History of cosmic accretion: obscured AGN

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The high-z Universe: open issues

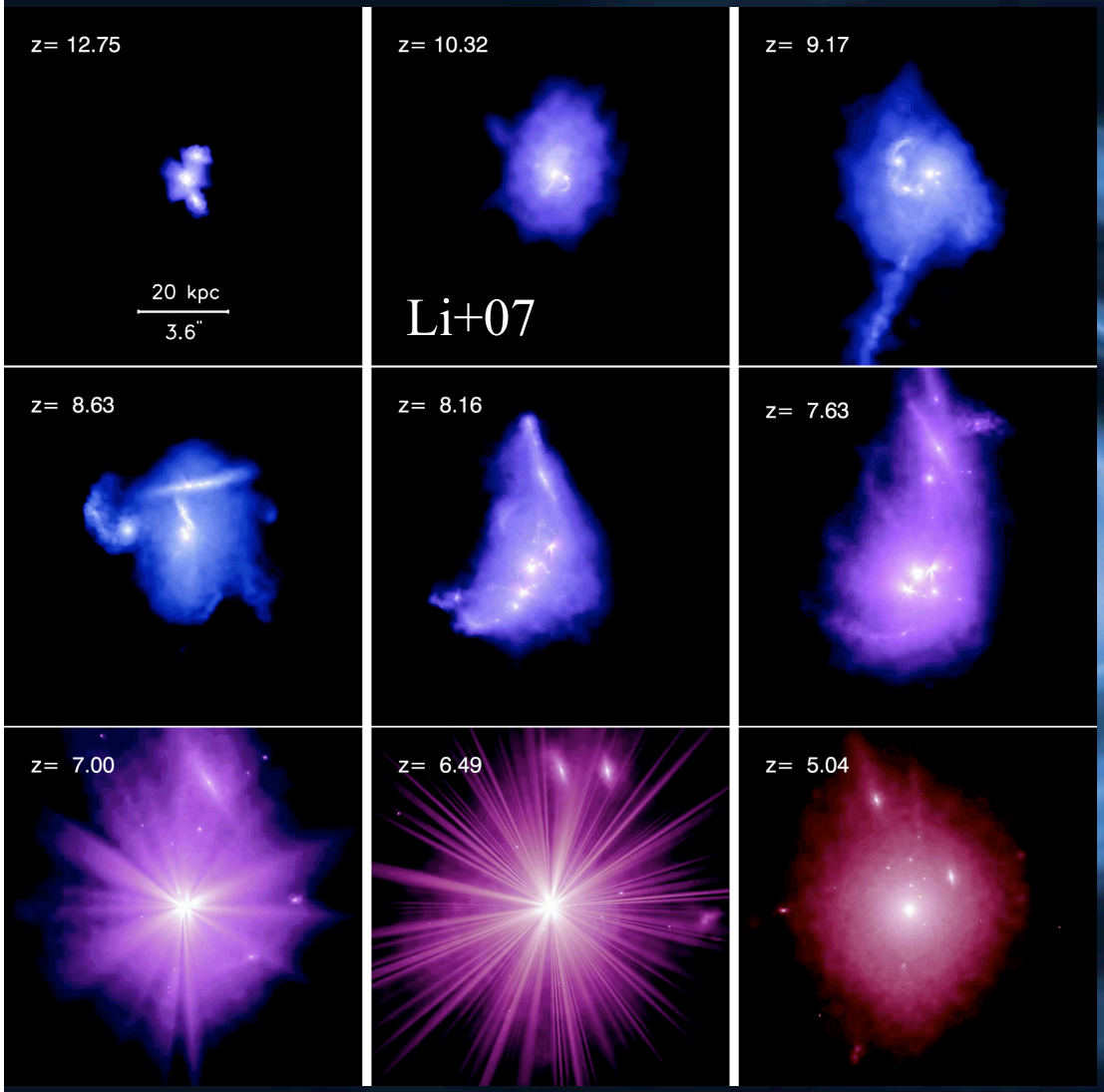
Future facilities (JWST, ALMA, ELT, EVLA.Lofar,) will investigate high-z galaxies and AGN in many bands. Questions for a future X-ray observatory:

How do early BHs form and grow?
What triggers nuclear activity? External (i.e.mergers, fly by) or internal ?
How do accretion modes evolve? [radiative efficiency, L/L_{Edd}, SED(α_{ox})]
What's the distribution of obscuring gas at "high" redshifts

What formed first, BH or galaxy?
Some evidence for larger BH per fixed stellar mass at z~0.3-0.6 (Treu+06,Woo+08).
Also, suggestions for M_{BH}/M_{*}~0.1-0.3 in bright QSOs at z>4
(Walter+04, Maiolino+07, Riechers+08)
What is the high-z BH mass function?

Representative samples of high-z (>4) and very high-z (>6) obscured SMBH

Building a ~ 10^9 M_{sun} BH at z=6.4

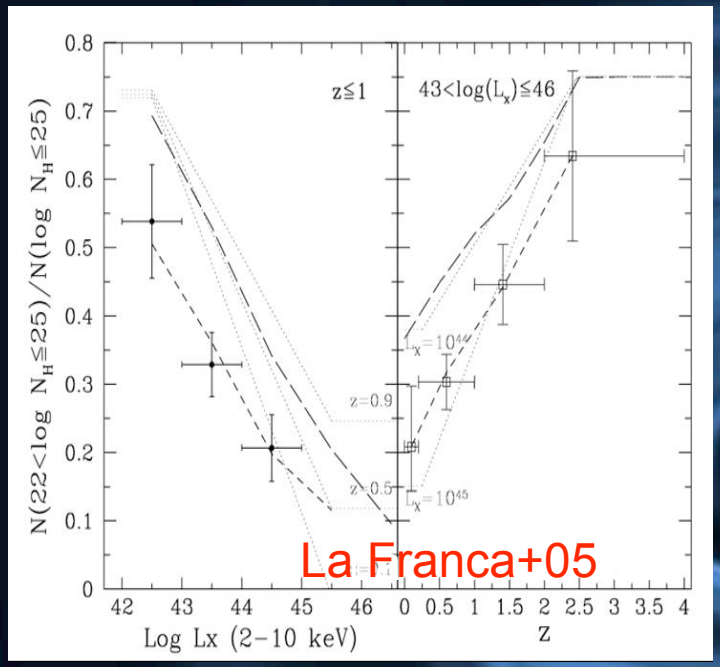


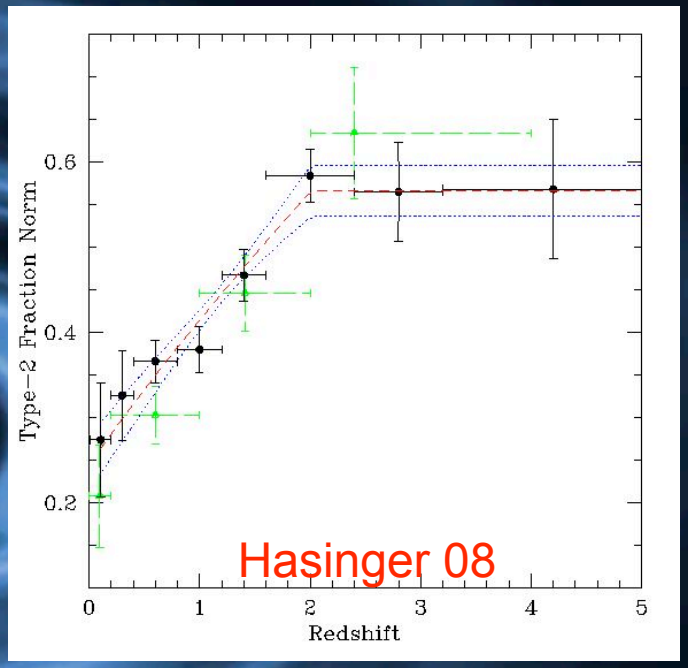
There is (just) time …
Without invoking
Super-Eddington

Multiple mergers with
Eddington limited accretion
can explain both BH and
host galaxy properties of
SDSS QSOs at z>6 (ε = 0.1)

