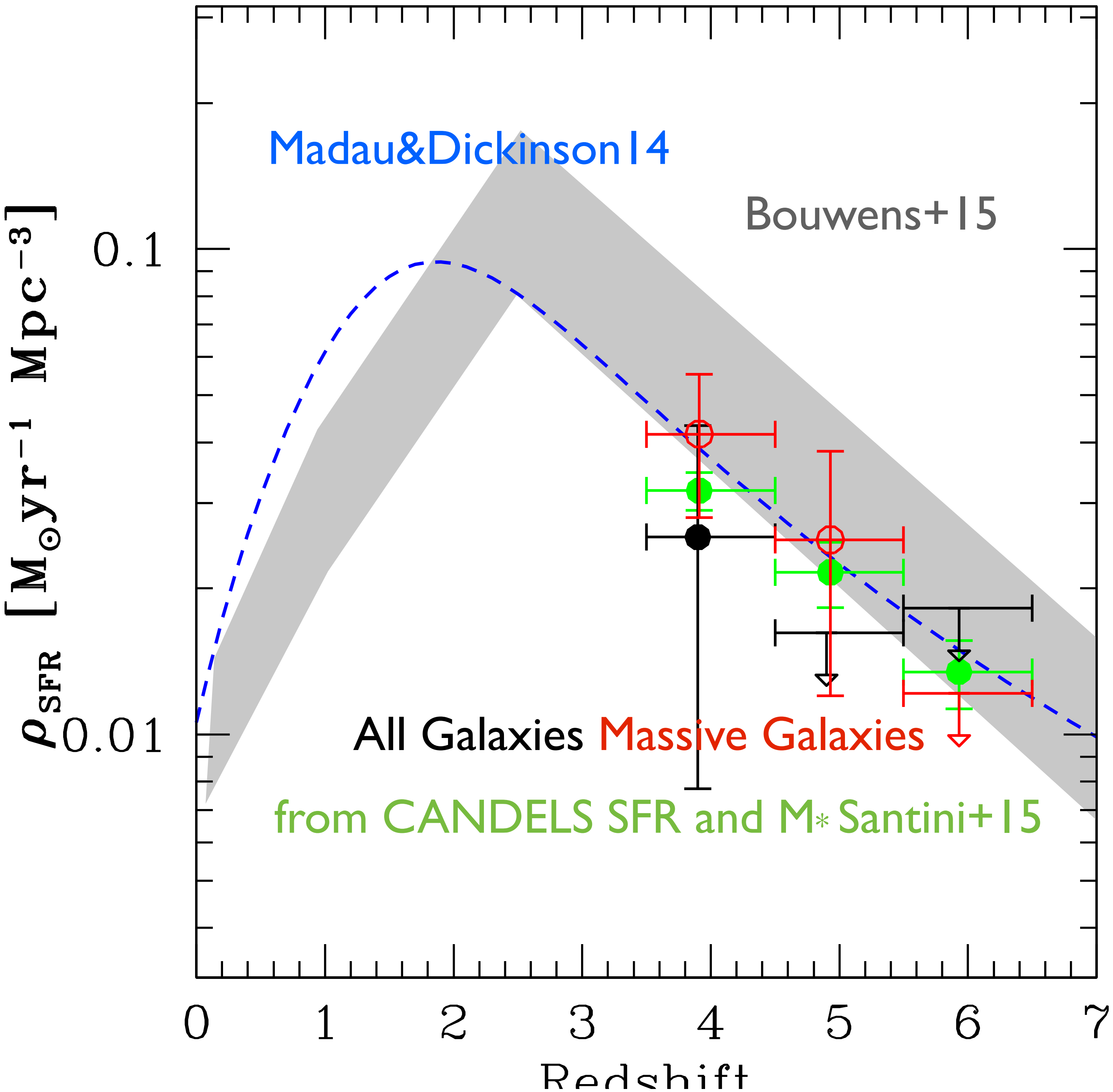
Significant detection of X-ray emission from massive galaxies @ z ~ 4

First detection (~2.7σ) @ z ~ 5

No signal @ z~6
(Cowie+12;Fiore+12 Treister+13)



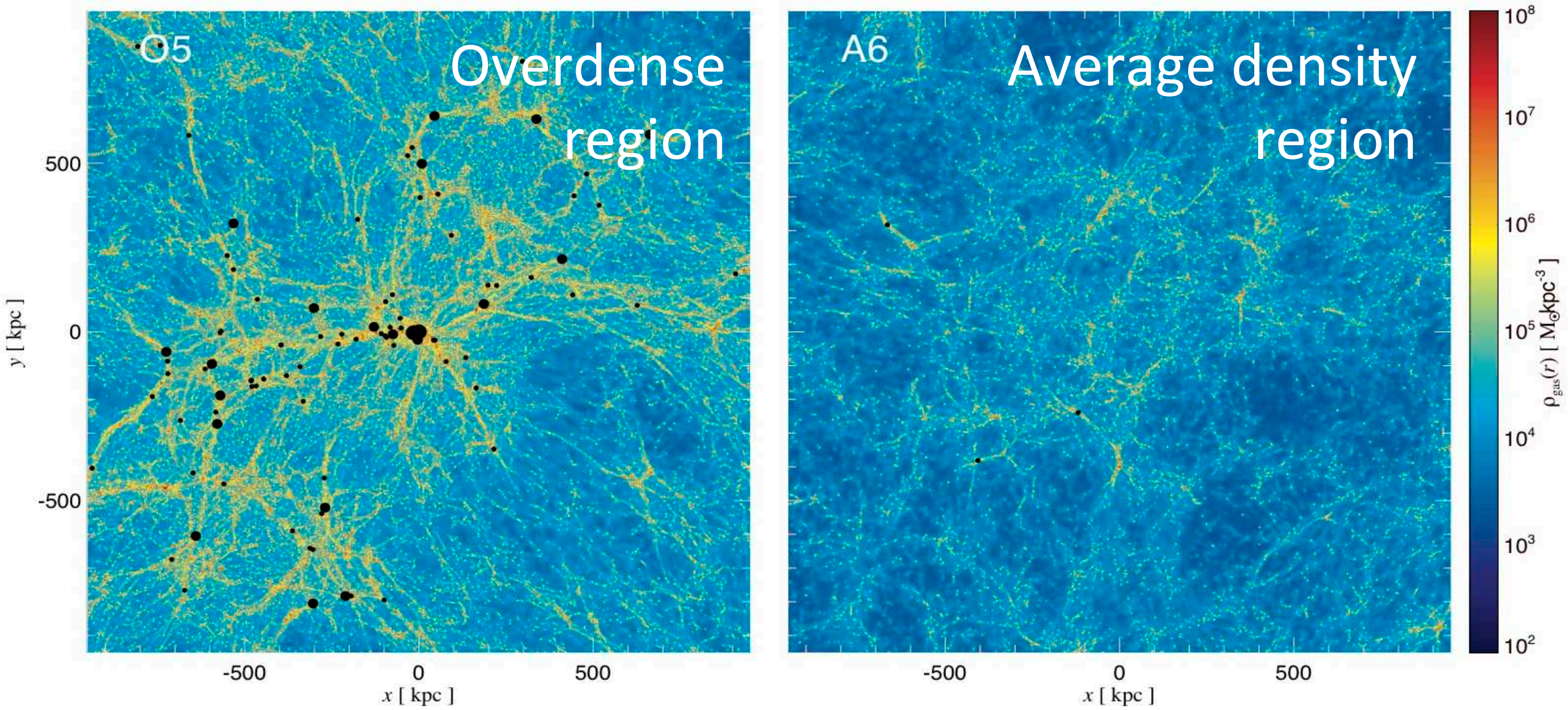
X-ray emission from galaxies?



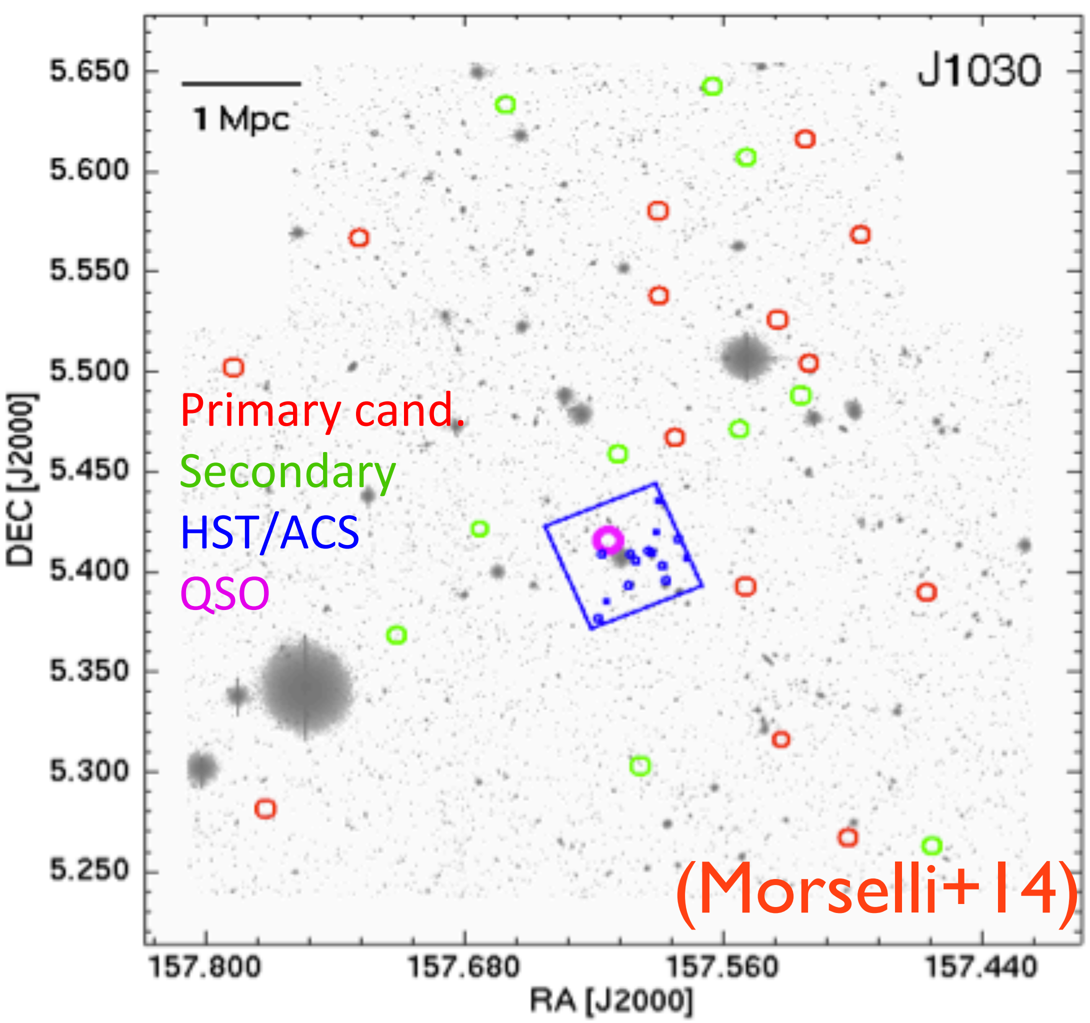
X-ray emission in high-z galaxies consistent with an origin due to SF processes (Binaries, gas,...) assuming the SFR-L_X relation calibrated at lower redshifts

