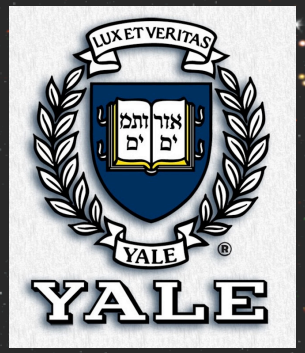
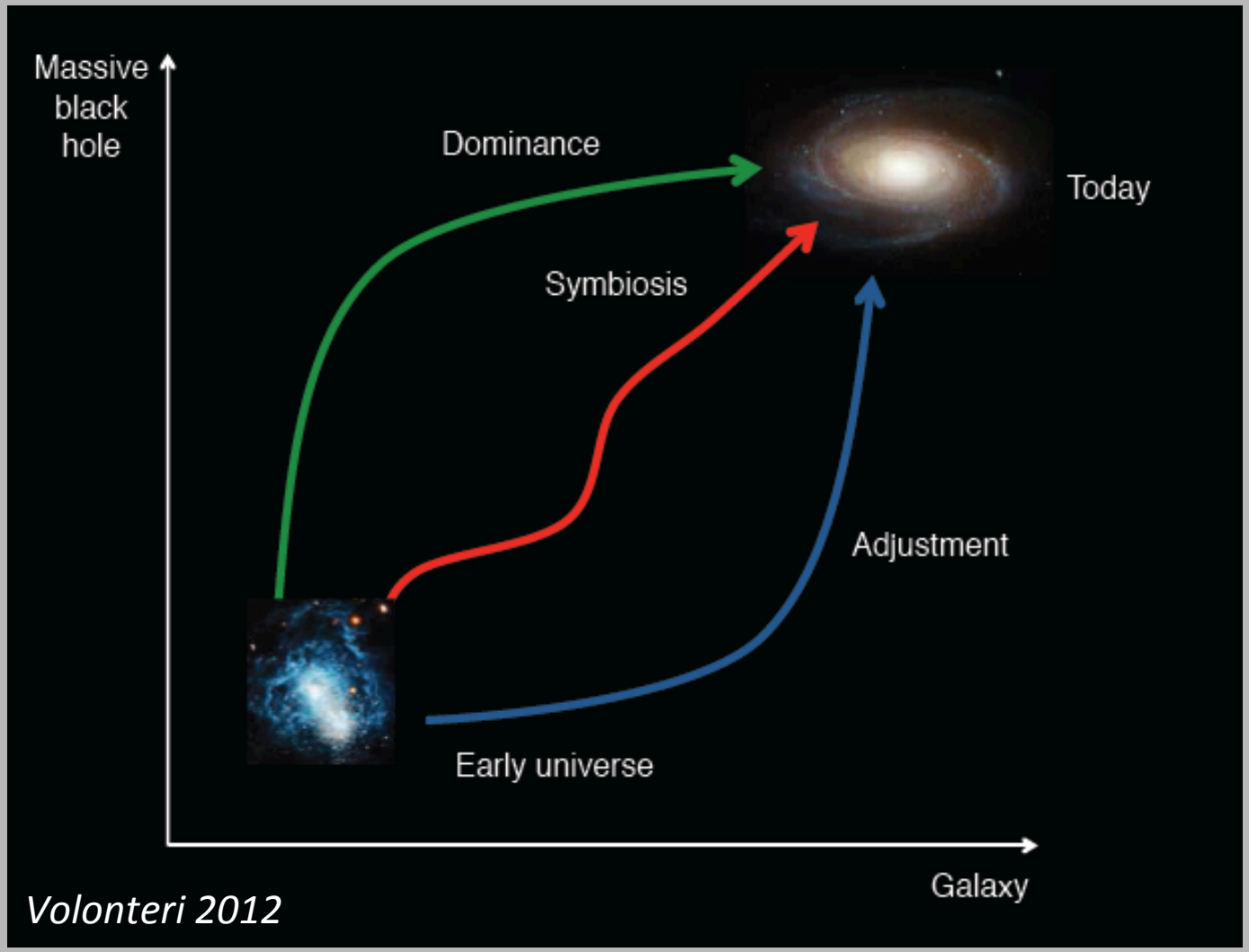
High resolution deep X-ray Surveys: a unique probe of the high-z universe

Francesca Civano

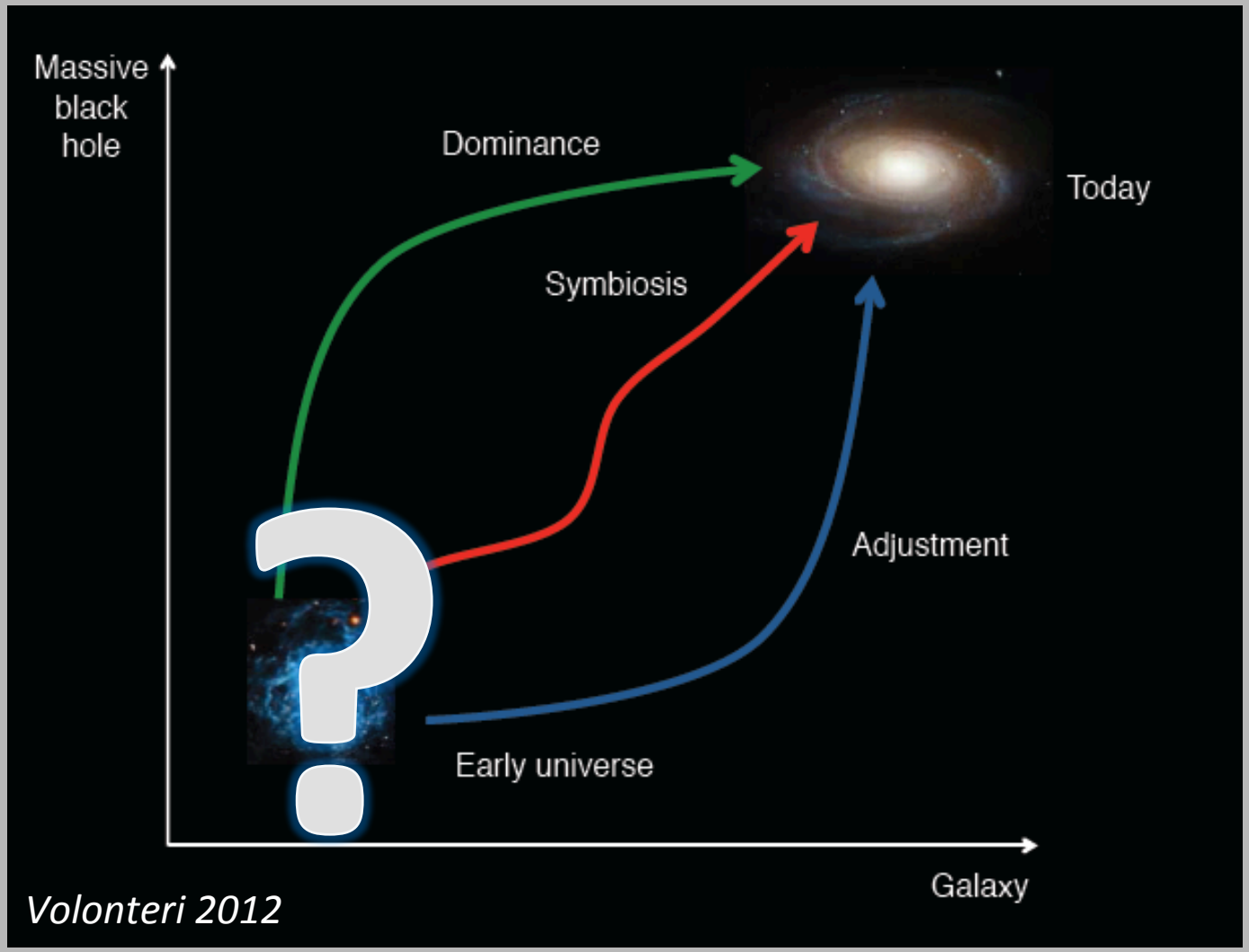
(YCAA, SAO)



How did the first Black Holes form, grow and evolve?