Early phase (Heavy)
Obscuration

Redshift dependence of obscured fraction in X-ray surveys

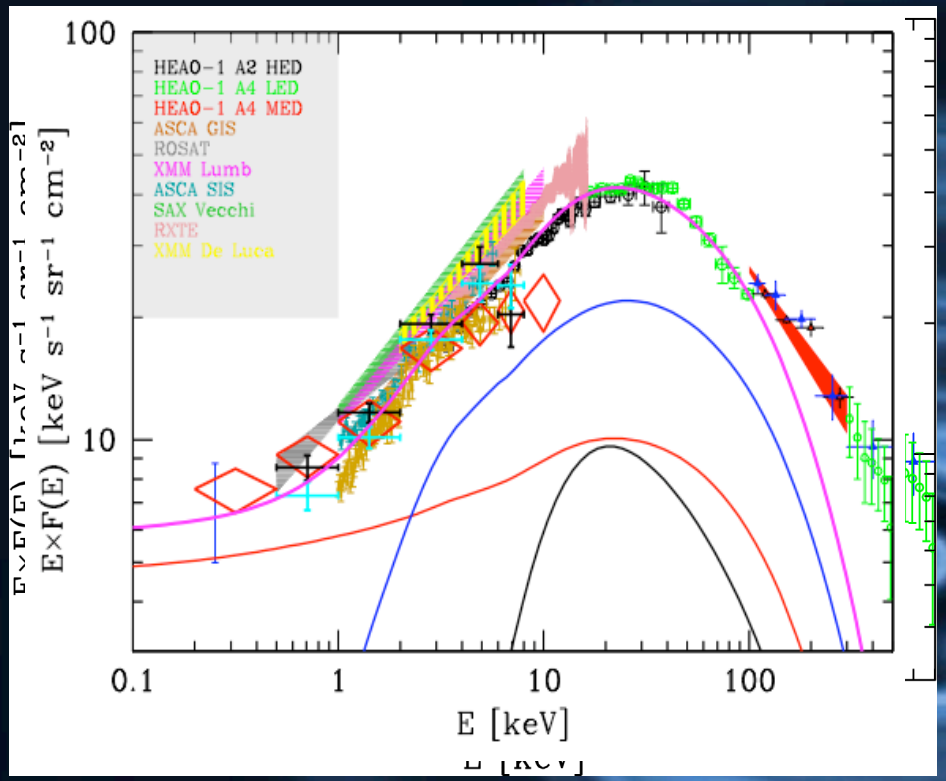


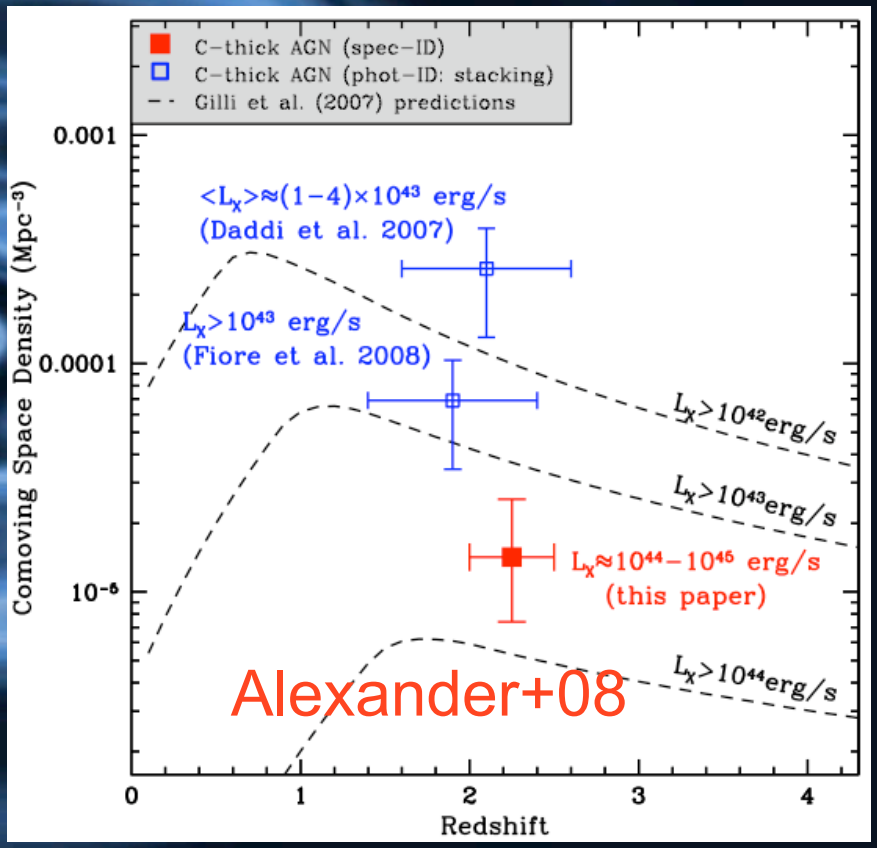


expected/predicted in feedback models (i.e. Menci+08)
Seen in (some) data [e.g. La Franca+05, Treister+06, Hasinger08], not seen in others (Ueda+03, Dwelly&Page 2006), not needed in XRB models (Gilli+07)

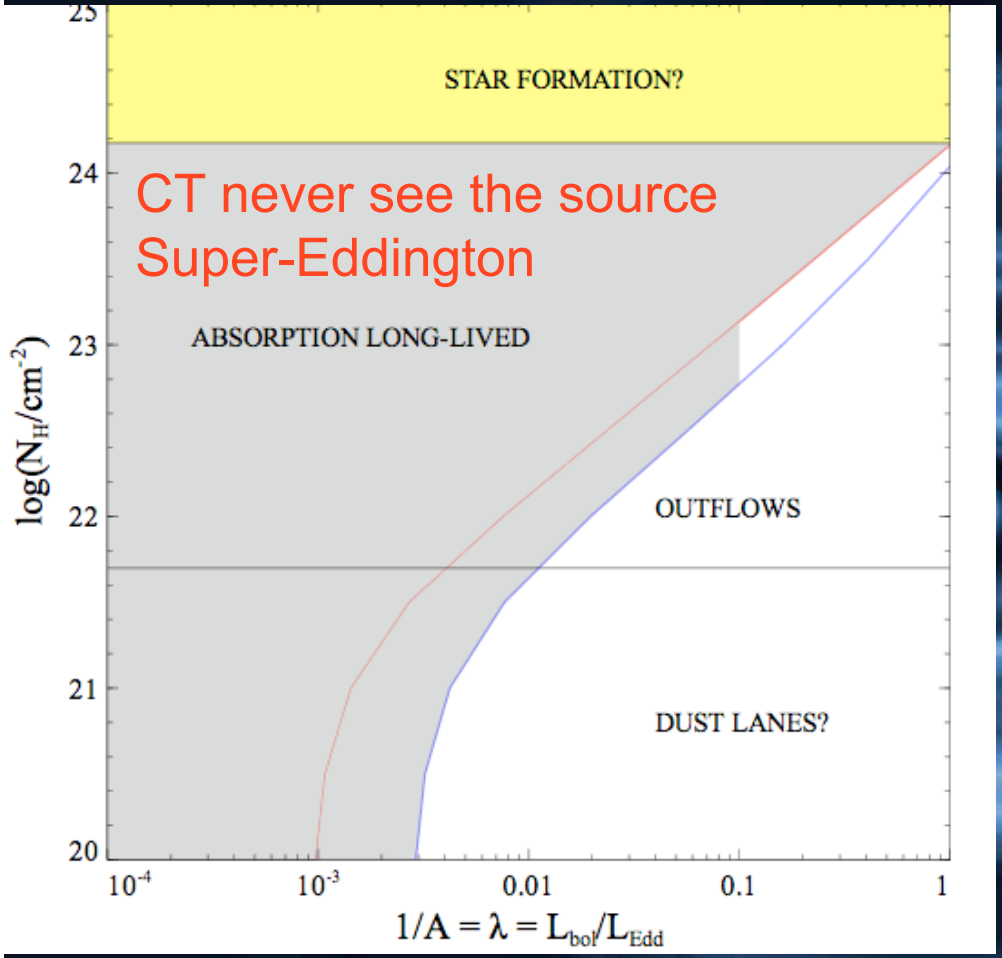
COMPTON THICK ?