Accretion luminosity in undetected AGN provides a negligible contribution

The environment of z~6 QSOs



According to simulations SMBH at z ~ 6 form only in overdense regions

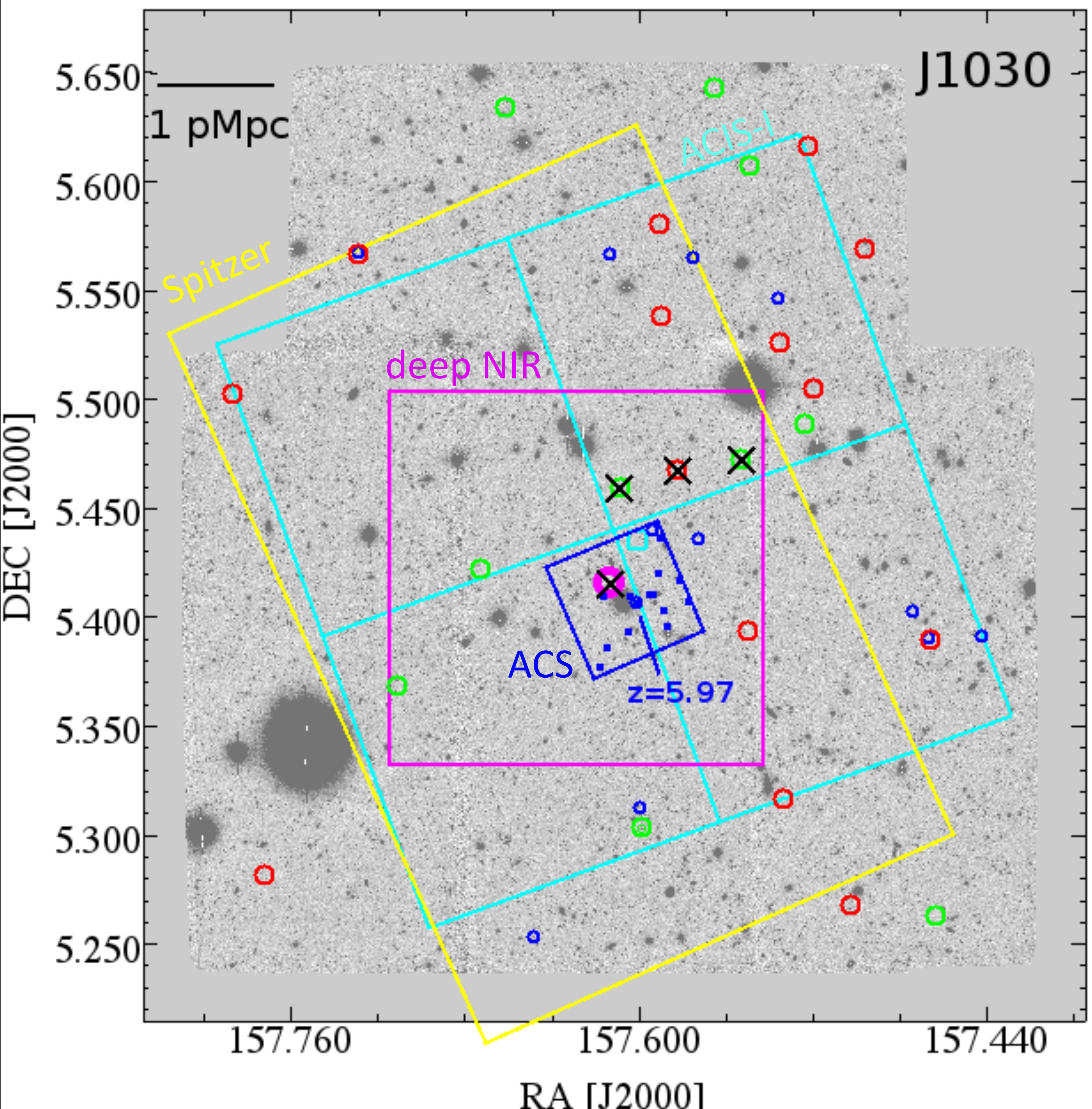


Overdensities might extend up to 30 arcmin from central QSOs (Overzier+09)

need wide field
LBC@LBT and HSC@ Subaru

Chandra LP (500 ks ACIS-I) on J1030

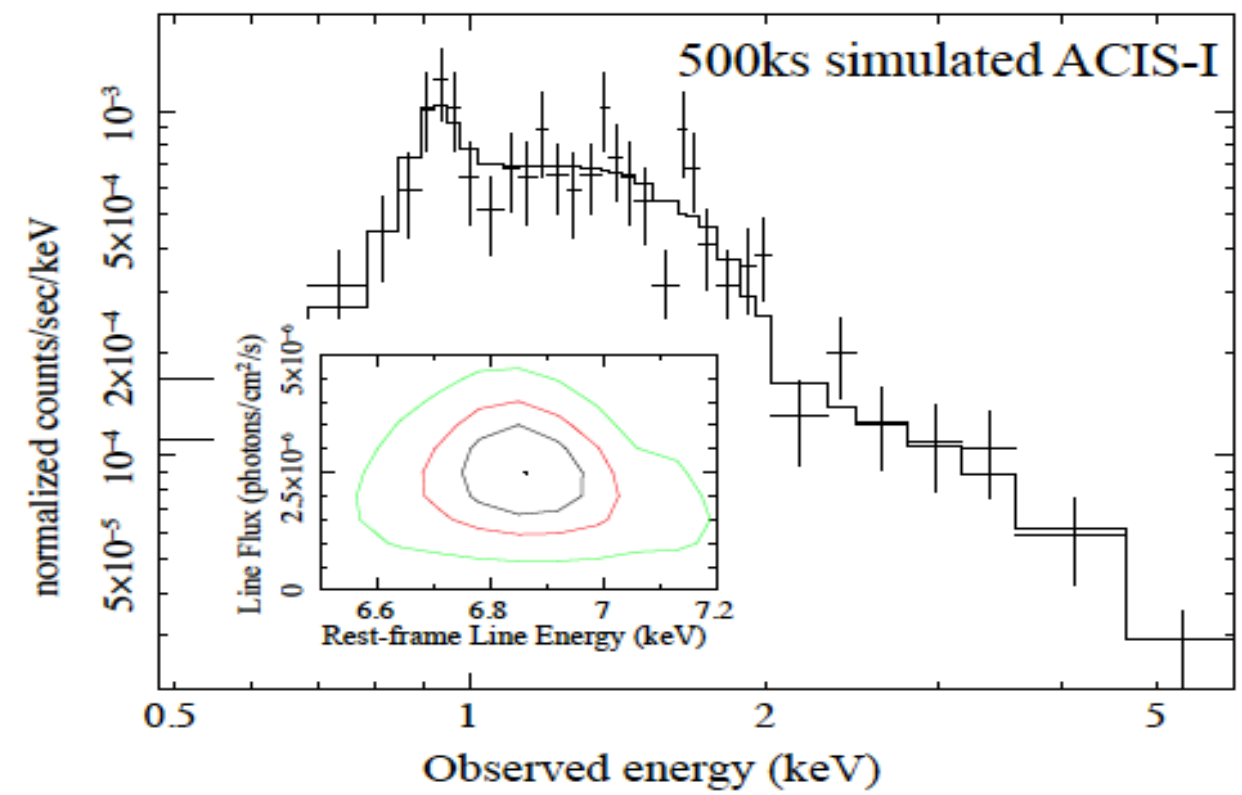
Scheduled Jan 2017 - 4th deepest survey to date - PI R. Gilli



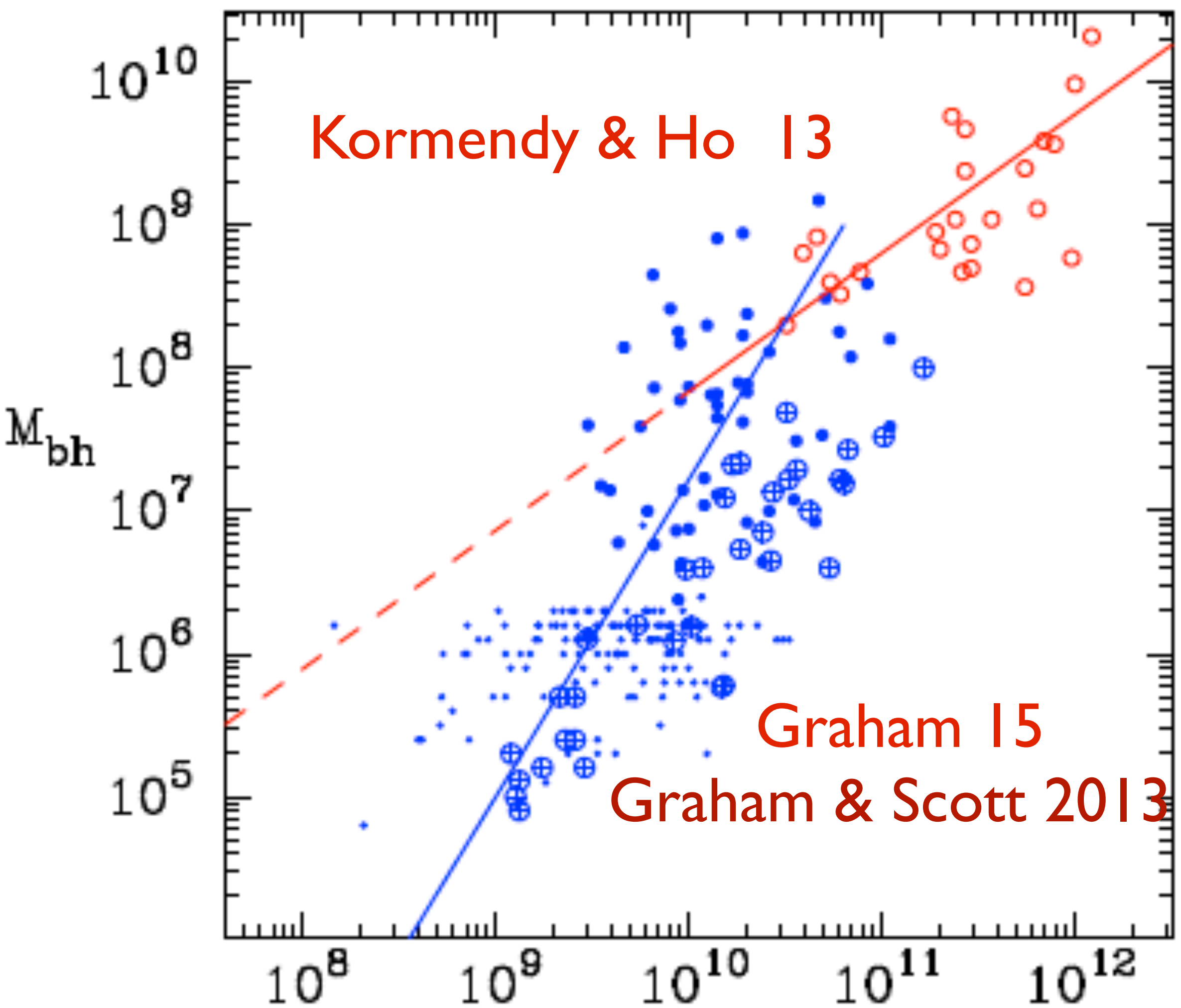
* Detection of faint satellite galaxies → growth of SMBH in LSS

* High-quality spectrum of z~6 QSO → iron features, UFO, ...