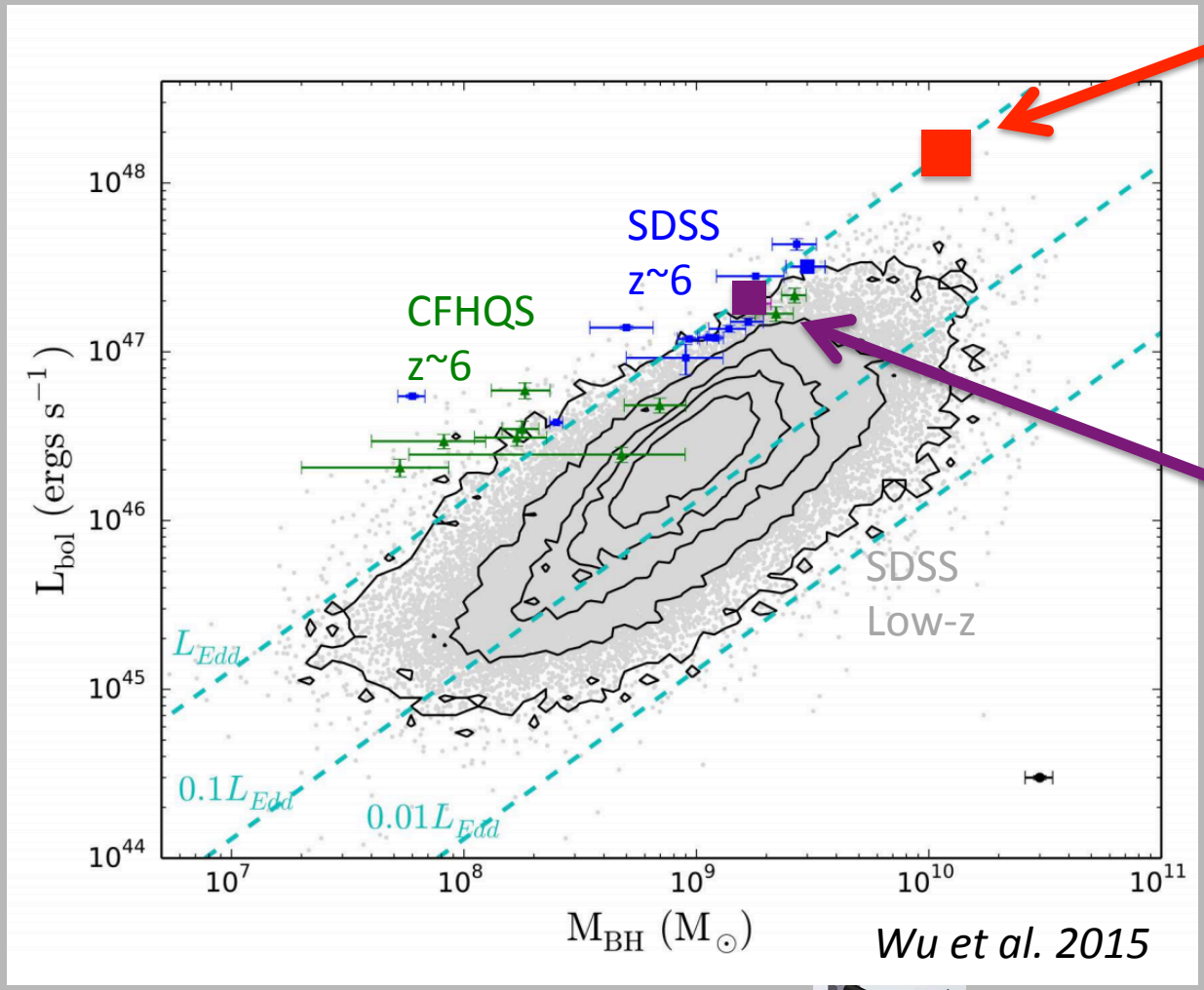


What do we know about early SMBHs?



The challenge of the first quasars

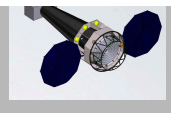
N~50-60 QSO at z>6 from optical and NIR surveys (SDSS, CFHQS, UKIDSS)



Wu et al. 2015

LARGEST MASS
SDSS J010013.02+280225.8
z = 6.30
L_{bol}~10^{48} erg/s
BH mass ~ 10^{10} M_{sun}
Wu et al. 2015

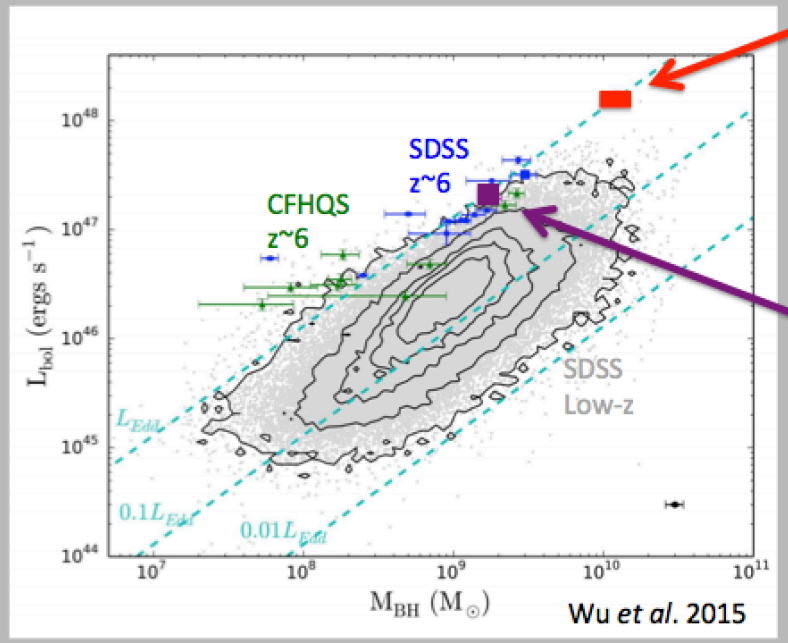
REDSHIFT record
ULAS J1120+0641
z=7.07
L_{bol}~10^{47} erg/s
BH mass ~ 10^{9} M_{sun}
Mortlock et al. 2011



The challenge of the first quasars: BH Formation

Constraints on BH formation scenario:

1. Un-interrupted Eddington limited accretion from z=20 to z=6-7
2. Low radiative efficency
3. BH seeds: PopIII stars or core collapse clouds
   (Volonteri 2010; Loeb & Rasio 1994; Begelman et al. 2006; Regan & Haehnelt 2009; many others)



LARGEST MASS
SDSS J010013.02+280225.8
z = 6.30
L_{bol}~10^{48} erg/s
BH mass ~ 10^{10} M_{sun}
Wu *et al.* 2015

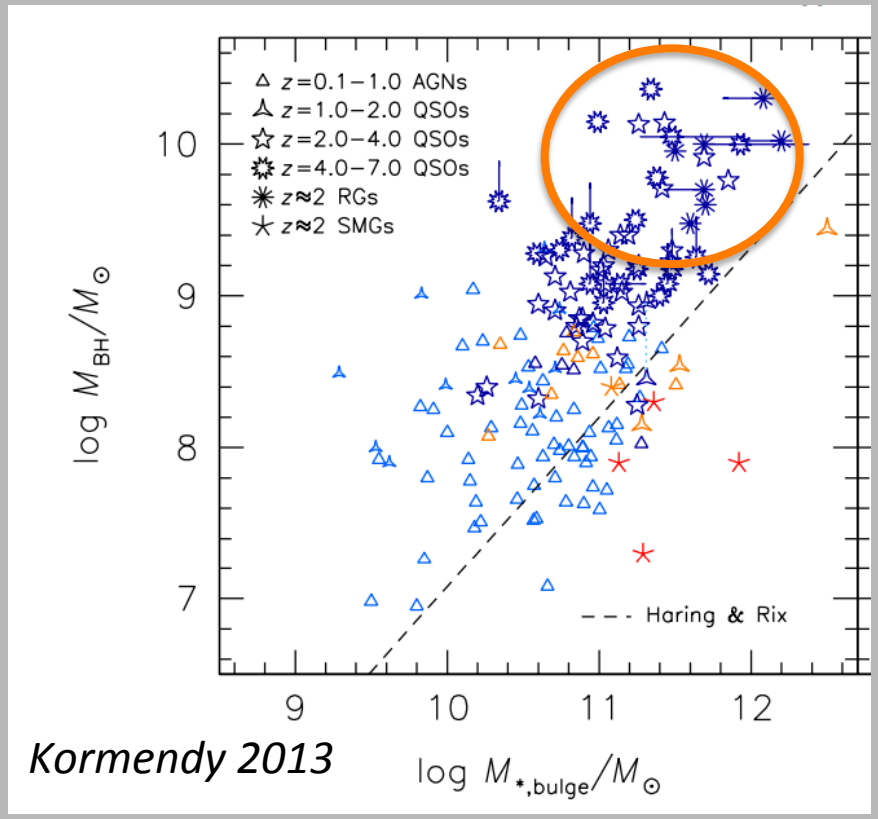
HIGHER REDSHIFT
ULAS J1120+0641
z=7.07
L_{bol}=5x10^{46} erg/s
BH mass ~ 10^{9} M_{sun}
Mortlock *et al.* 2011

The challenge of the first quasars: Host Galaxy Connection

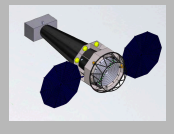
BH to galaxy mass ratio is off the extrapolation from the local relation:

- BH is growing first and the galaxy assembly later (DOMINANCE SCENARIO)
- Intense SF episodes (1000 M_{sun}/yr) or super solar metallicities can lead to a relatively fast growth of the host (*Mor +2012; Wang+2013; Calura+2014; Leipski+2014)*

- Supercritical accretion model (*Volonteri +2015*)



Kormendy 2013



The tip of the iceberg

High-z quasars samples are dominated by optical/IR selected sources:

- High Luminosity (=very massive)
- Unobscured
- Selected with color-color techniques (analogue of low-z QSO)

The tip of the iceberg

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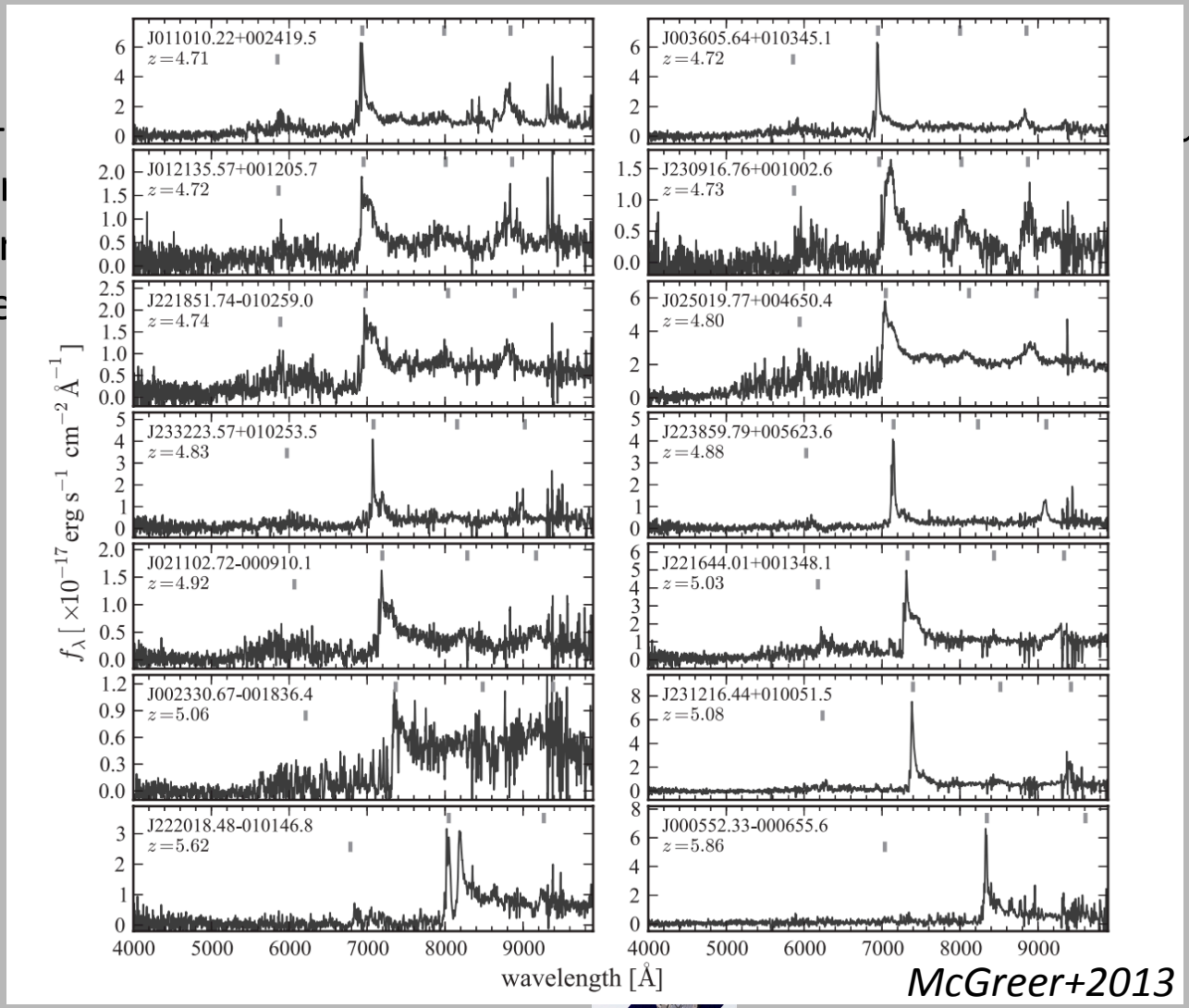


McGreer+2013

The tip of the iceberg

High-z quasars samples are dominated by optical/IR selected sources:

- Only High Luminosity (=very massive)
- Unobscured
- Selected with color-color techniques (drop-outs)

What are we missing?

Obscured and Low-luminosity

The tip of the iceberg

High-z quasars samples are dominated by optical/IR selected sources:

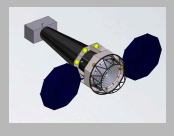
- Only High Luminosity (=very massive)
- Unobscured
- Selected with color-color techniques (drop-outs)

What are we missing?

Obscured and Low-luminosity

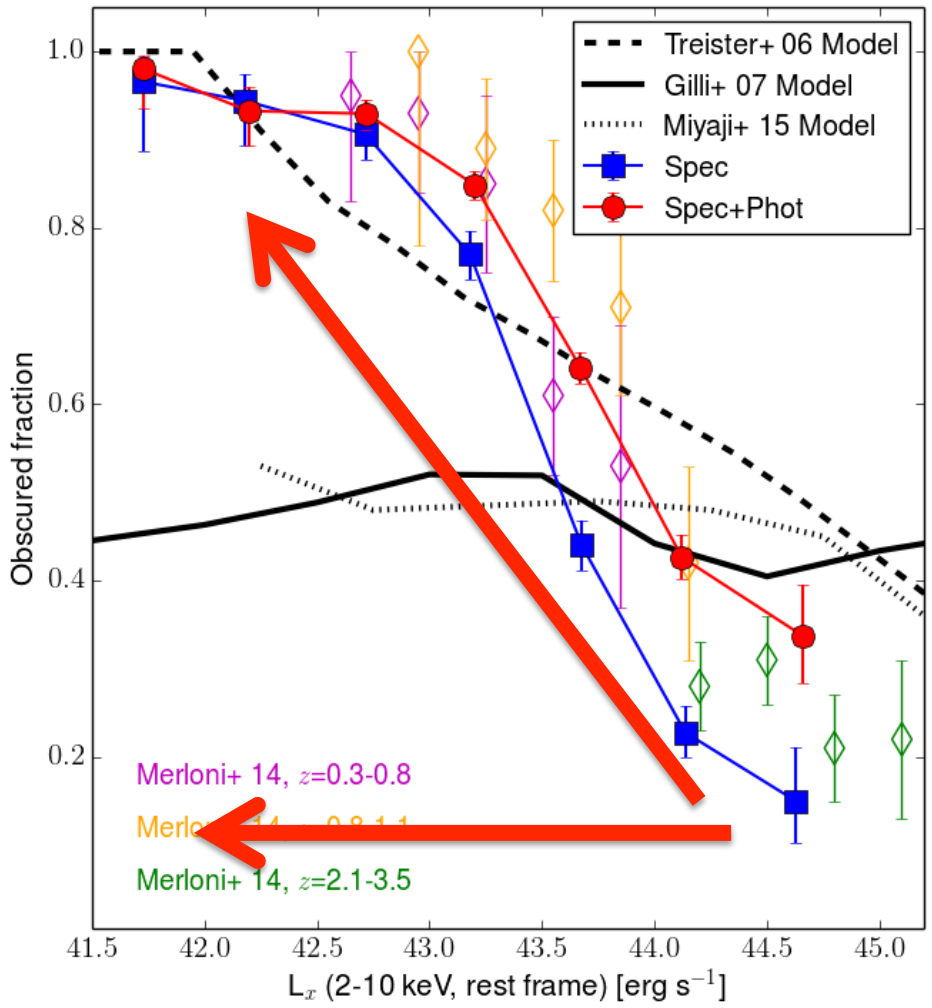
→ Need X-rays to get the dominant (80-90%), obscured BH population

→ Obscured fraction is constant (or even increase) with redshift *(e.g. Hasinger 2008)* therefore we are missing a large population of obscured sources



The tip of the iceberg

Marchesi, Civano+2015 submitted



High-z quasars

urces:

- Only High
- Unobscure
- Selected w

→ Need X-ray

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→ Obscured f

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Hasinger 20

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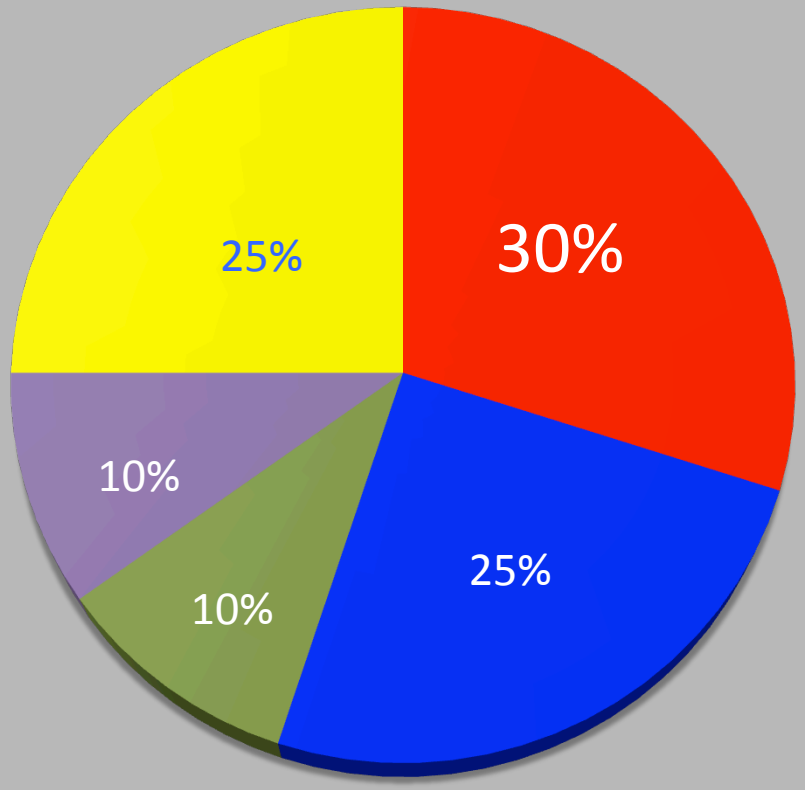
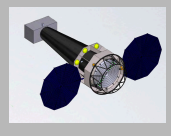
Importance of X-ray selection

Number of AGN/QSO selected using different wavelenghts
(low-z compilation in the COSMOS field)



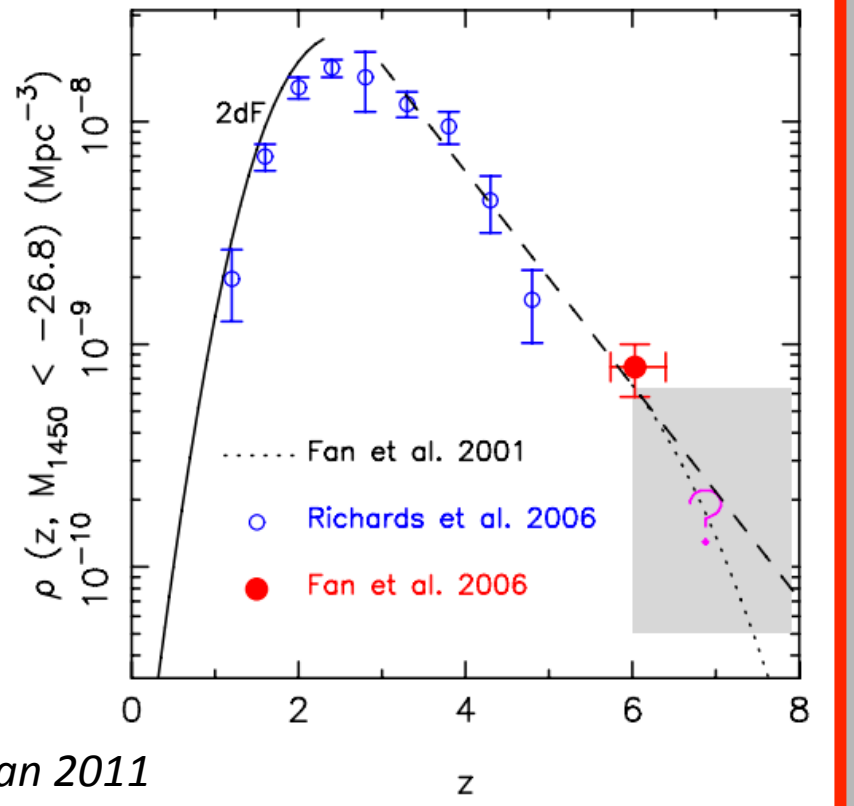
- X-ray → Largest contribution
- IR → Contamination from SFR galaxies could be a problem
- Radio
- Optical → Optical diagnostic have z-limitations (missing low-L sources)
- Common