XRB


HEAO−1 A2 HED
HEAO−1 A4 LED
HEAO−1 A4 MED
ASCA GIS
ROSAT
XMM Lumb
ASCA SIS
SAX Vecchi
RXTE
XMM De Luca
E×F(E) [keV s⁻¹ sr⁻¹ cm⁻²]
E [keV]
100
10
0.1
1
10
100


C−thick AGN (spec−ID)
C−thick AGN (phot−ID: stacking)
Gilli et al. (2007) predictions
<Lx>≈(1−4)×10⁴³ erg/s
(Daddi et al. 2007)
Lx>10⁴³ erg/s
(Fiore et al. 2008)
Lx≈10⁴⁴−10⁴⁵ erg/s
(this paper)
Lx>10⁴²erg/s
Lx>10⁴³erg/s
Lx>10⁴⁴erg/s
Alexander+08
Comoving Space Density (Mpc⁻³)
Redshift
0.001
0.0001
10⁻⁵
0
1
2
3
4

Compton Thick "obsession"



Effects of rad. pressure on dusty gas Fabian+08

Back of the envolope argument (i.e.Daddi+07)

Compton Heating by hard X-rays

$M \sim 10^{11}\ M_{sun}$
$E \sim M\ \sigma^2 \sim 10^{59}\ f_{gas}$ erg (300 km/s)
$L_X \sim 10^{44}$ erg s^{-1}
$f_{gas} \sim 0.1$

$t \sim 3 \times 10^6$ yr

Accretion Parameters

$< \varepsilon > = 0.06 - 0.10$

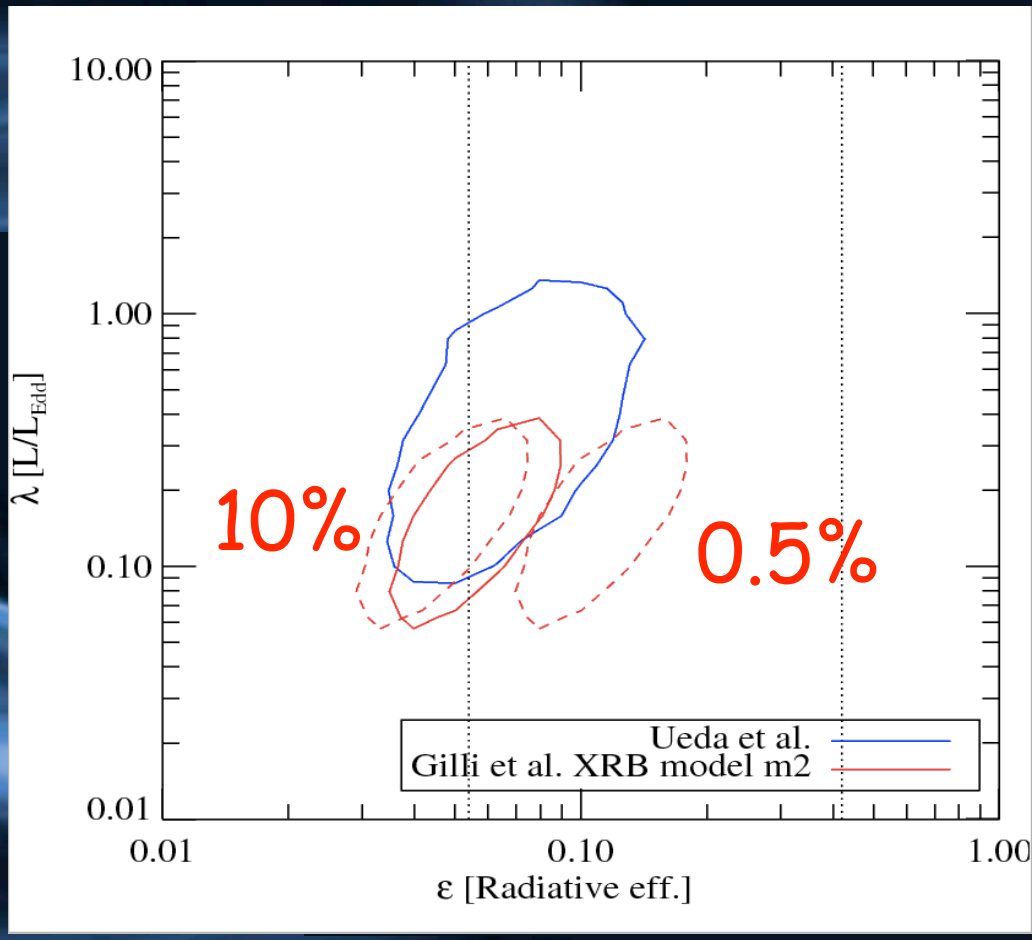
$< \lambda > = 0.2 – 1.0$

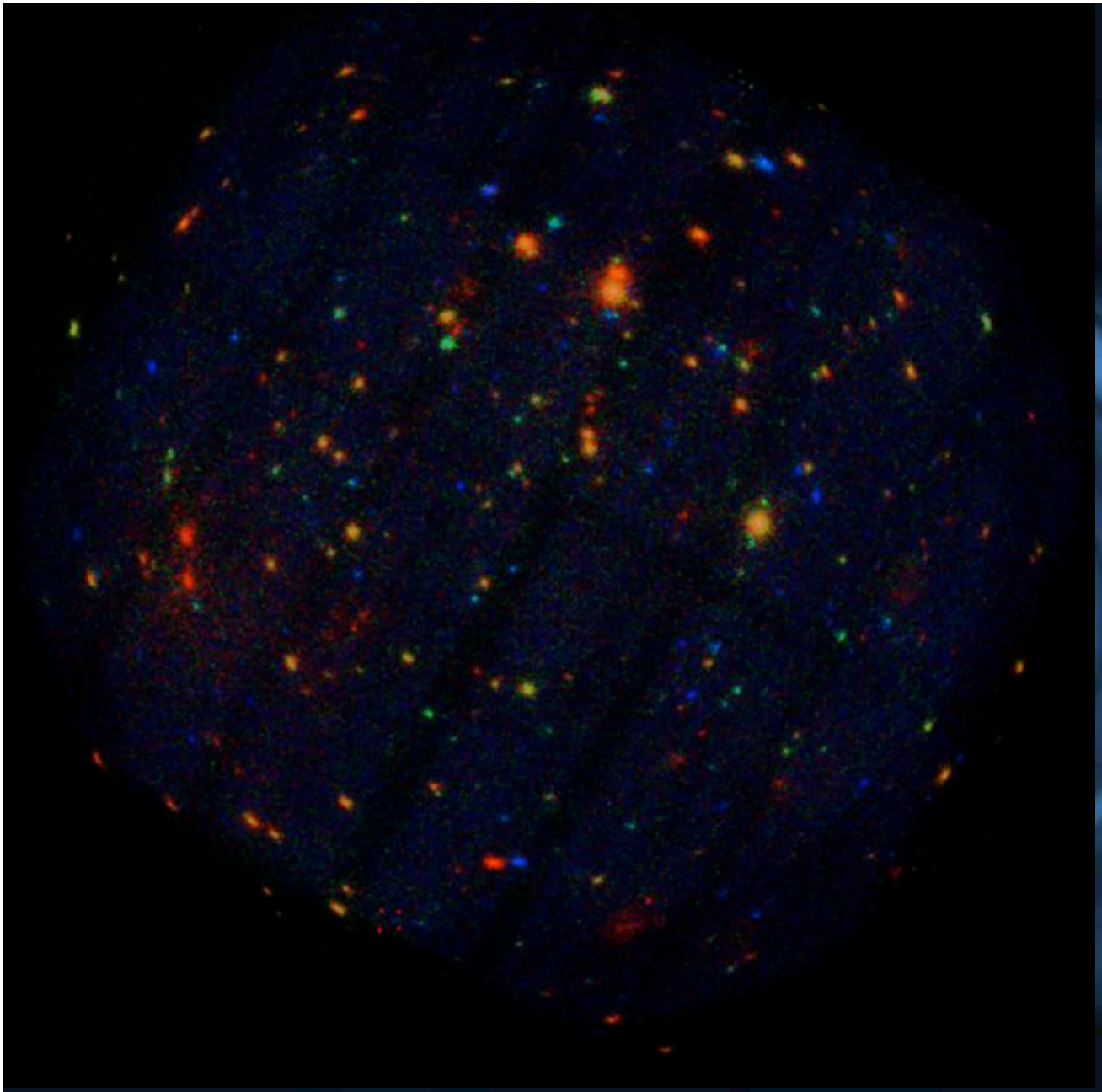
Marconi+04 (see also Yu&Tremaine02, Shankar+04, Merloni+08,…)

The average radiative efficiency depends on the obscured AGN fraction, especially C-thick AGN, unknown at high-z.

Is there any dependence on redshift?