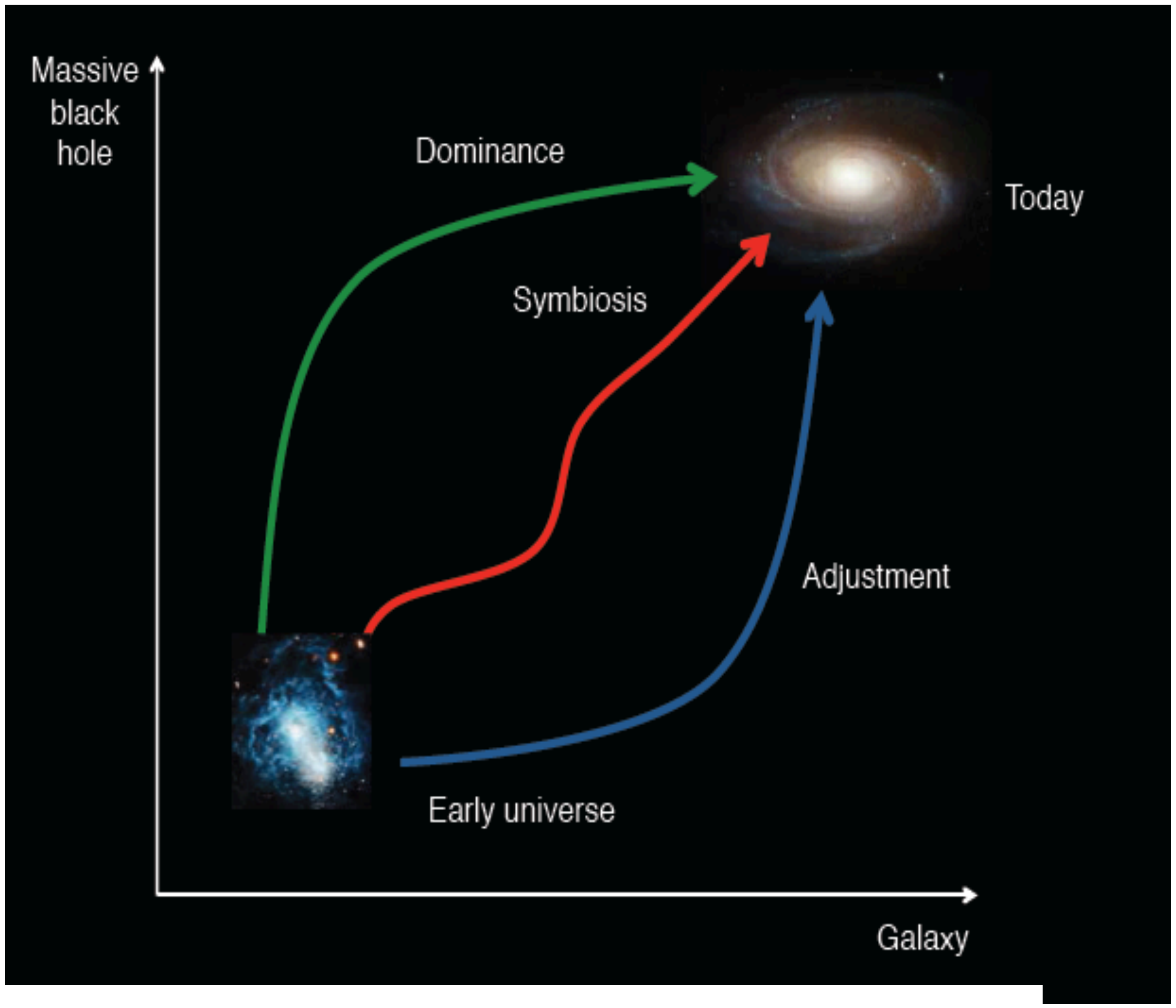
* deep multi-λ survey

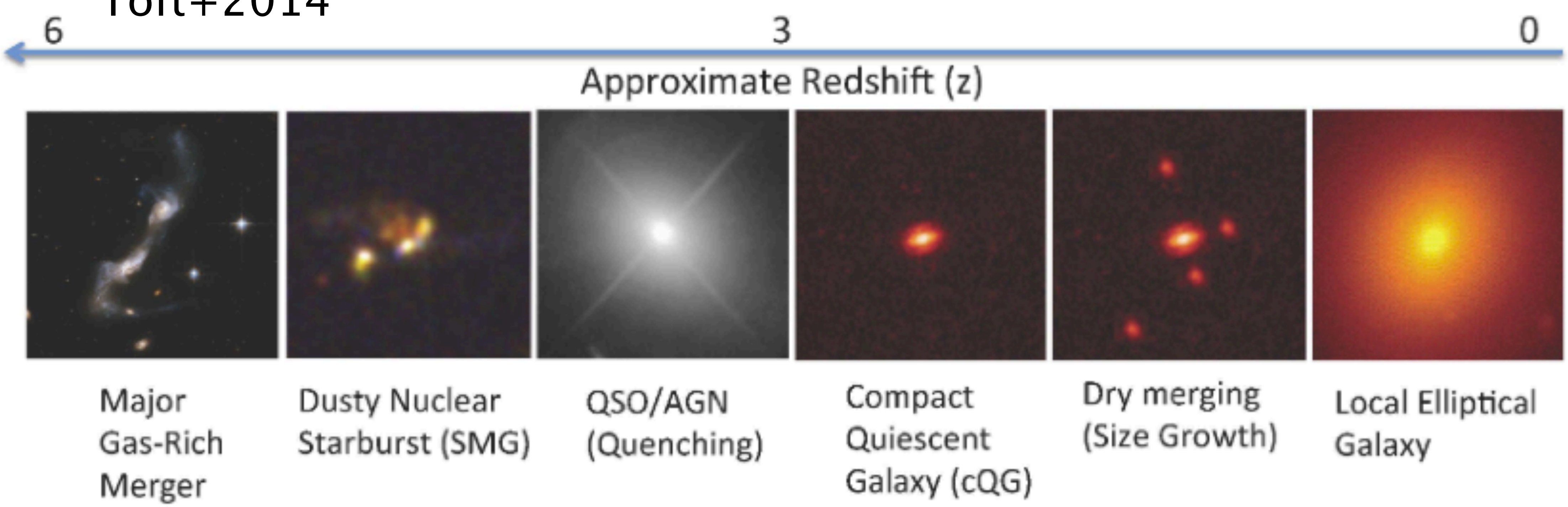


Obscuration and joint SMBH/Host evolution



Toft+2014