Courtesy of M. Brusa



Evolution of QSO space density

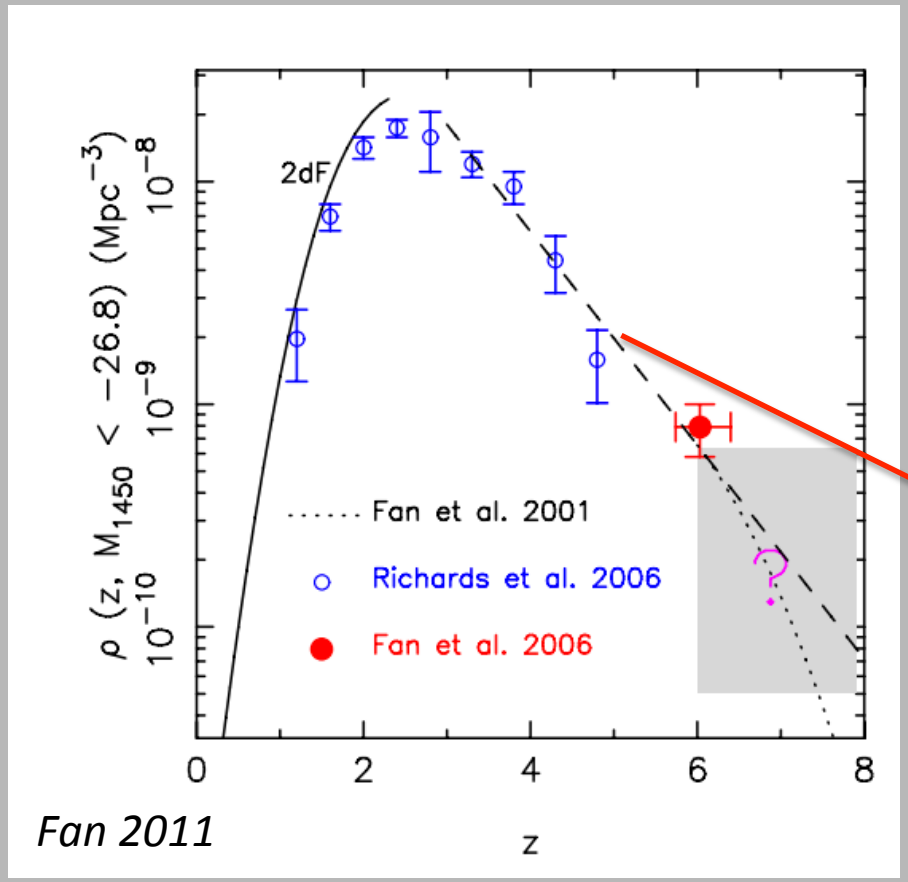
SDSS sources with Lbol=10^{47} erg/s



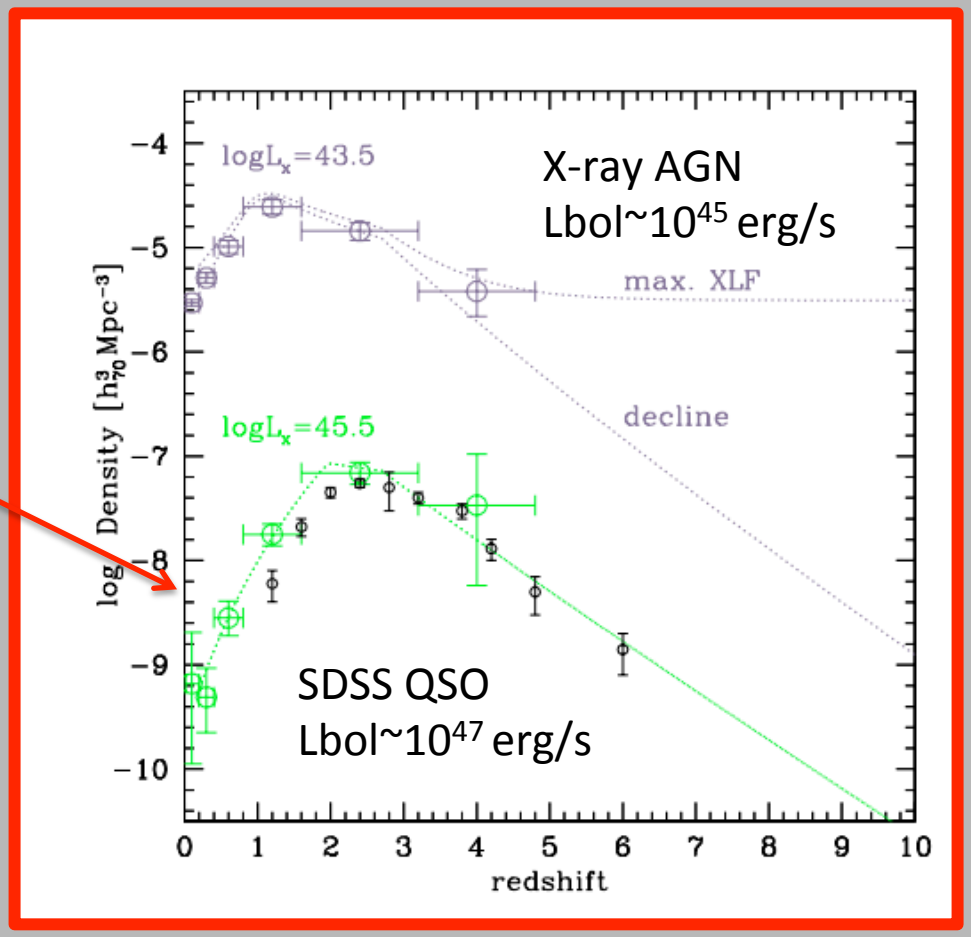
Fan 2011

Evolution of QSO space density

SDSS QSO with Lbol~10^{47} erg/s



Fan 2011



X-ray selected:

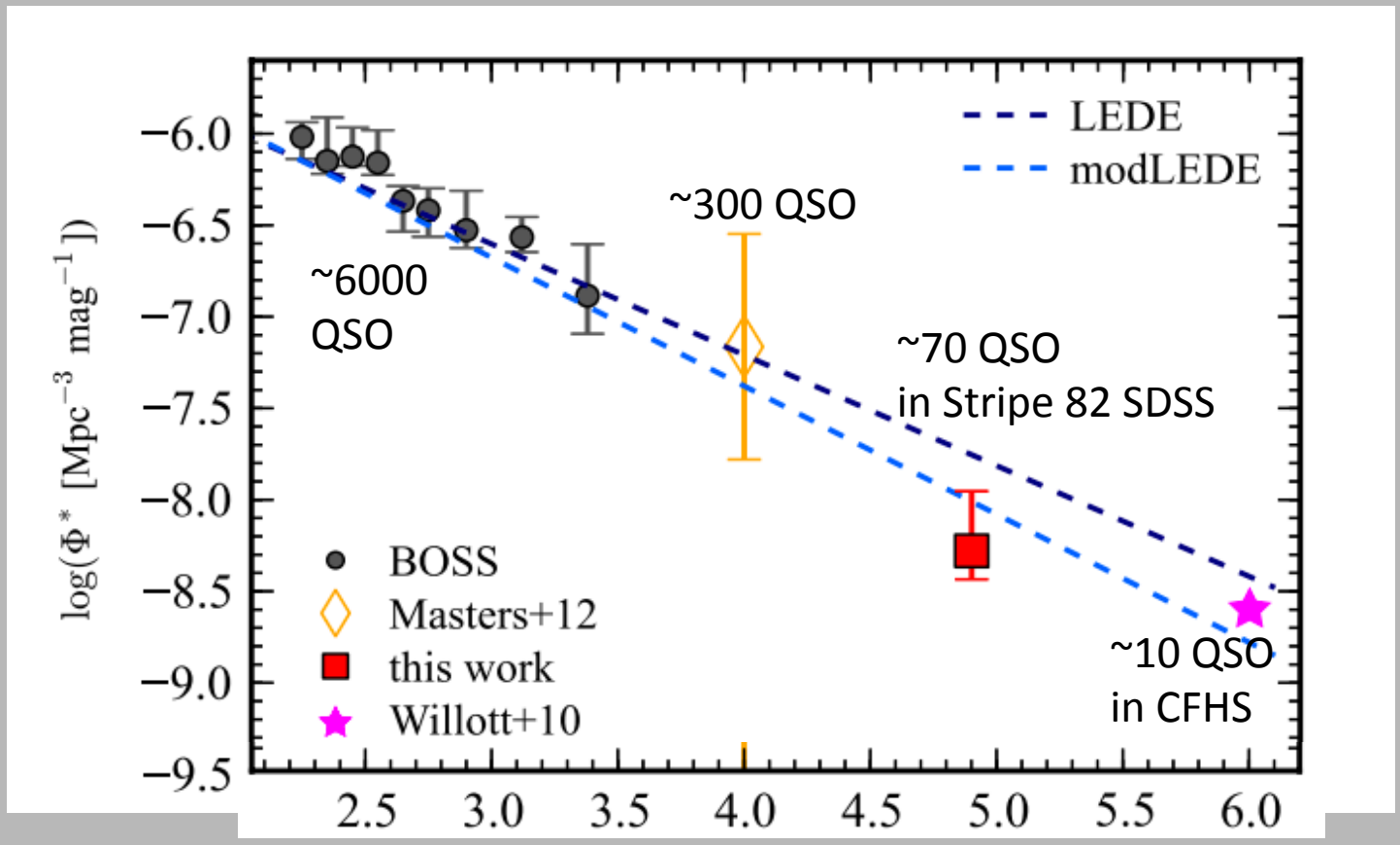
1- less luminous (intrinsically or because of obscuration effects)

2- more numerous

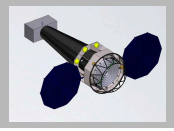
Gilli+ 2014

Hasinger 2008

Optical Space density at z>3

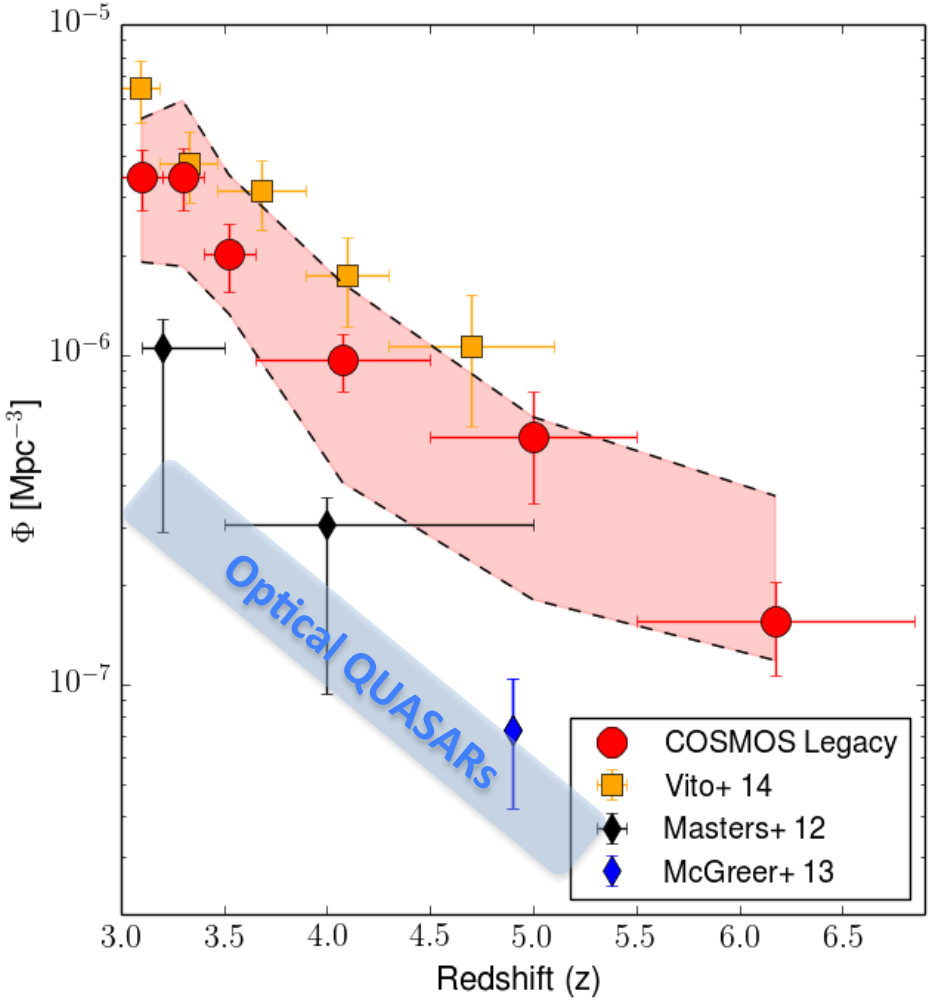


McGreer+2013



X-ray AGN Space density at z>3

Lbol~10^{45} erg/s



Marchesi, Civano+ to be sub.