Is spin (i.e. ε) dependent on z or BH mass? (see eg. Volonteri+05)





Chandra 2 Ms

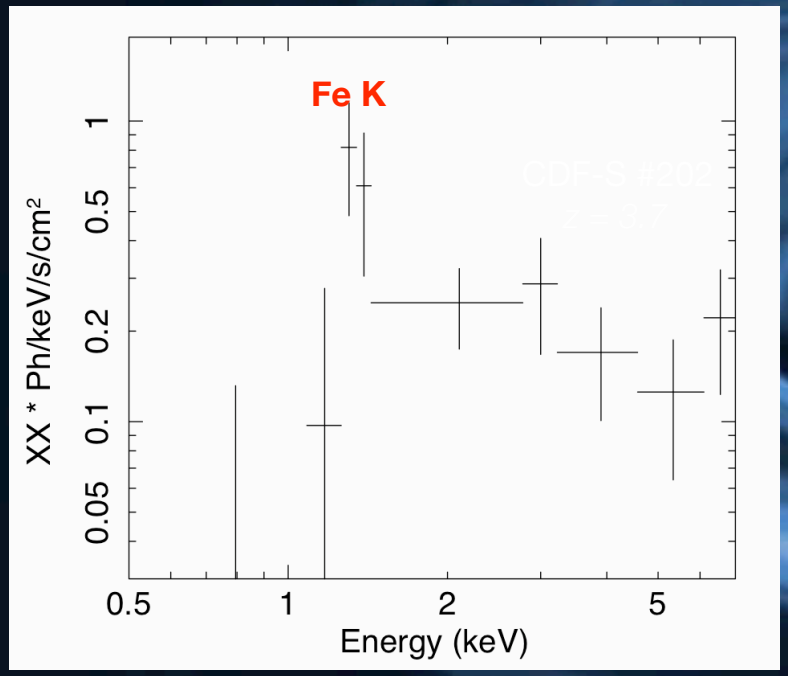
aim at 5 Ms

XMM ~ 0.7 Ms
will reach
~ 3 Ms

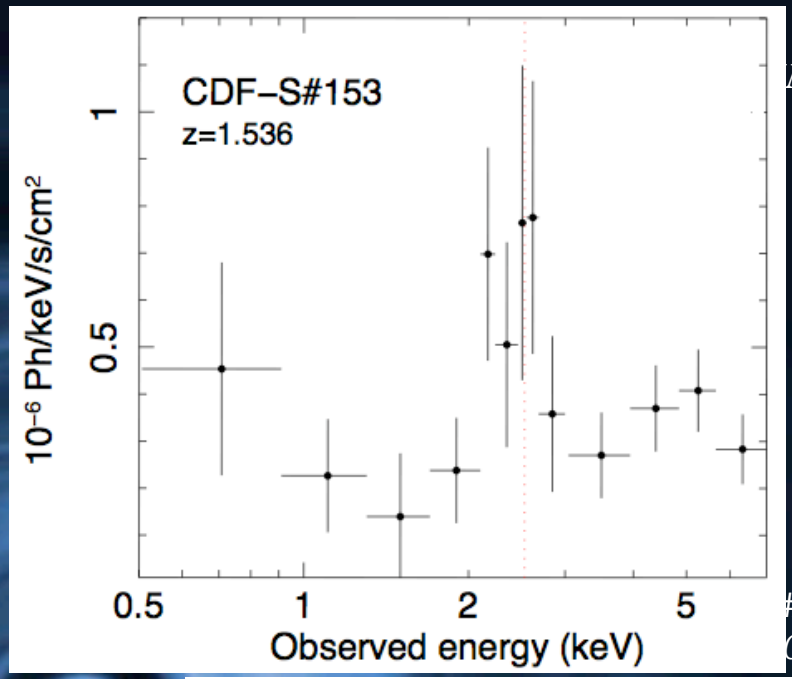
Fe K line sources

known from the Chandra observations

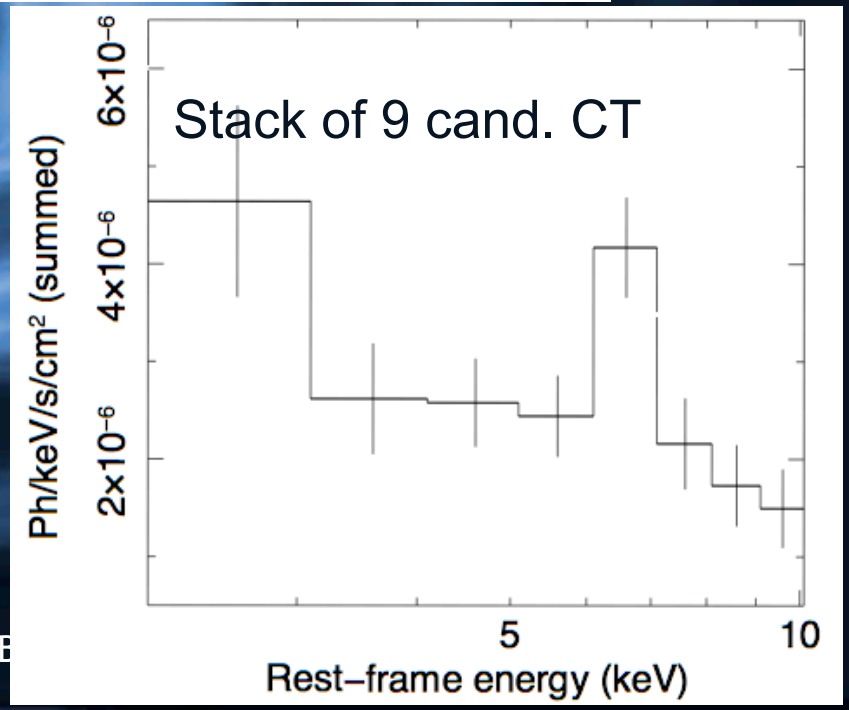
✦Type2 QSO z = 3.7
(Norman+02)