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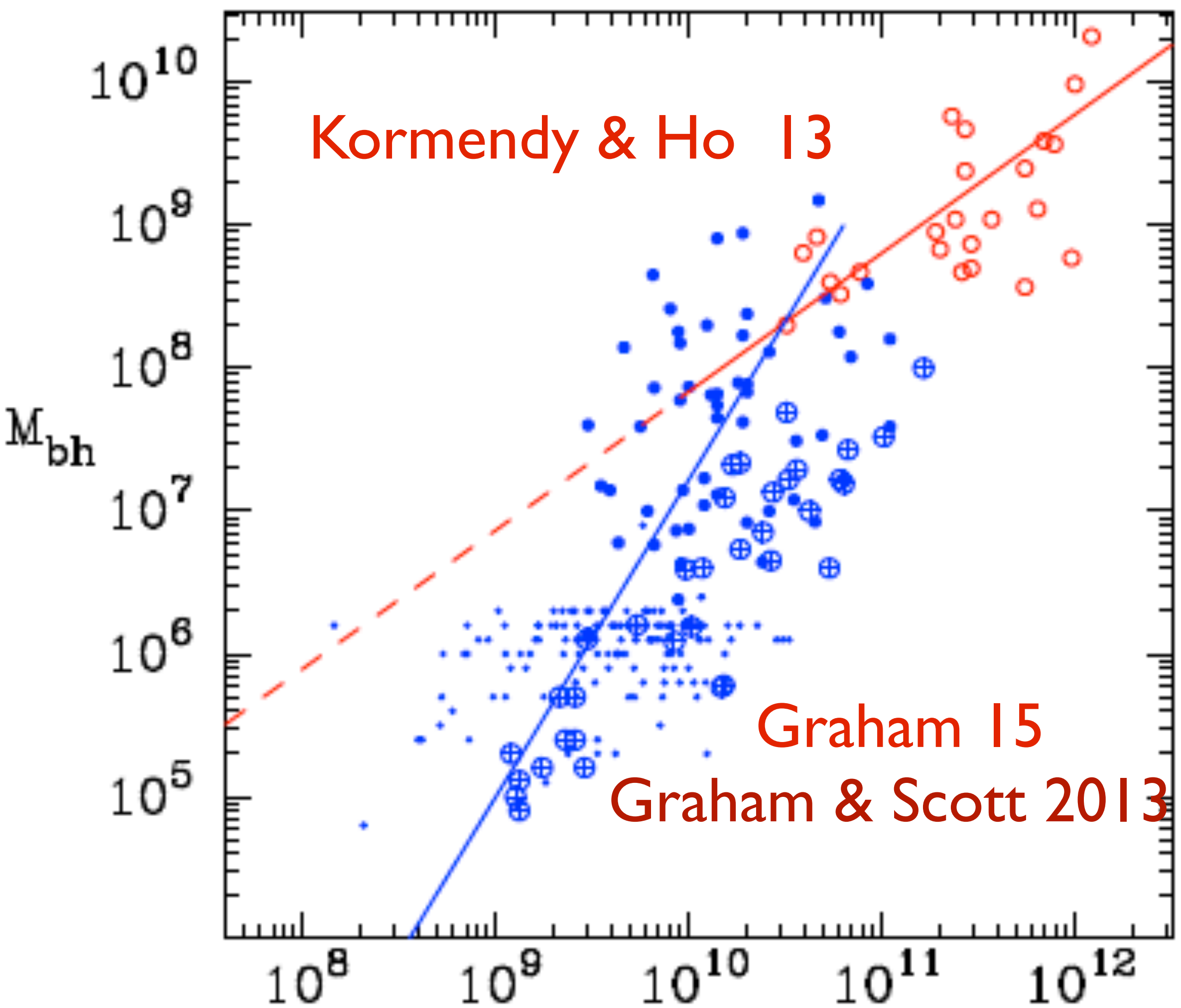
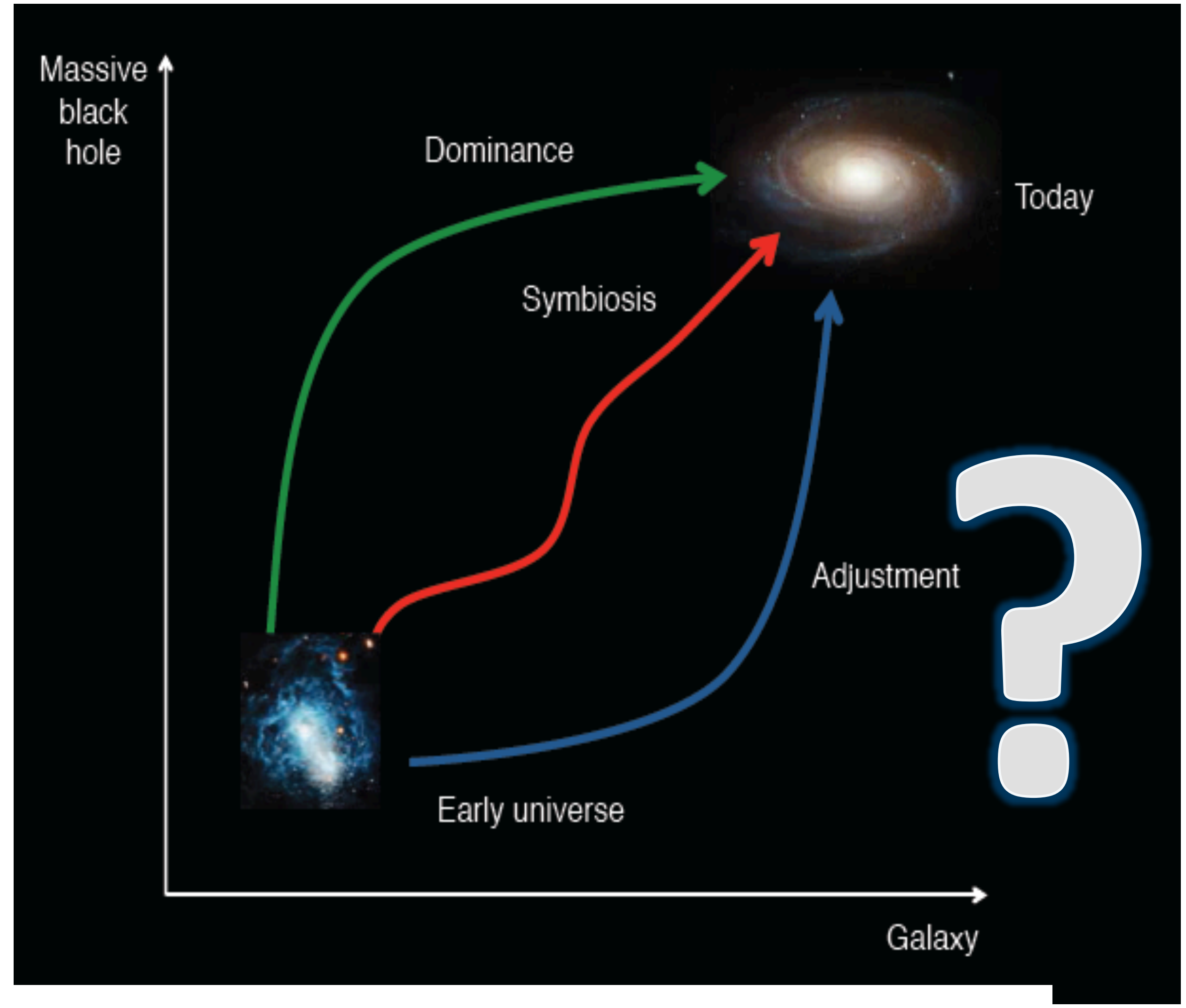
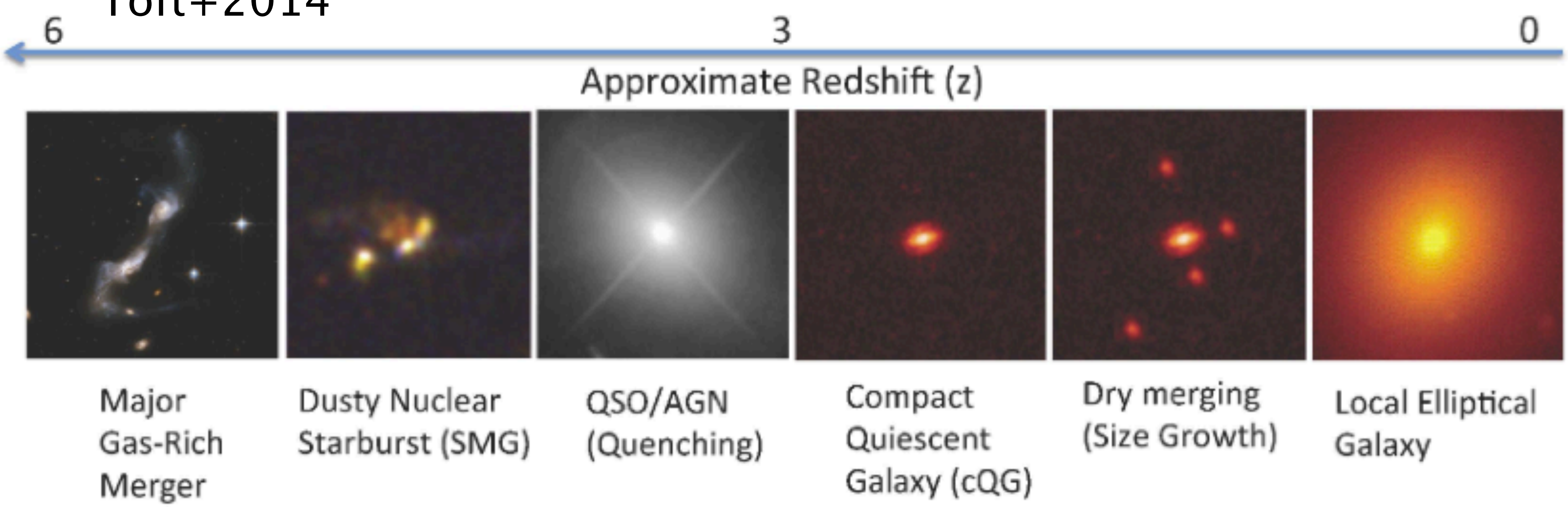
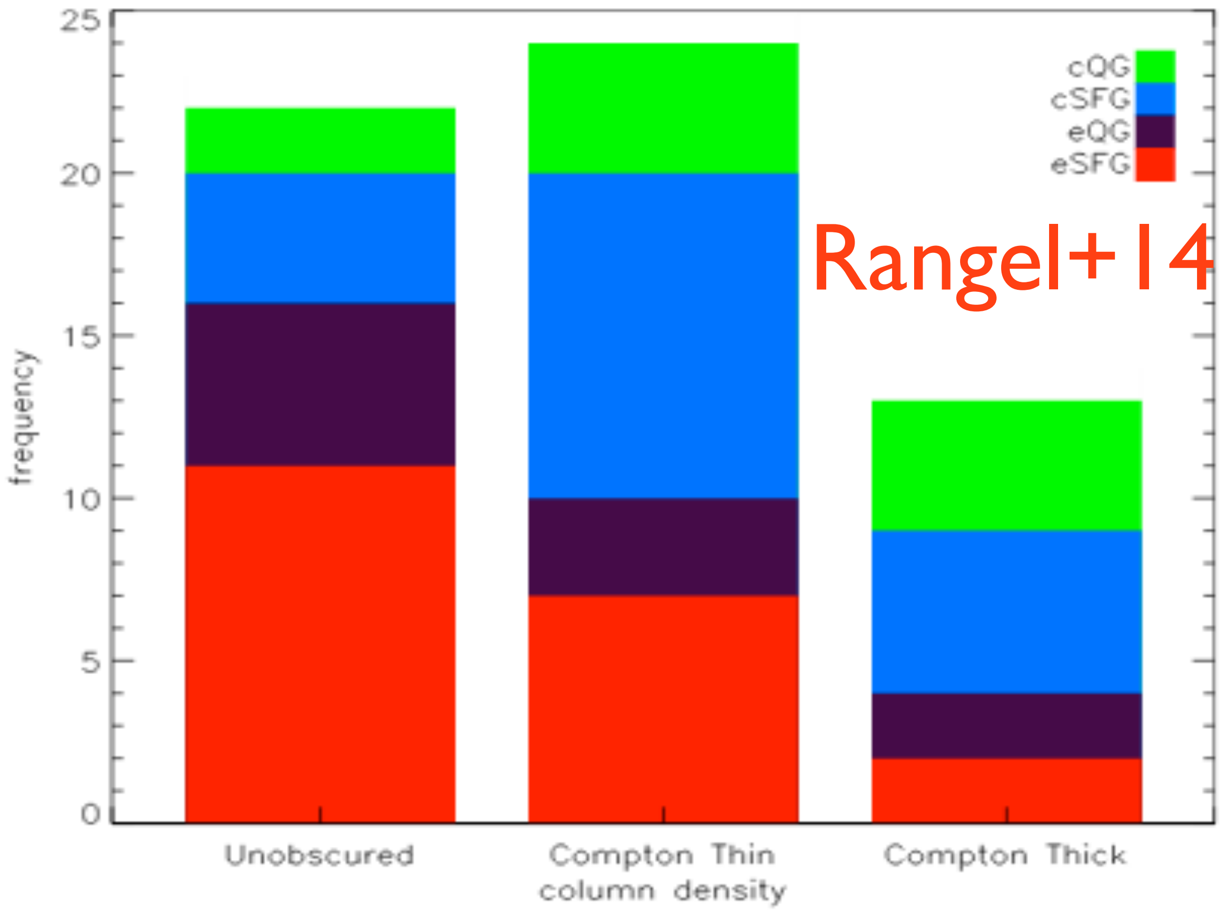