→ COSMOS: ~200 X-ray selected AGN
→ Largest sample in the X-ray band to be compared with few x 1000s in optical

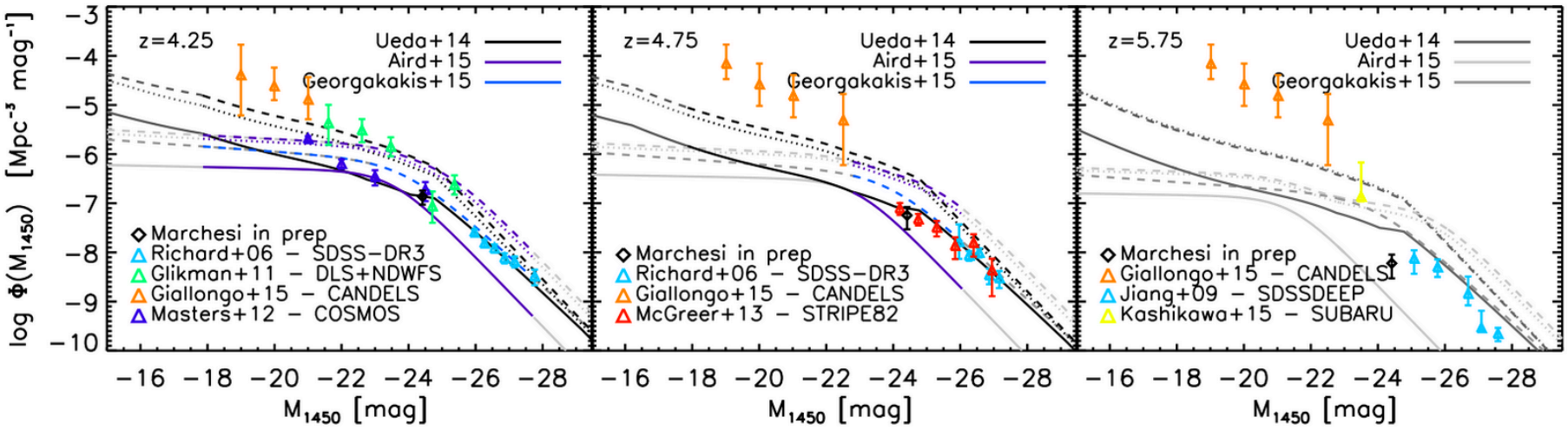
→Downsizing as observed in the optical

→Optical surveys miss the obscured AGN population

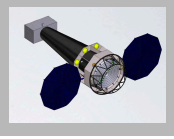
See also, Brusa+ 2009, Civano+ 2011, Ueda+ 2014, Kalfountzou, FC+ 2014, Vito+ 2014

X-ray versus Optical: faint end and controversial results

Giallongo et al. 2015: 6 X-ray detected z>5 AGN in CDFS (4Ms)
Weigel et al. 2015: NO X-ray detected z>5 AGN in CDFS (4Ms)

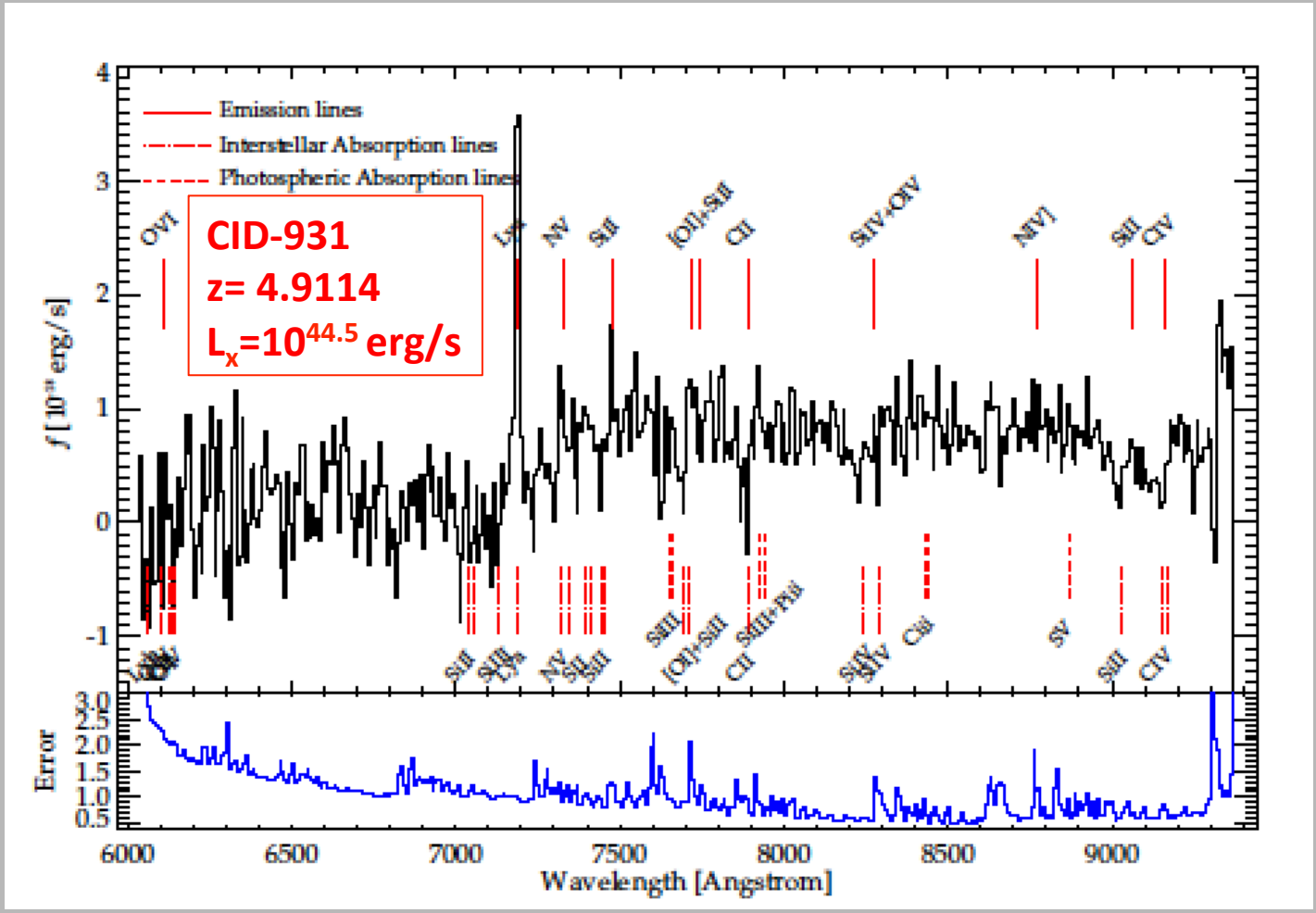


Ricci, Marchesi, Civano+ ApJ in prep.



The problem of obscured AGN

- Spectra like normal Lyman Break Galaxies at z=2
- NOT EASY TO RECOGNIZE USING COLOR-COLOR SELECTION!



Kalfountzou, Civano et al. in prep.

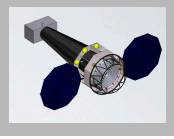
The role of X-ray Surveyor

- Providing large samples at low-L (small mass)
- Detecting the missing obscured sources
- Positional accuracy to λλλ identify the X-ray sources