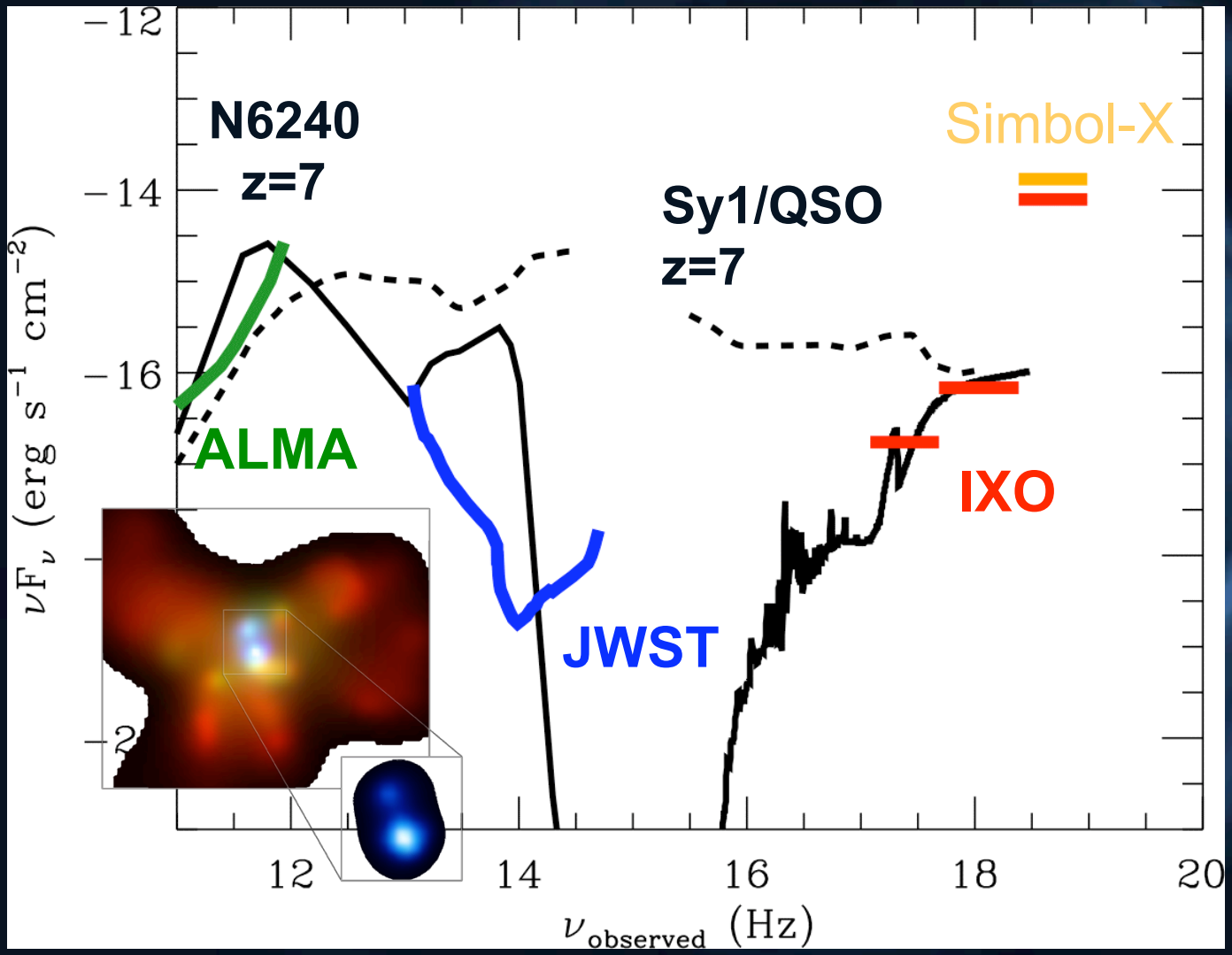
MM-Newton



#56
05



Synergies



The high-z Universe is a key science driver of JWST & ALMA E-ELT - TMT

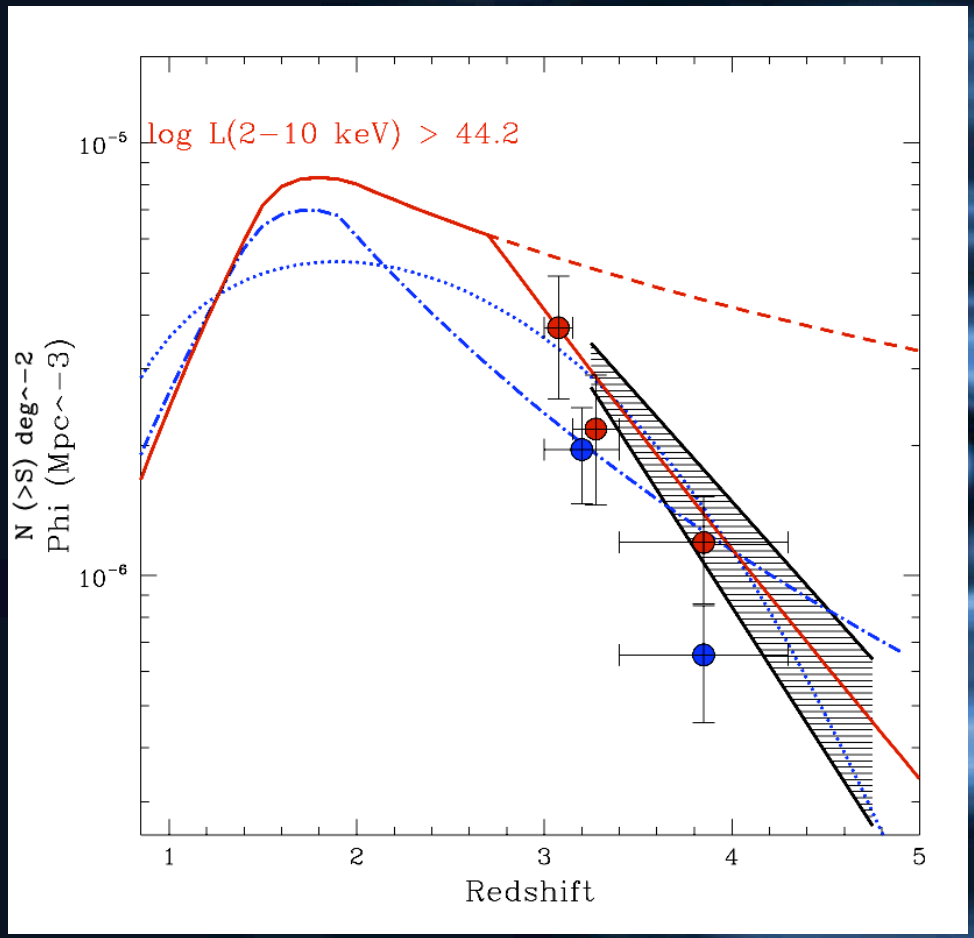
…

mainly SF

accretion & co-evolution - > IXO

REDSHIFT !!!

Where do we stand ?



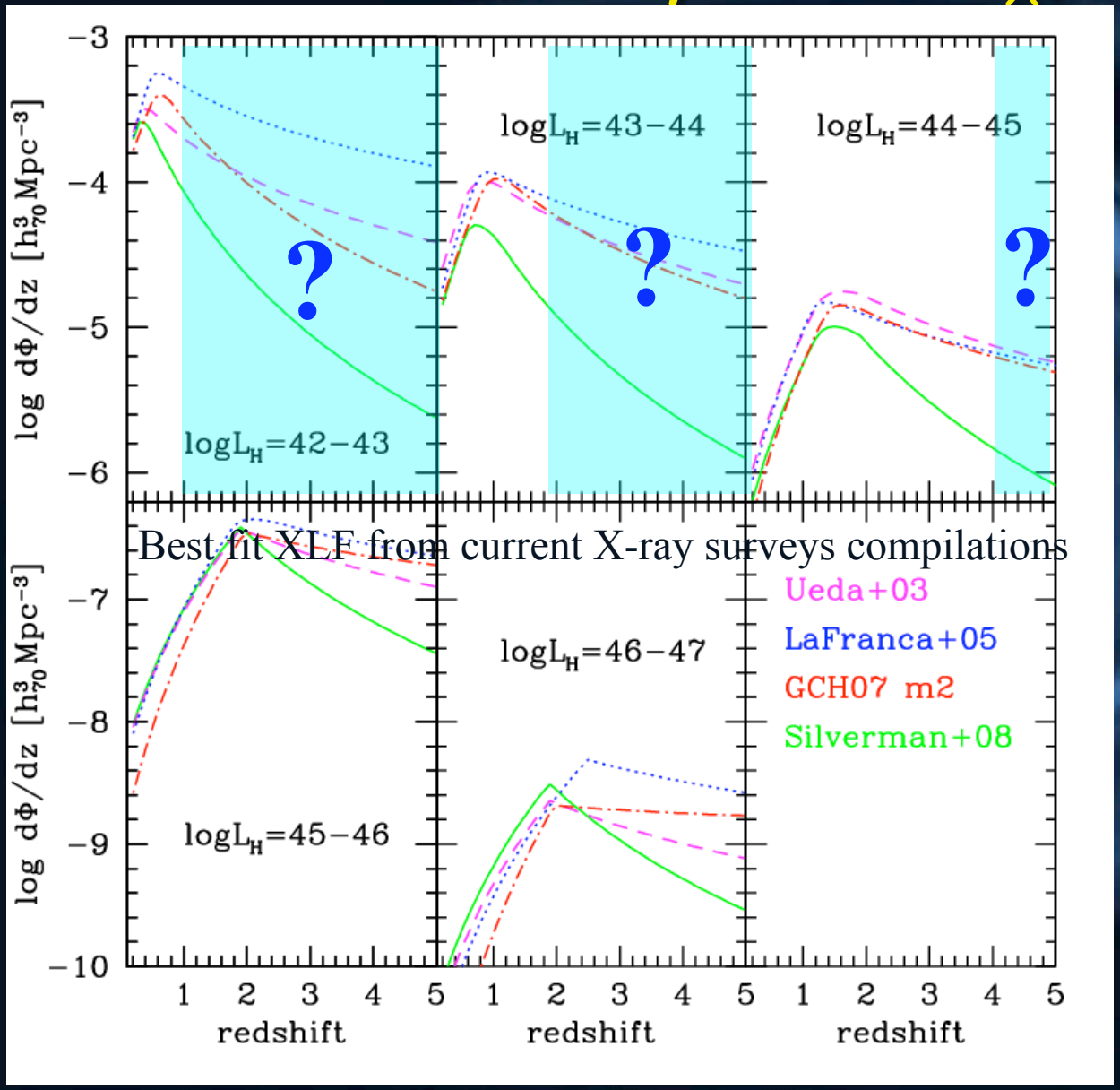
The number of high-z AGN detected so far

	SDSS*	X-ray sel.$
z > 3	8000	50
z > 4	1500	11
z > 5	150	3
z > 6	10	0

*from DR6 "SpecObjAll" table

$ see eg. compilations by Silverman+08, Hasinger08

What's the density of low L_X, high-z AGN?



Evolution of the bulk of the AGN population still to be determined at moderate to high-z.

Flatter evolution or decline as for high luminosity?