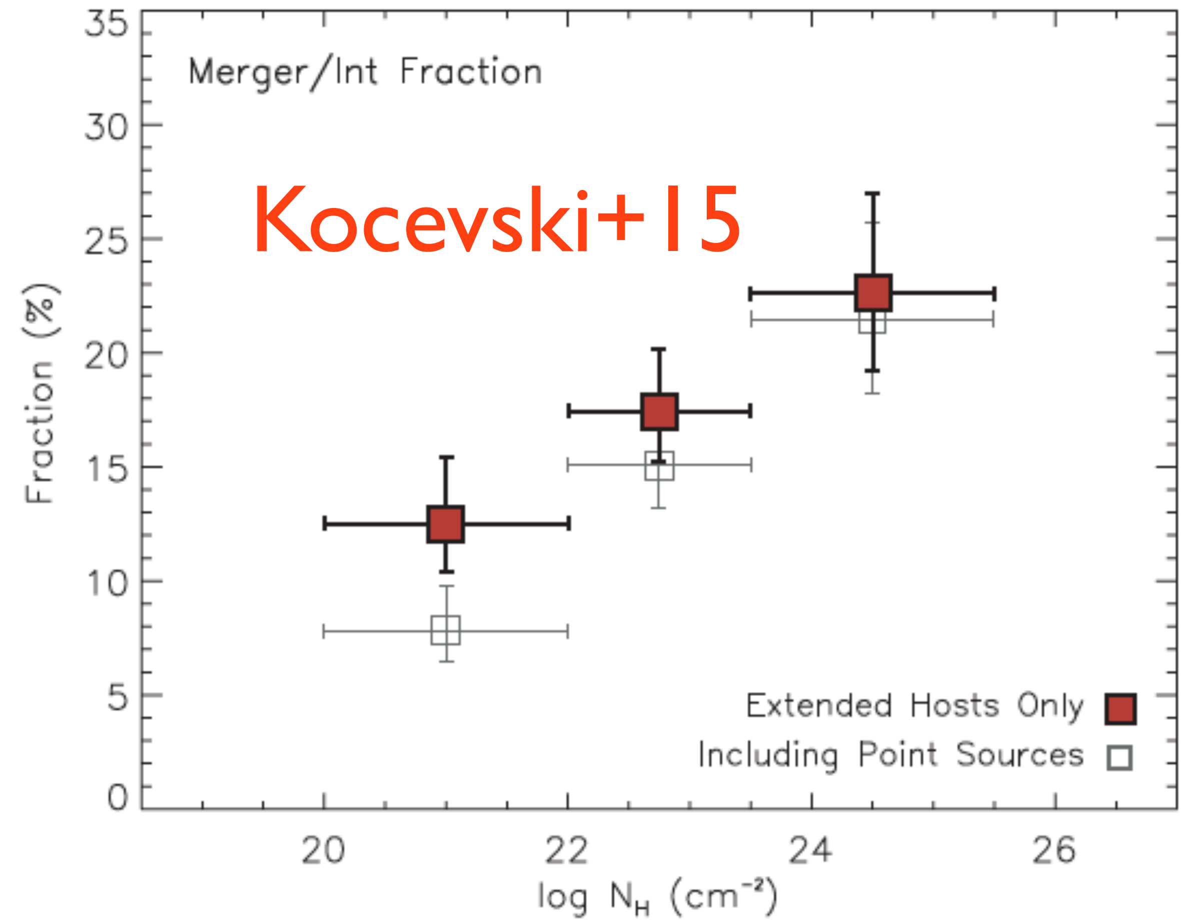
Toft+2014





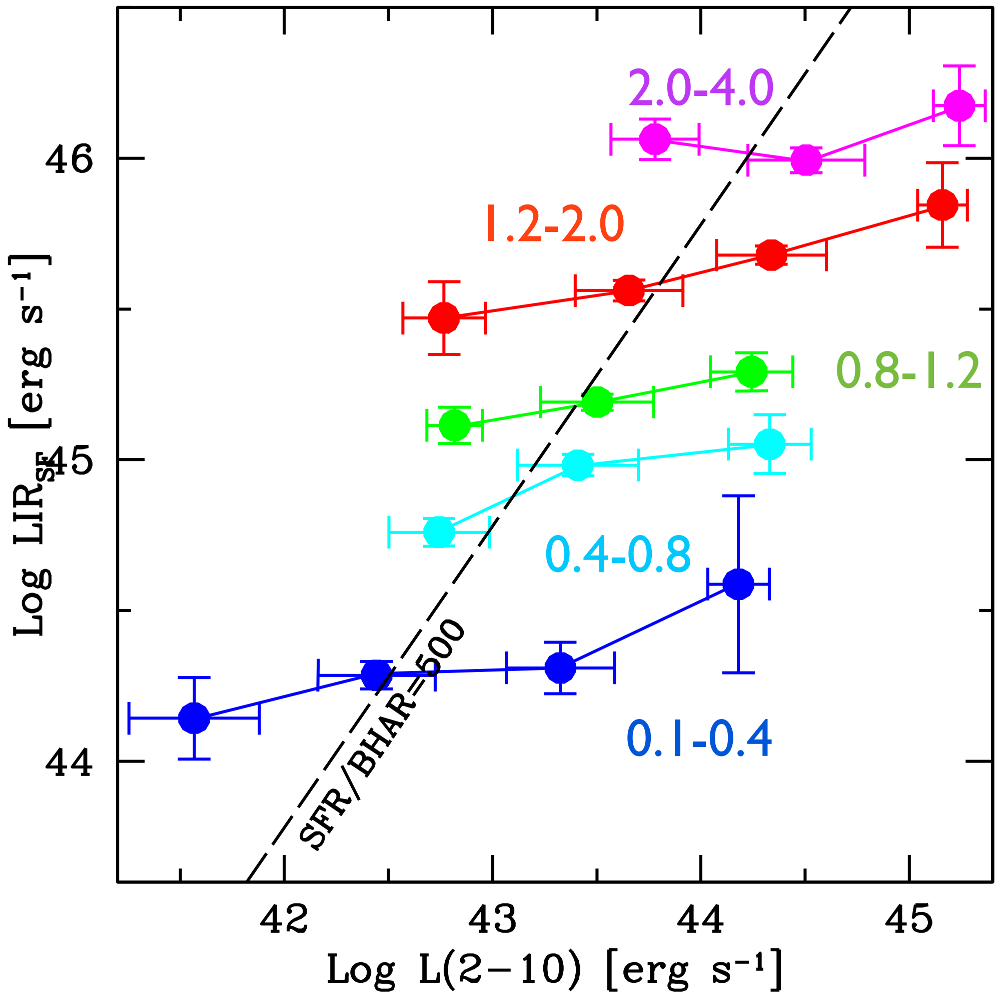
AGN vs Host

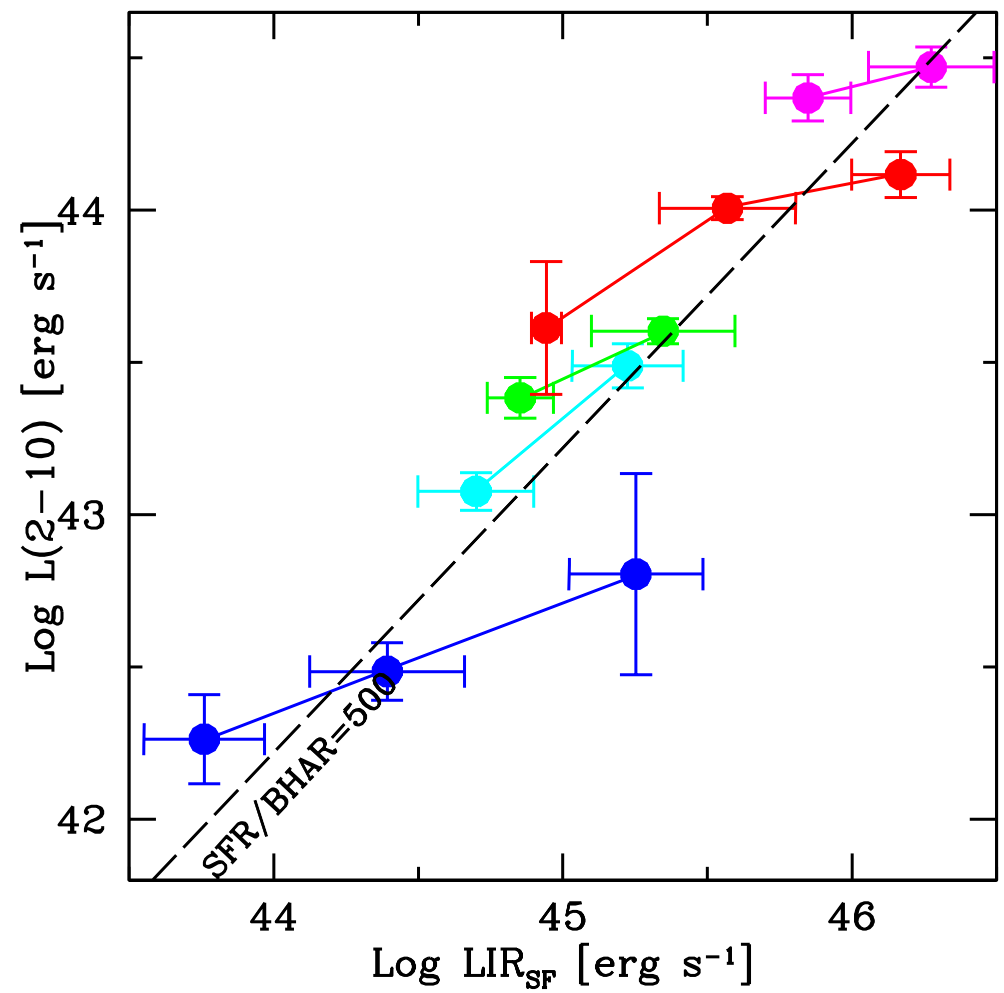




Heavy absorption associated to merger disturbed morphology and host compactness (two modes of accretion?)

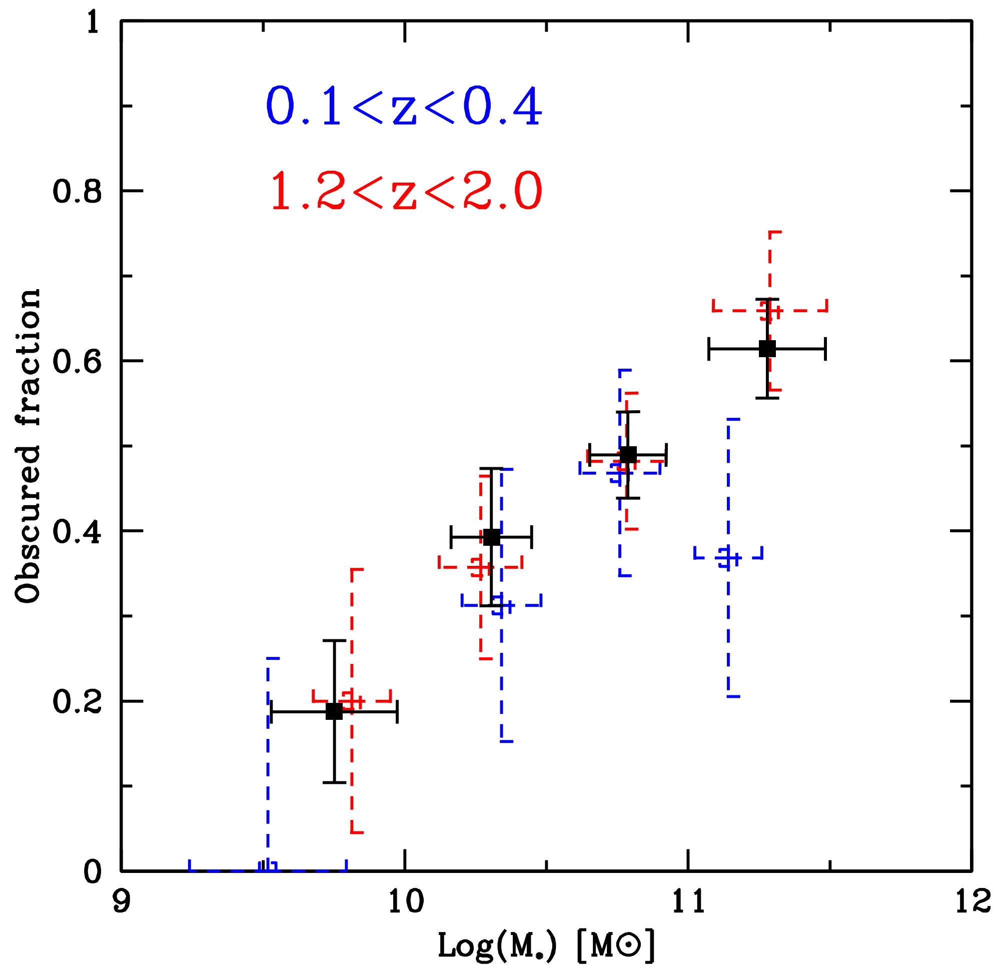
Molecular gas supply is a key parameter in driving SF and AGN feedback. IR and X-rays to probe gas and dust obscuration