→Large fov & high speed

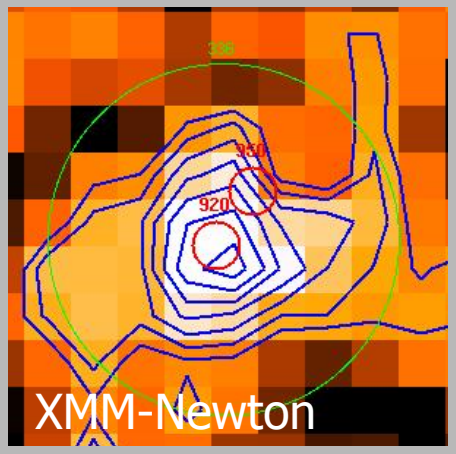
→Large Effective Area

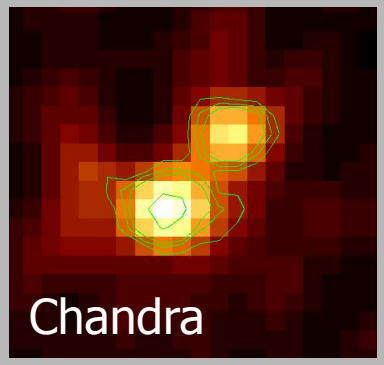
→High Spatial Resolution

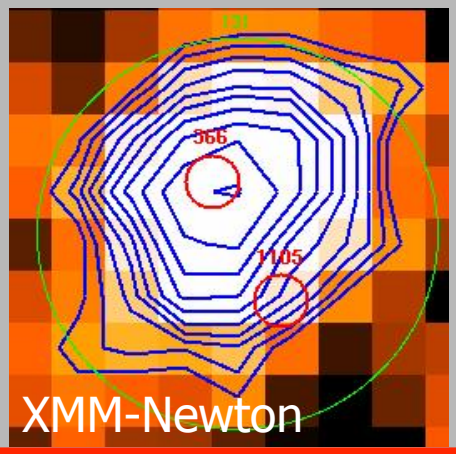


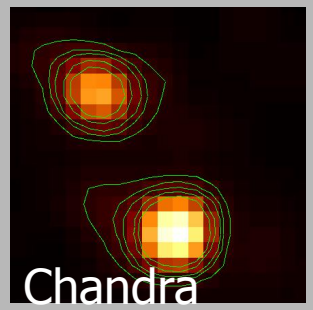
Spatial Resolution is critical for Ids

XMM-COSMOS versus Chandra COSMOS Legacy *(Brusa+2010 Civano+ 2012)*





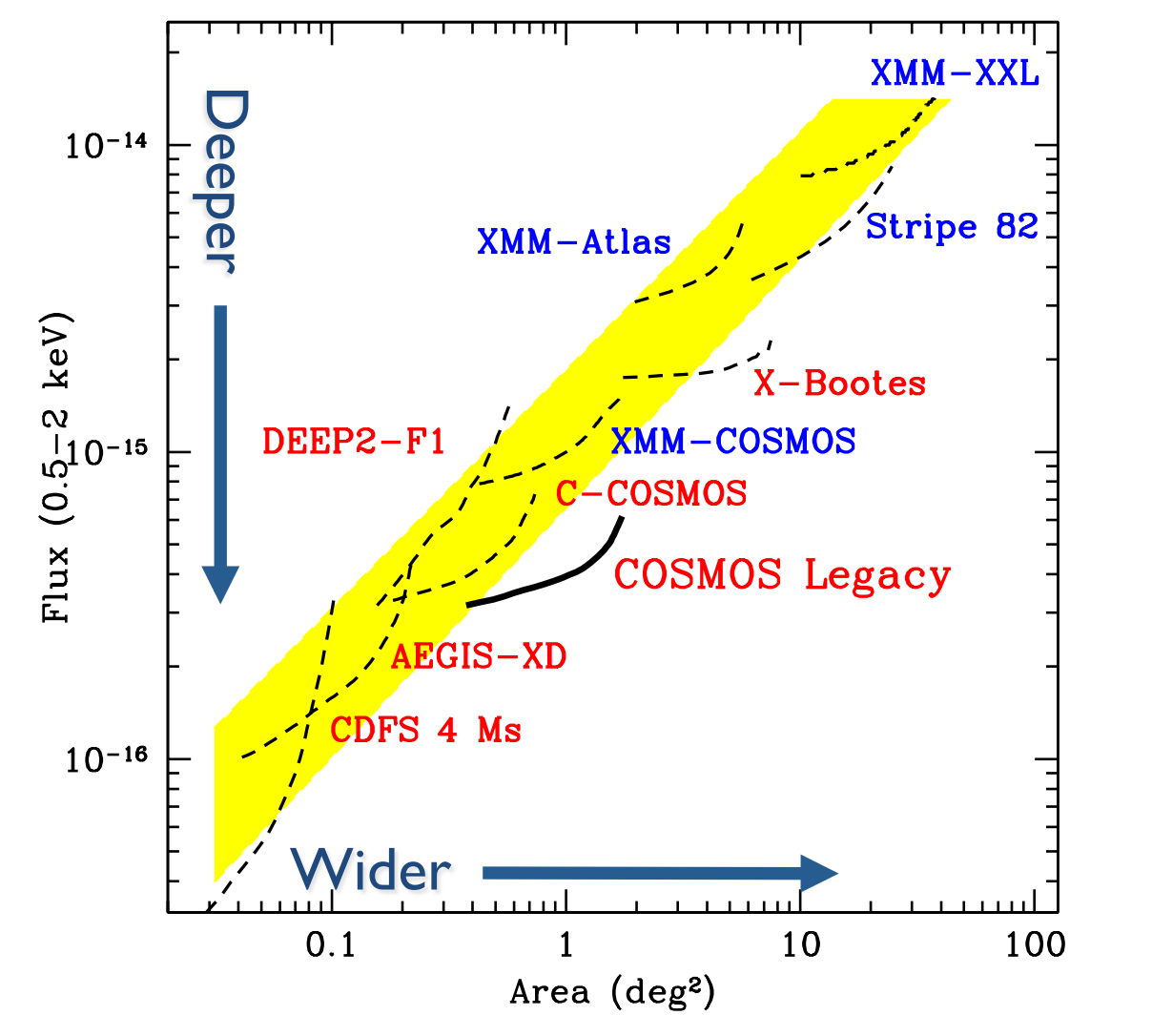




JWST galaxy density at the limit: ~2×10^6 gal/deg2 = 0.15 gal/arcsec^2 *(Windhorst et al 2006)*

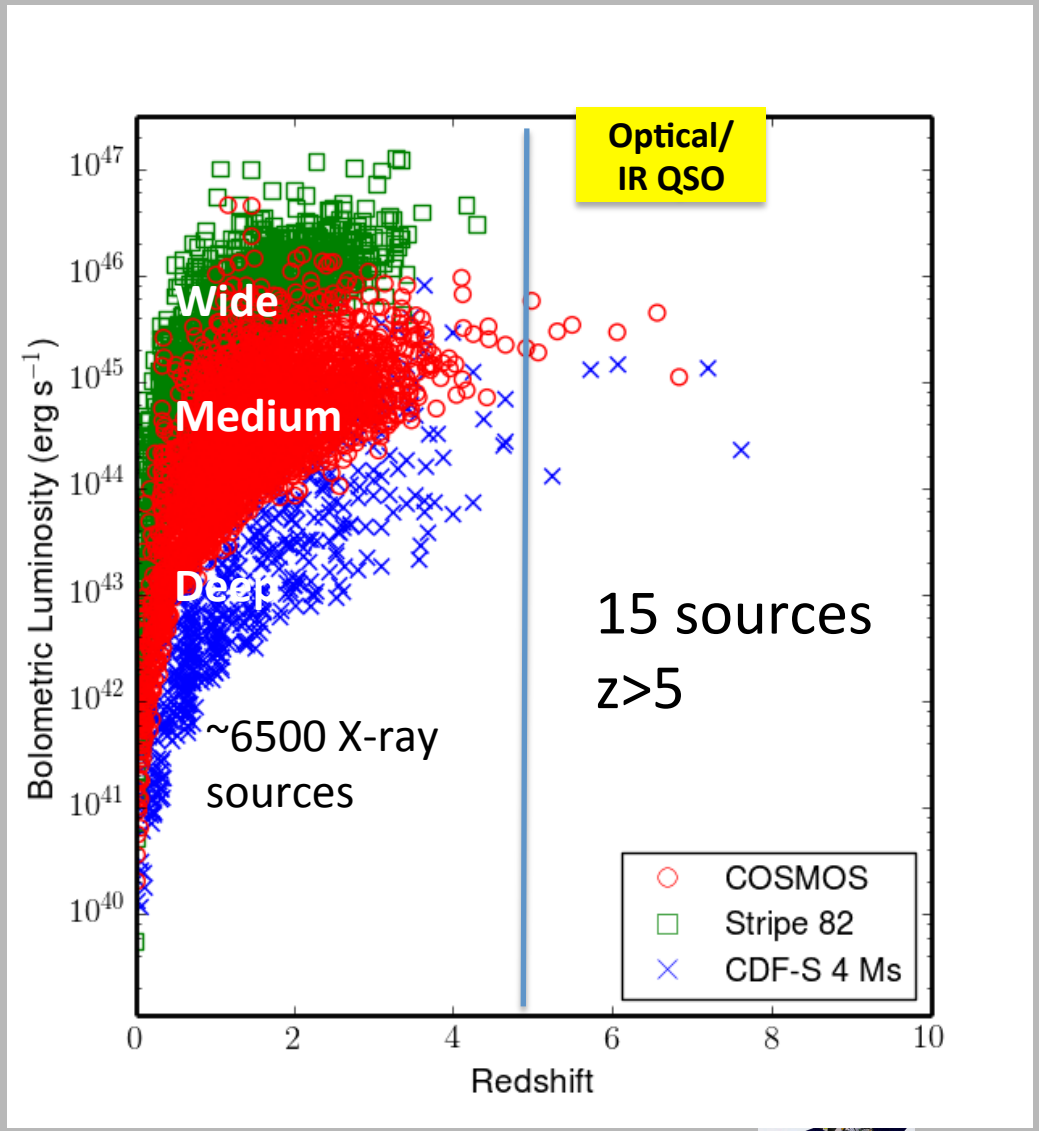
→ 4 galaxies in a 5″ beam; <1 galaxy in X-ray Surveyor beam (*Vikhlinin+2014)*