Sensitivity needed for high-z AGN census

<u>What do we expect?</u>

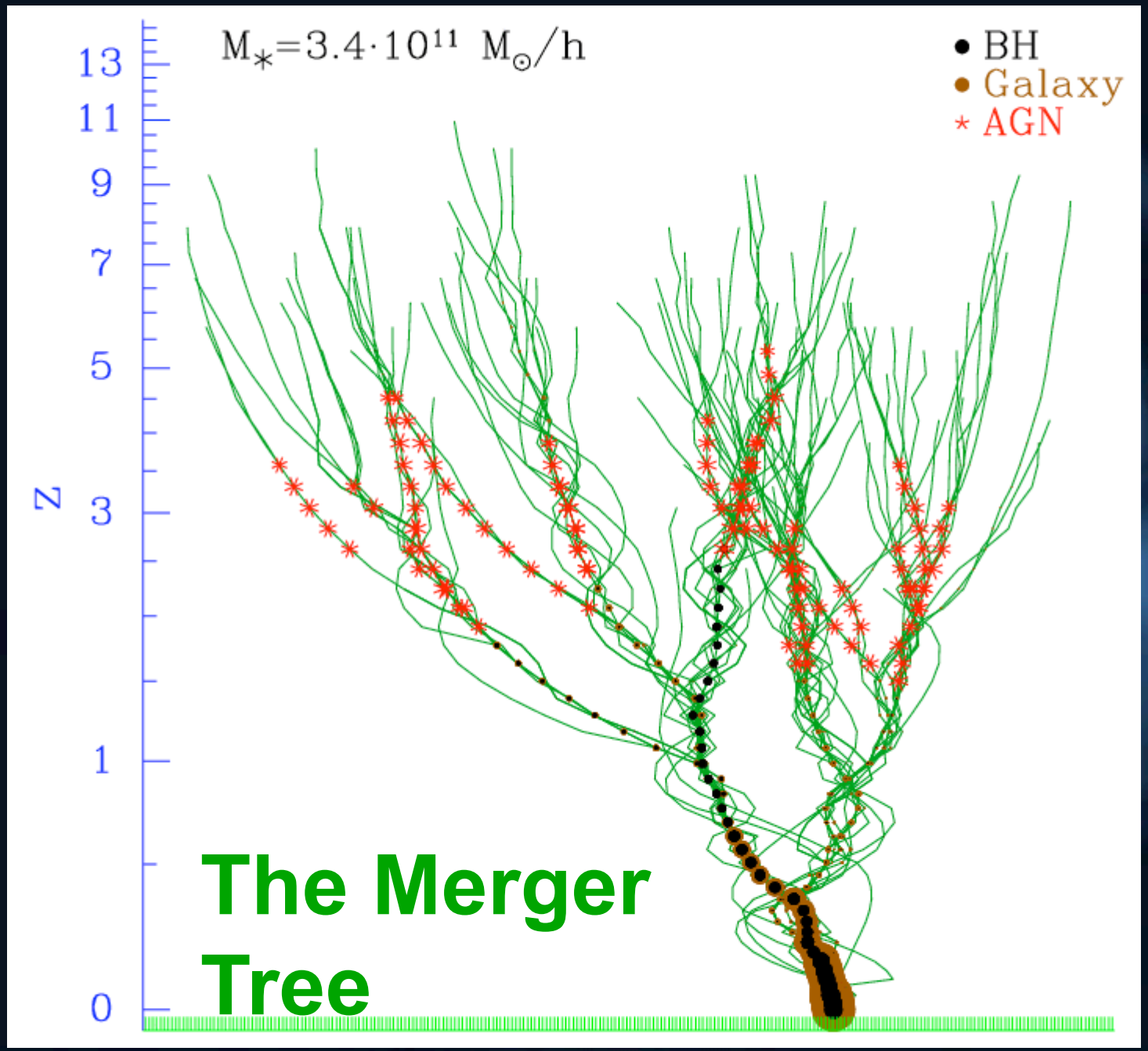
Semi analytic models of BH growth

Many semi-analytic models based on LCDM:
Volonteri+06, Salvaterra+06, Rhook&Haehnelt08, Menci+08, Marulli+08.
These follow the evolution and merging of Dark Matter Halos with cosmic time and use analytic recipes to treat the baryon physics. Some use the Press-Schechter formalism to get halo merger trees, others are based on the Millennium simulation.

Common assumption: nuclear trigger at merging

Free parameters:

- BH seeds (from ~20 to 10^4 M_{sun}) as remnants of PopIII ($M>260$ M_{sun}) stars (Madau&Rees01): $M_{BH} \sim M_{popIIIstar}$, zero metallicity, no mass loss Massive seeds (10^4 M_{sun}) also possible (Koushiappas+04, Volonteri+08).
- recipes for accretion (radio mode and QSO mode) ➔ Eddington ratio, AGN lightcurves
- relation between initial BH mass and halo mass (eg bias)
- SED (eg obscuration)
- room for accretion due to internal processes (i.e. not related to mergers)

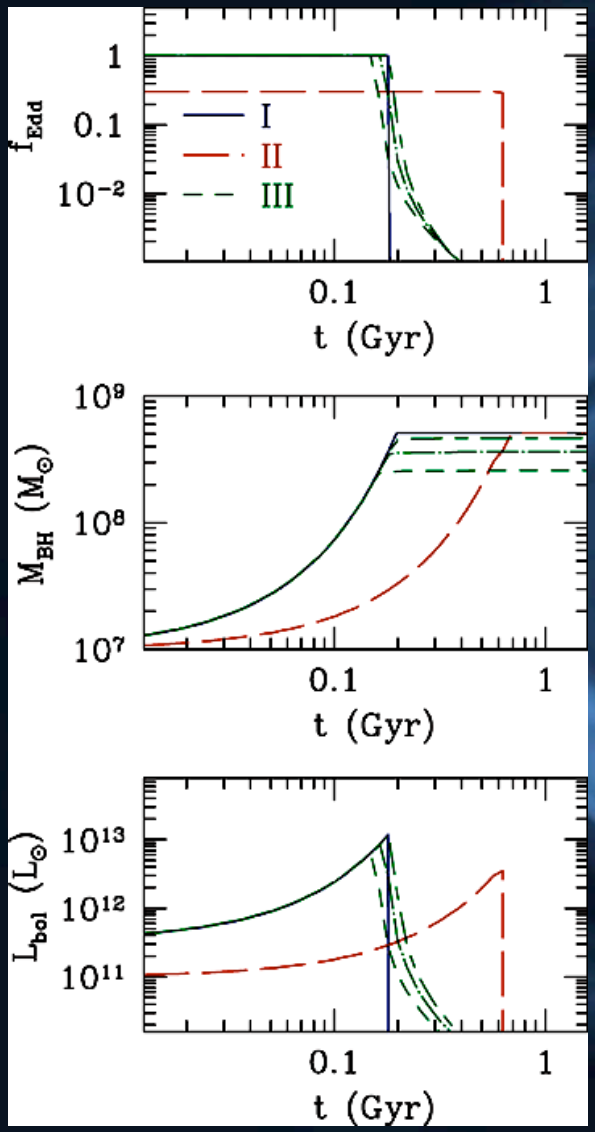


Marulli+09

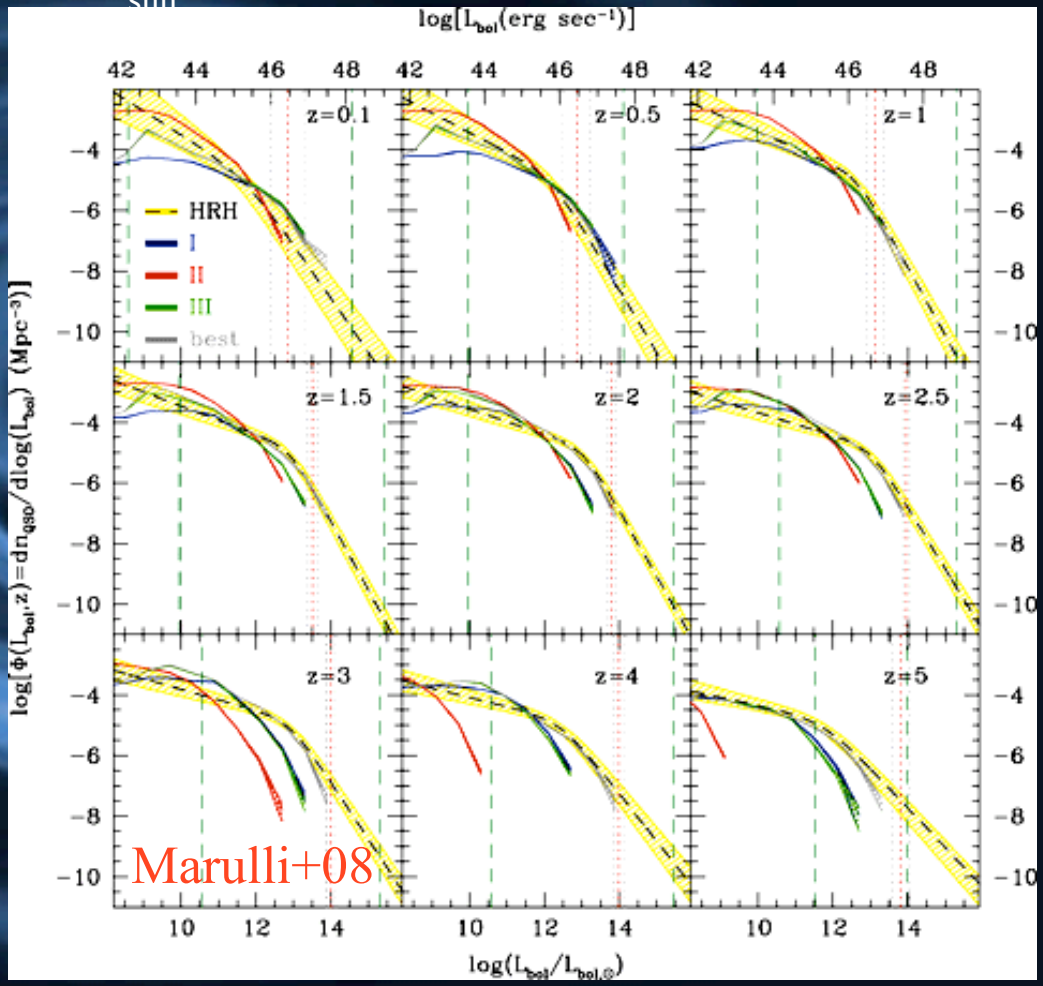
Extension of Croton+06 & De Lucia+07 SAM models based on Millennium