dashed line
SFR/BHAR=500

Lanzuisi+16

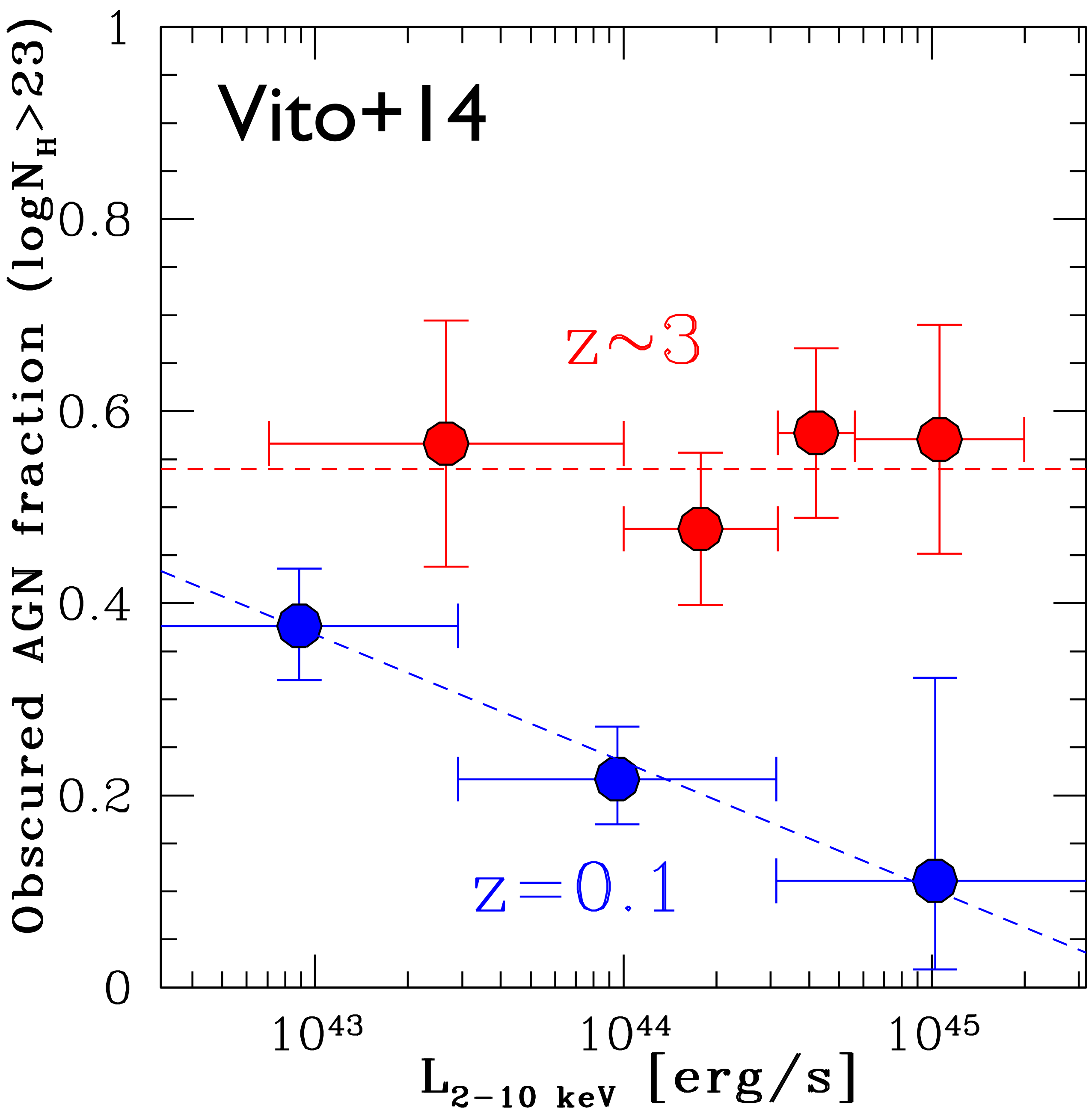


Luminosity relations may be affected by averaging slowly changing SFR with rapidly varying BHAR i.e. Hickox+14

Obscuration vs Host Mass (cfr. Juneau+13)
Not seen by Rovilos+12 & Rosario+12
Related to Mass vs Metallicity relation?

Herschel+Chandra/XMM in COSMOS ~700 sources

Obscured AGN fraction at high-z



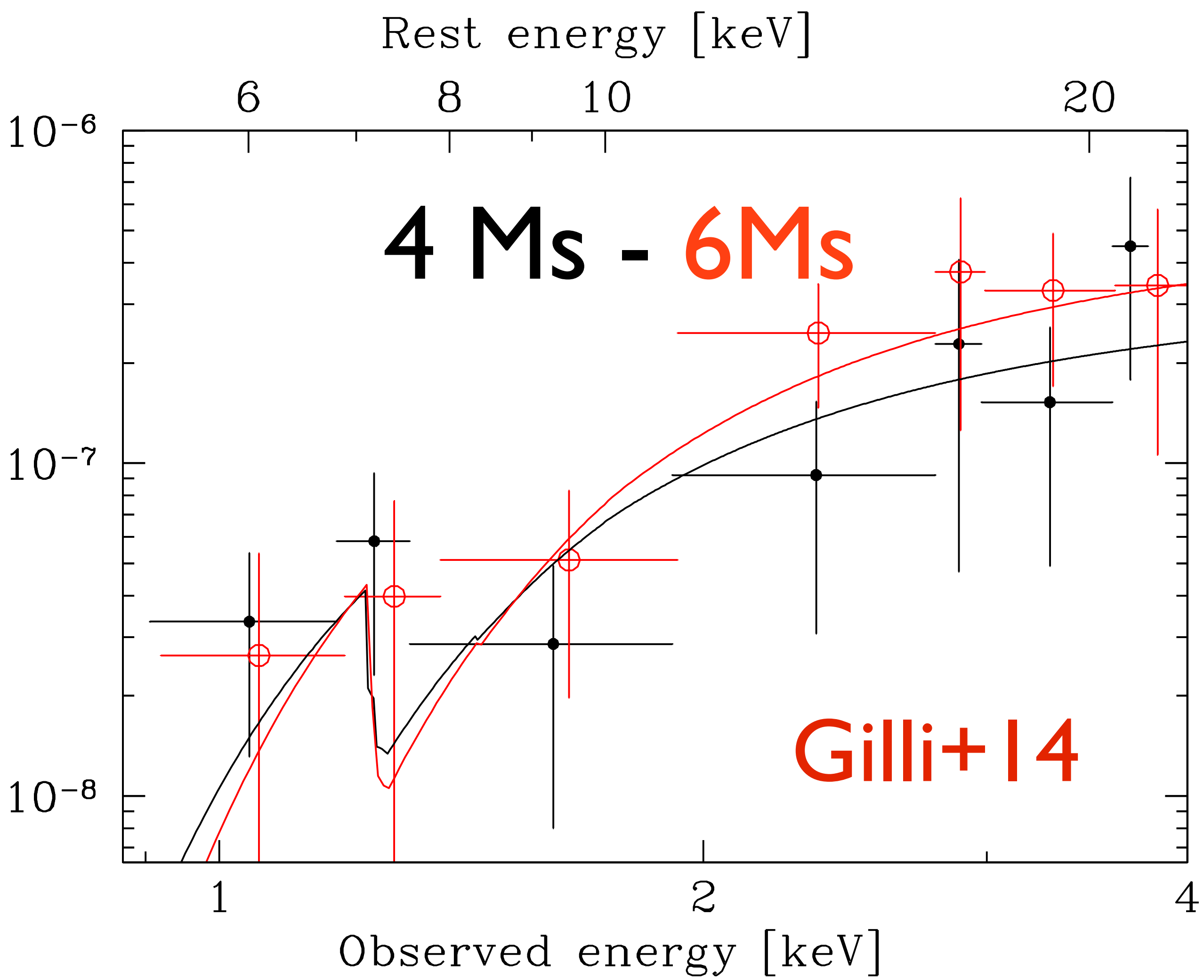
The Fraction of obscured QSOs increase with z and is luminosity dependent

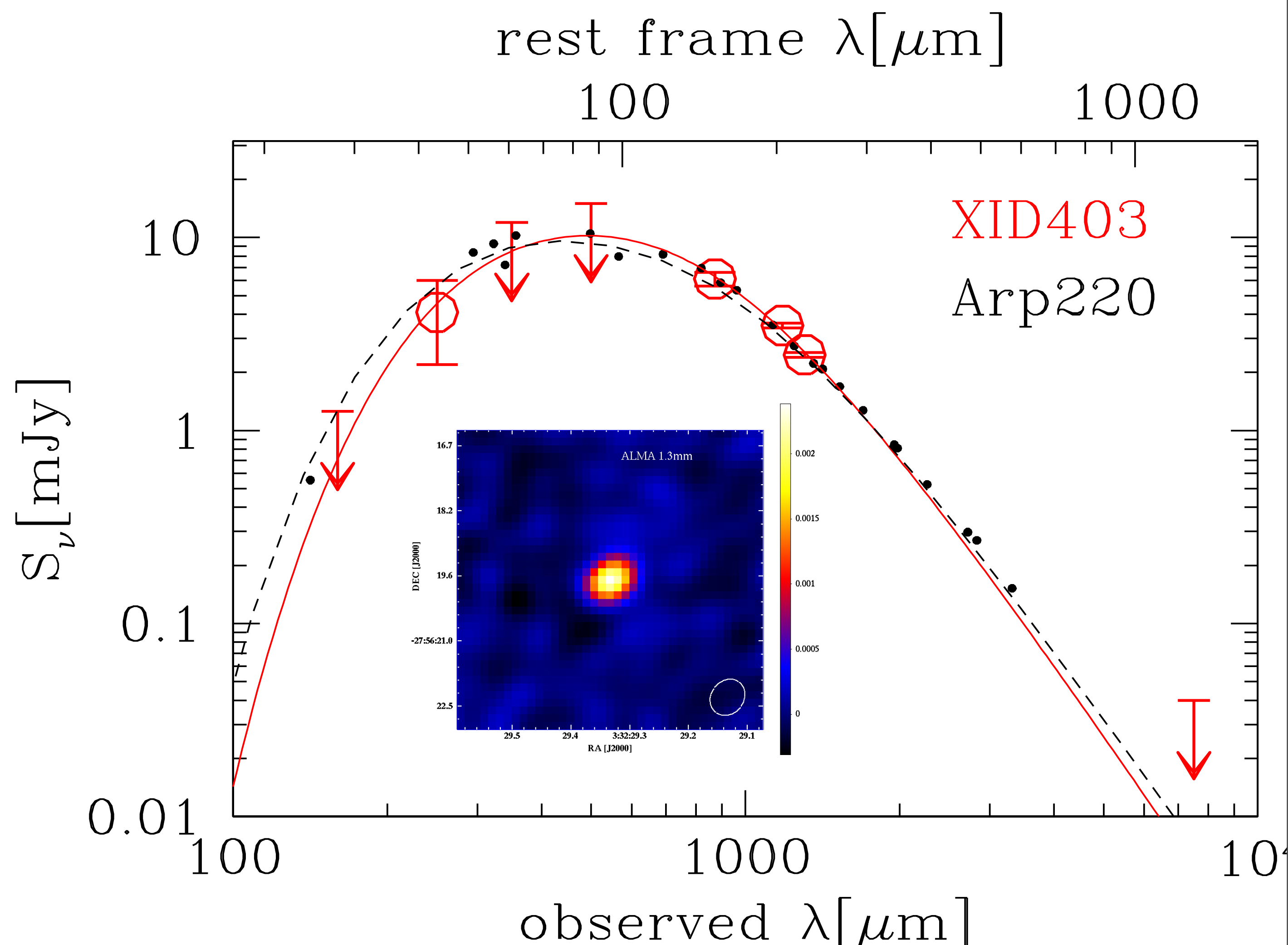
@z>3 half of the objects are heavily obscured $\log N_H > 23$