AGN lightcurves and luminosity functions

Example of ligthcurves
for 10^7 M_{sun}



Bolometric LF

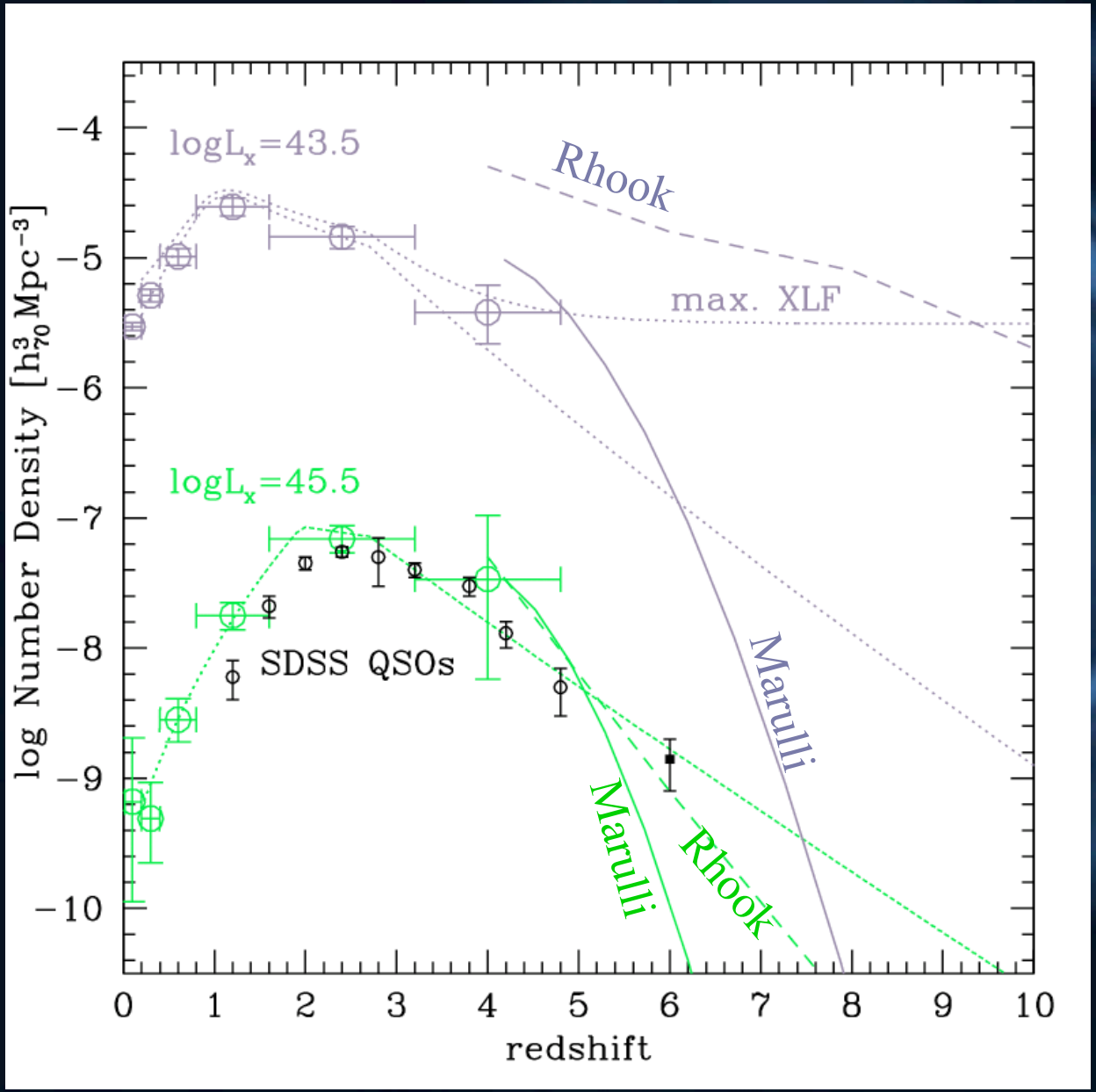


What will we see? Prospects for IXO

Two possible ways to make predictions on the high-z Universe:

1) "Fair" (?) extrapolations towards high-z and low luminosities of present XLF (obscured fraction/distribution …)

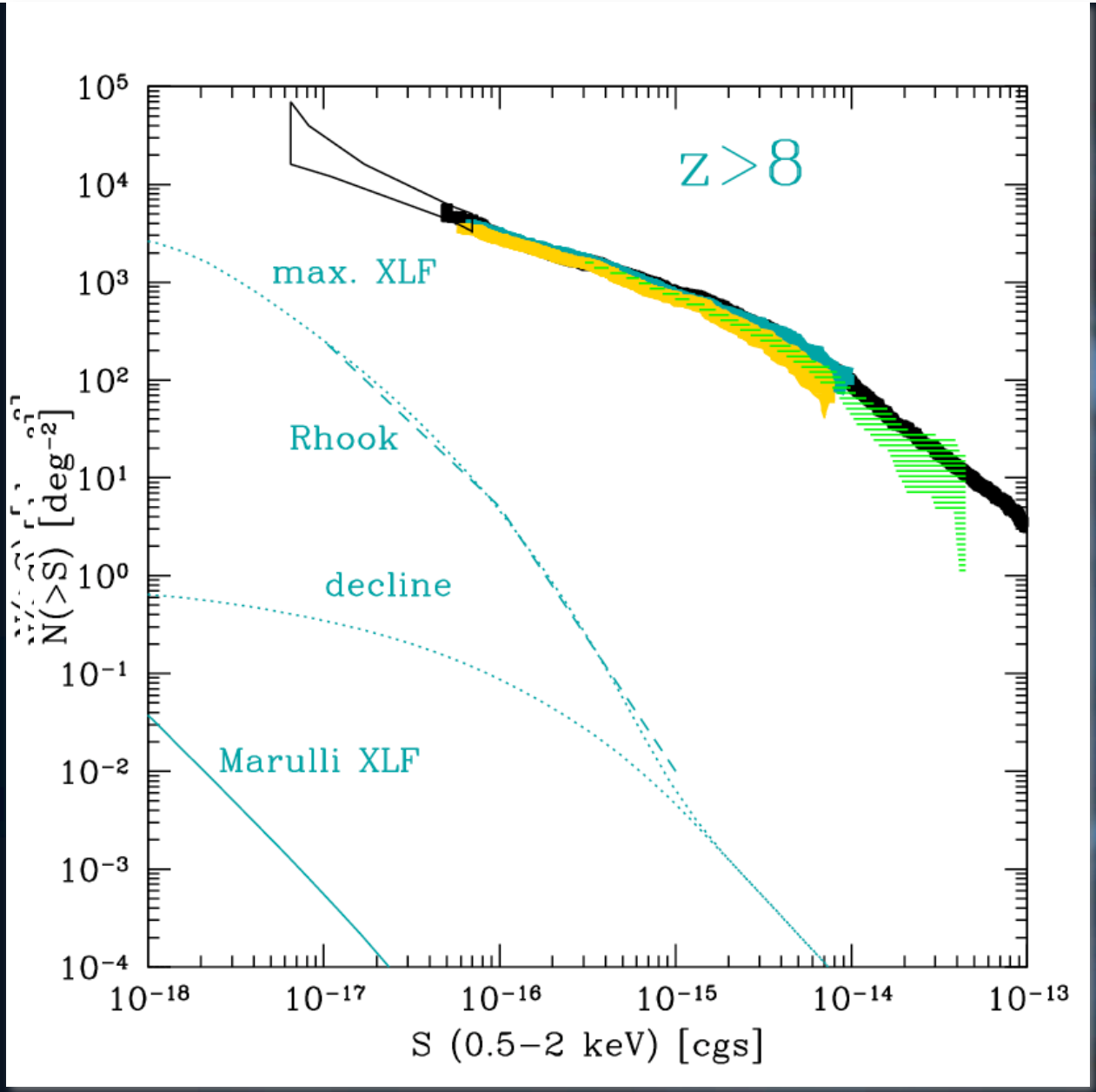
2) SAM models for early BH growth from seed BHs



Predictions for high-z Universe very, very Uncertain …

max. XLF:

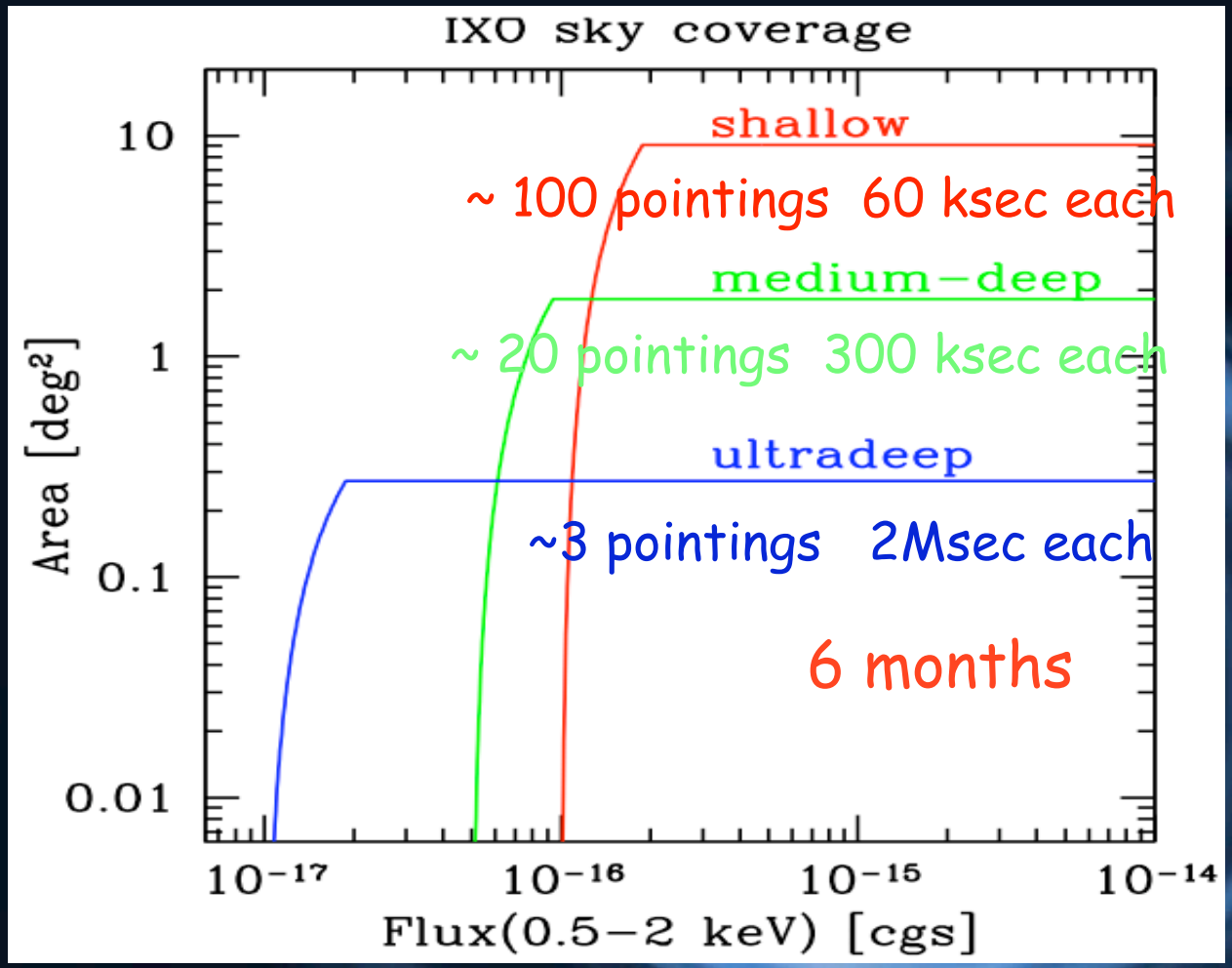
XLF that predicts the maximum number of high-z AGN while being in agreement with current “low-z” XLF.



Confusion
at N(>S) ~ 2×10^{4} deg^{-2},
i.e. S ~ 10^{-17} erg/cm^{2}/s
in ~1 Msec (depending on the bkg level)

XLF @ z > 6
would constrain the physics of early BH formation

BH seeds mass function, accretion mechanisms



high-z AGN yields:
$N_{tot} \approx S^{1-\alpha}$

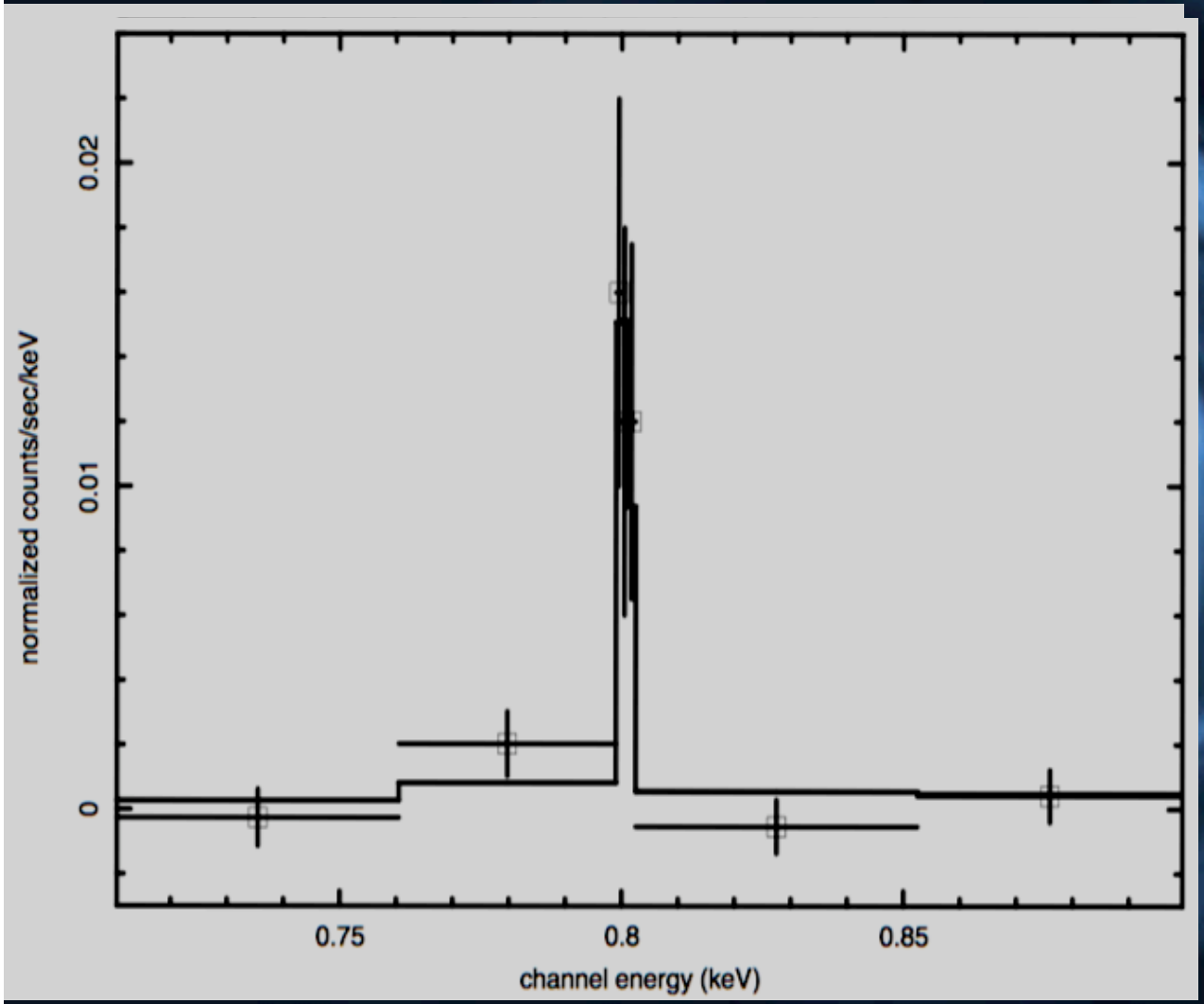
if $\alpha > 1$
deep in a single field

if $\alpha < 1$
wider areas

	Decline	maXLF	SAM
z > 4	355	1350	1375
z > 6	15	300	4

FOV ~ 18'x18'
Vignetting as in Willingale document

IXO X-ray Spectra



Compton Thick (N_H ~ 10^{24} cm^{-2}) AGN at z = 5 (L_X ~ 10^{43} cgs - F_X ~ 10^{-16} cgs, line EW ~ 1 keV (rest-frame)

XMS simulation of a Compton Thick AGN at z = 7, L_X ~ 5 x 10^{42} cgs - F_X ~ 5 x 10^{-17} cgs , line EW ~ 1.2 keV (rest-frame) .

Final remarks

- 5” HEW or better + ~350 arcmin^2 or larger
  enough z>6 objects to build up an XLF and constrain early BH formation and growth (assuming a “clever” strategy is adopted and “enough” time is invested in surveys)

- IXO is well matched to the sensitivity of other future facilities like JWST and ALMA to recognize high-z SMBH

- IXO would provide excellent spectra for moderately bright high-z QSOs. Unique capability to identify through X-ray spectroscopy faint obscured AGN at high redshift. Dedicated follow up observations of high-z QSO identified by eROSITA and/or Pan-STARRS , LSST.