At high-z galaxies are more compact and gas rich, likely denser ISM and host galaxy absorption?

La Franca+05,Treister&Urry06,Iwasawa+12,Ueda+14

XID 403 @ z~4.76



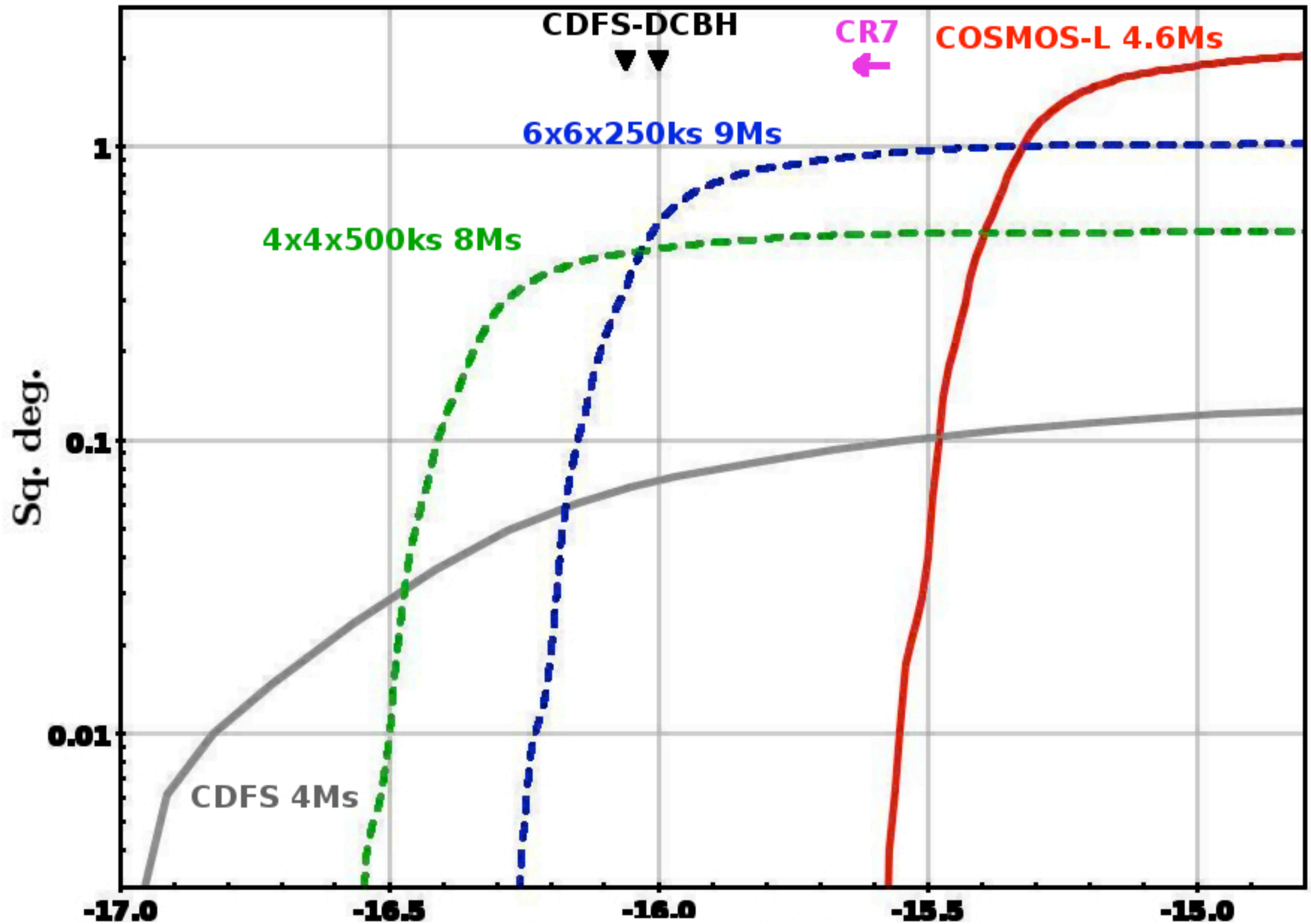


N_H~1.2-2.1 x 10^{24} cm^{-2}

N_{gas}~0.3-1.1 x 10^{24} cm^{-2}
from M_{gas} and r ~0.9 kpc
ALMA continuum

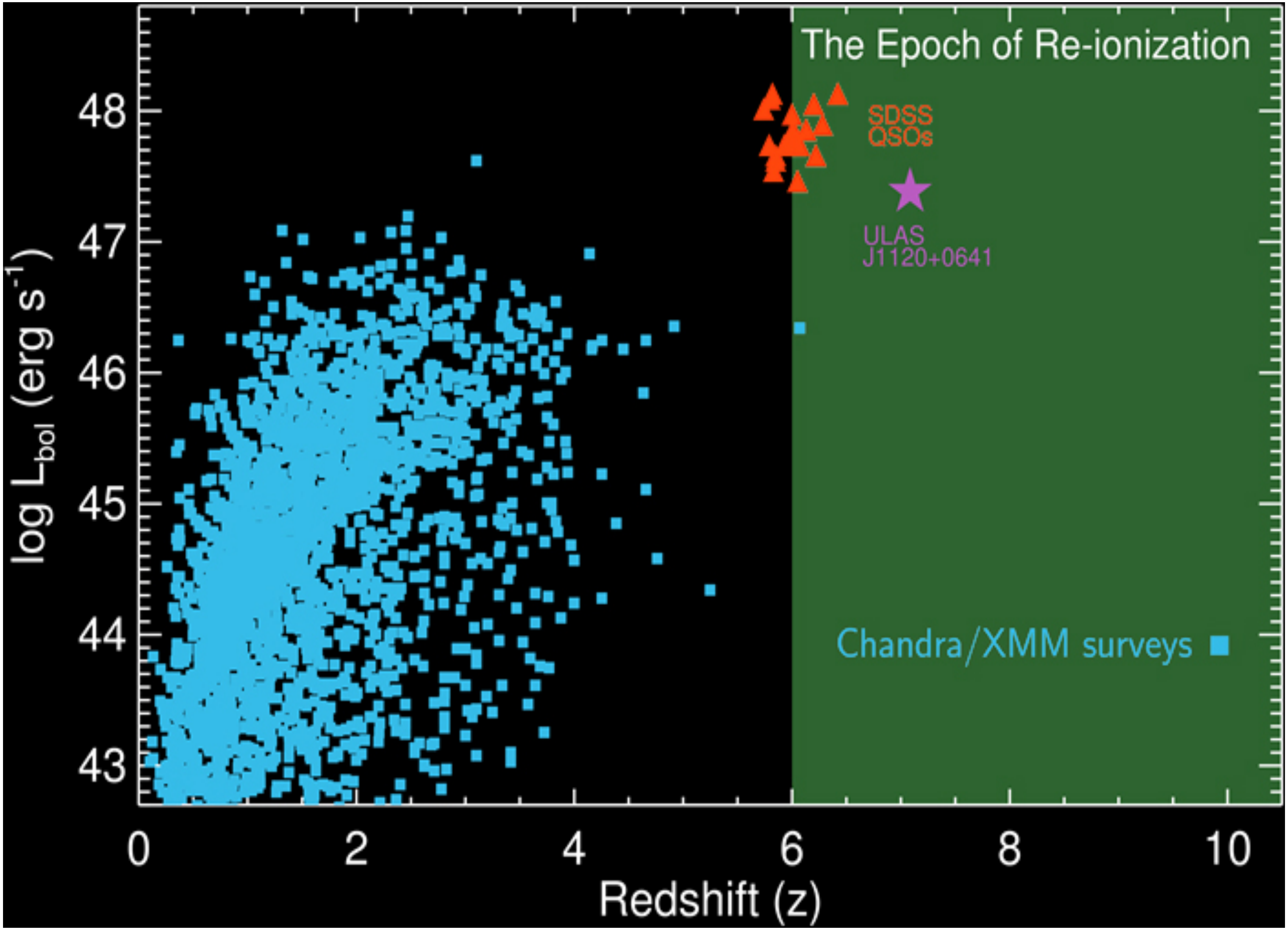
The absorption may be due to host ISM for solar metallicities

Chandra Surveys



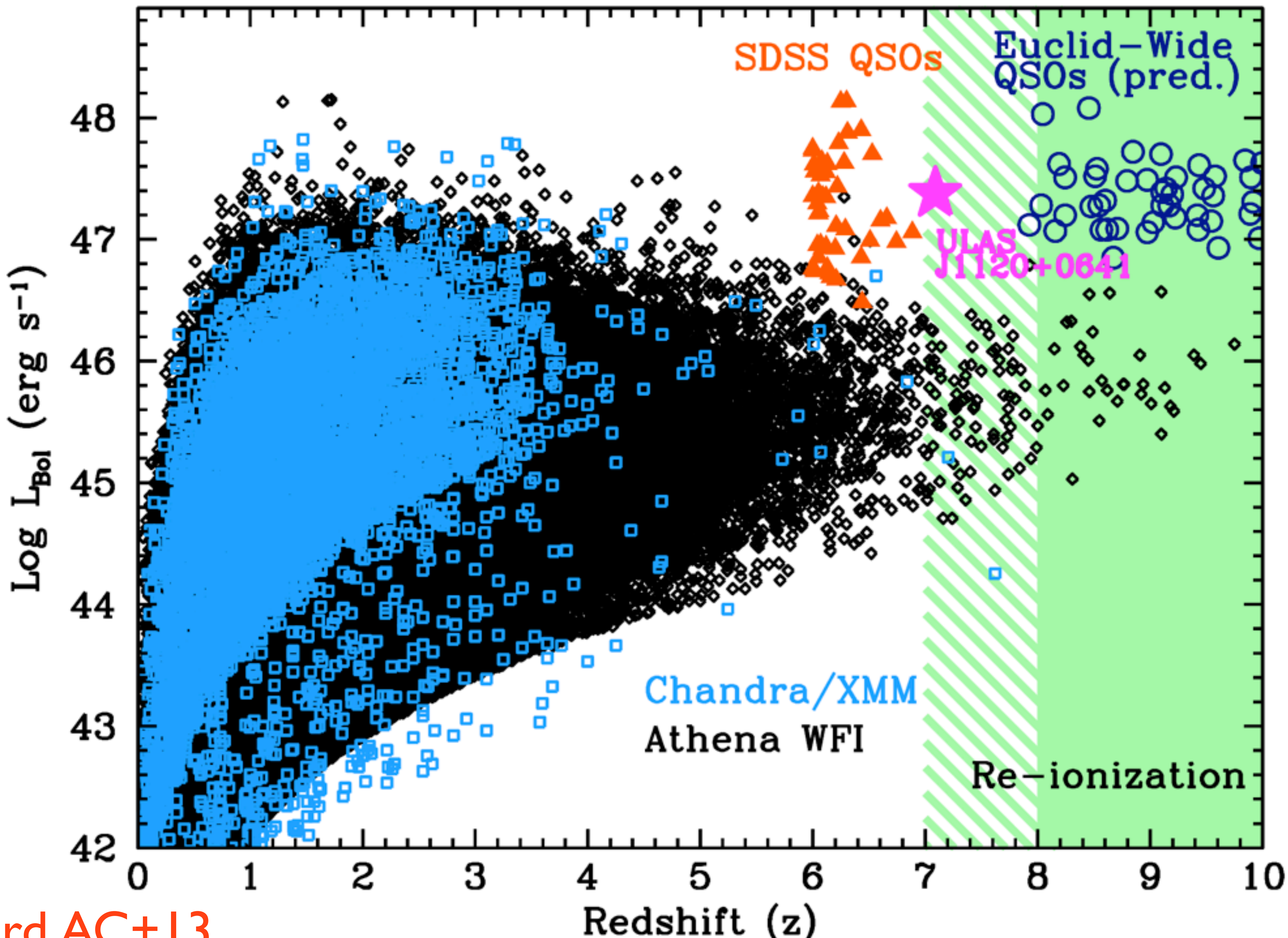
log Flux 0.5-2.0 keV

The history of SMBH growth with ATHENA



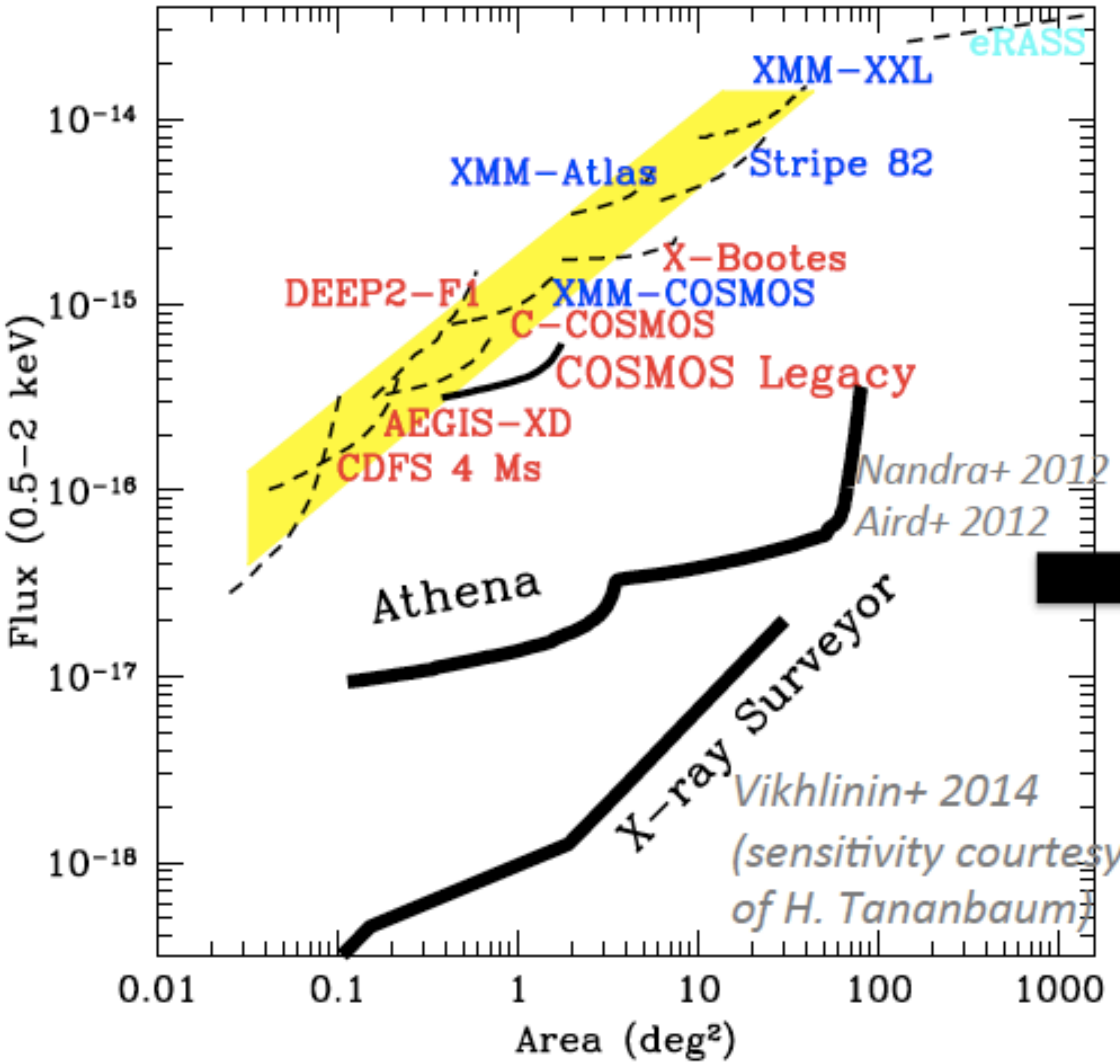
Aird,AC+13

The history of SMBH growth with ATHENA



Aird,AC+13

Survey Sensitivities

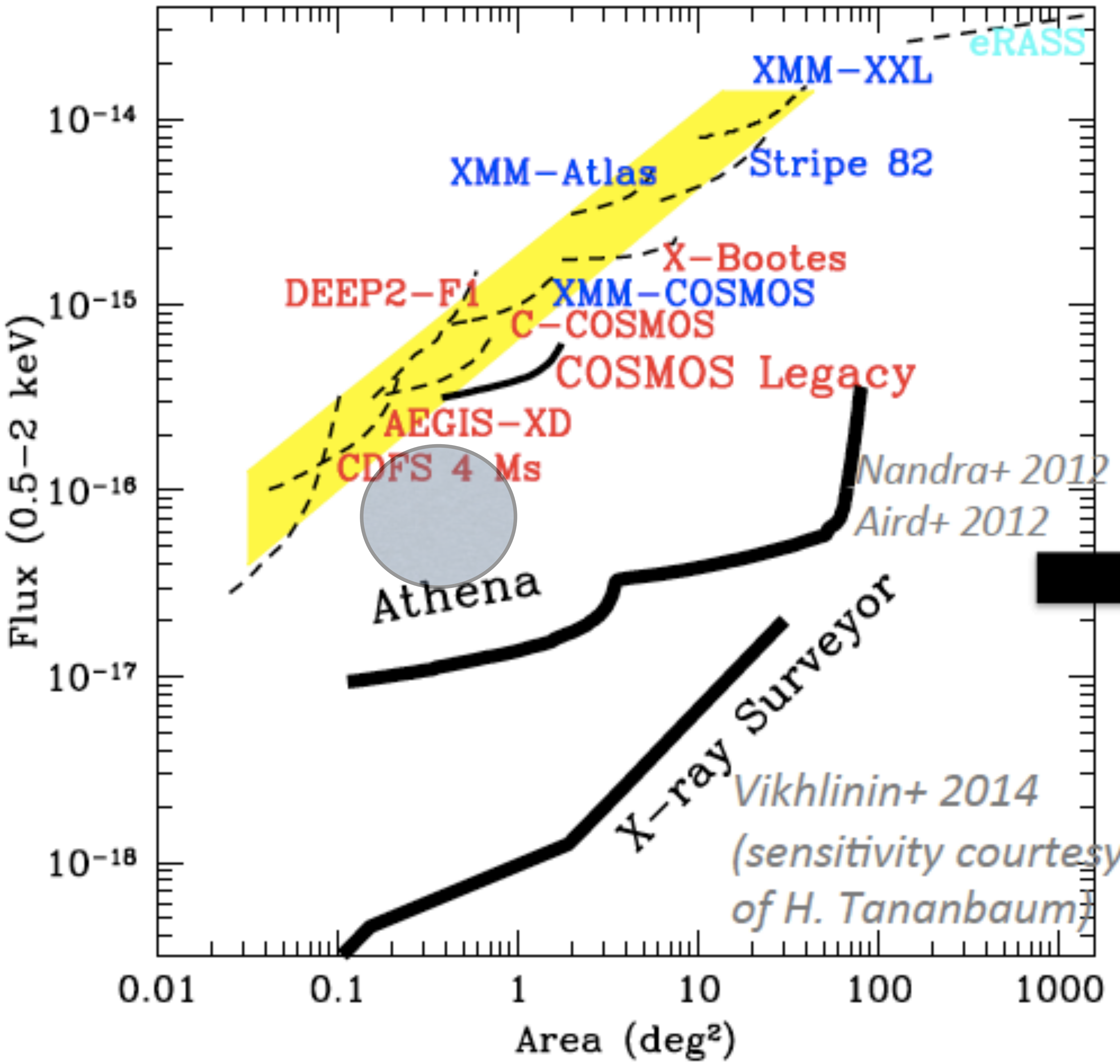


Current:
>50 Ms
of total
exposure

Future:
25 Ms Athena
Multitiered
surveys
Chandra
10-15 Ms

Credit: Francesca Civano

Survey Sensitivities



Current:
>50 Ms
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Future:
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Chandra
10-15 Ms

Credit: Francesca Civano

Lessons learned & Perspectives
Chandra 2016-2026

The science cases of high-z universe and BH-Host co-evolution could be addressed with a 10-15 Ms time survey

Increase the area by an order of mag at fluxes where z~6 AGN should be found. JWST and ALMA "follow-up" for robust spectroscopic identification

Relatively large sample of "representative" heavily obscured AGN, Need full multi-wavelength coverage from radio to X-rays. Origin of the obscurer and BH vs Host properties relations.

COSMOS Legacy, CDFS/XSERVS, Stripe82 or "Overdense" z~6 QSOs fields are excellent starting points.