Current Surveys Sensitivity



Civano+ 2015

Luminosity vs. Redshift



Summary of X-ray high-z detections

COSMOS
9 (2) sources at z>5
4 (0) sources at z>6

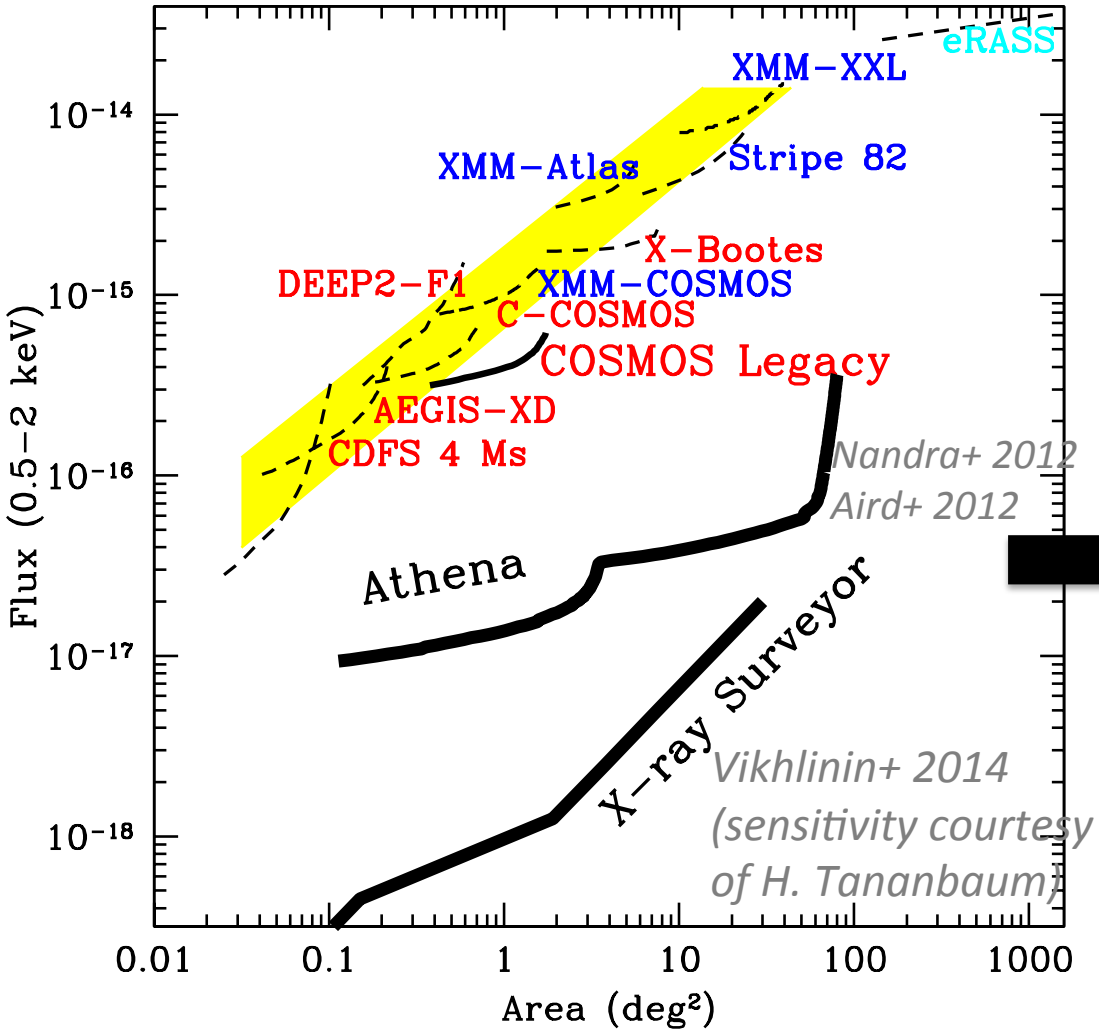
CDFS
5 (0) sources at z>5
2 (0) sources at z>6

Stripe 82
1 source at z>5

Adapted from
Marchesi, Civano+ 2015 submitted

Future Surveys Sensitivity

Current:
>50 Ms
of total
exposure

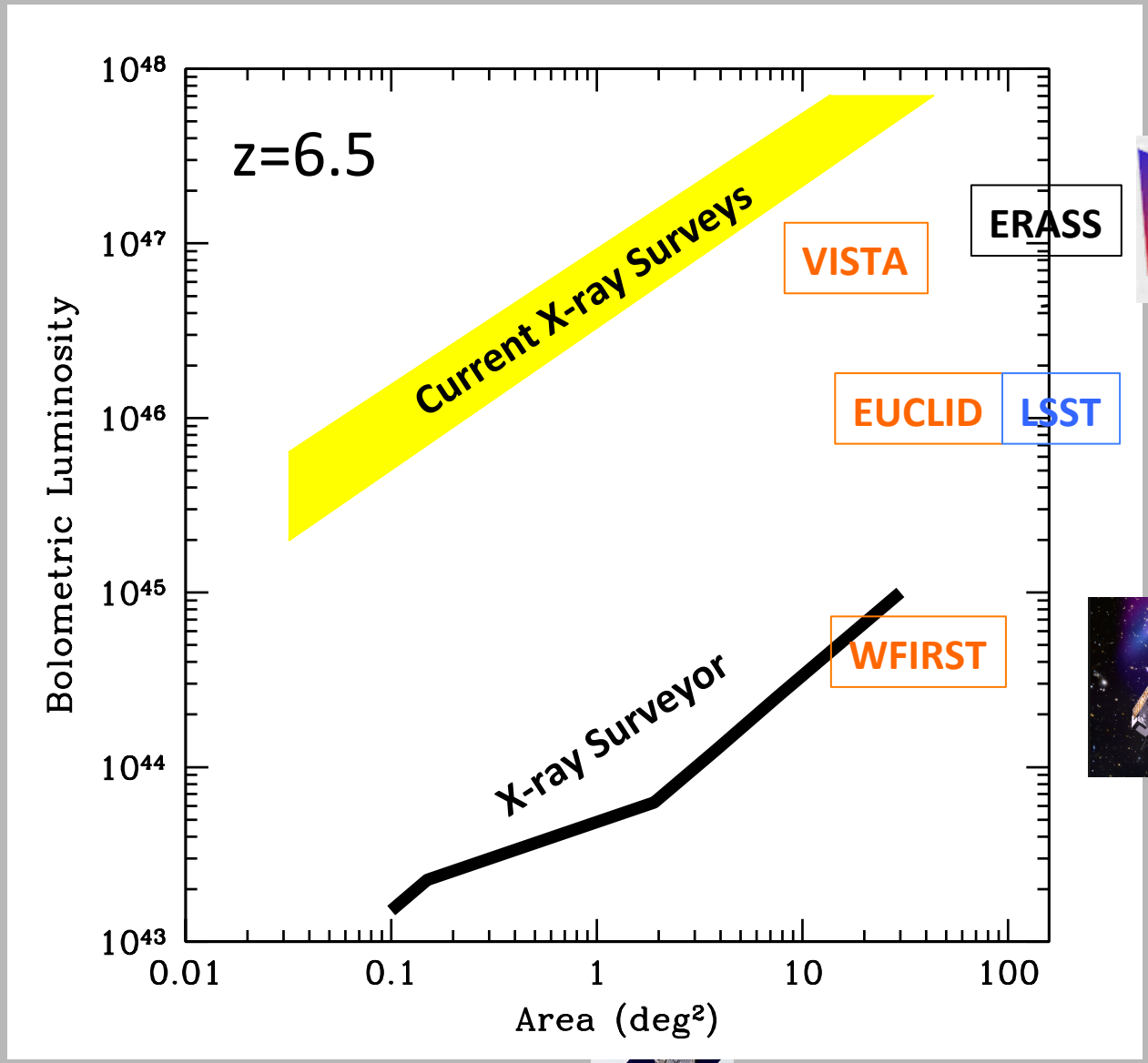


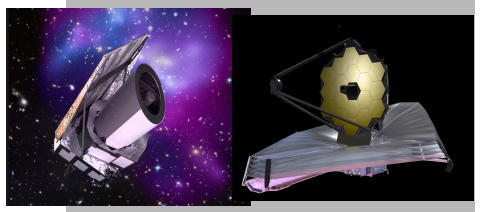
Future:
20 Ms each
of exposure

Wide Survey
+
Medium Survey
+
Deep Survey

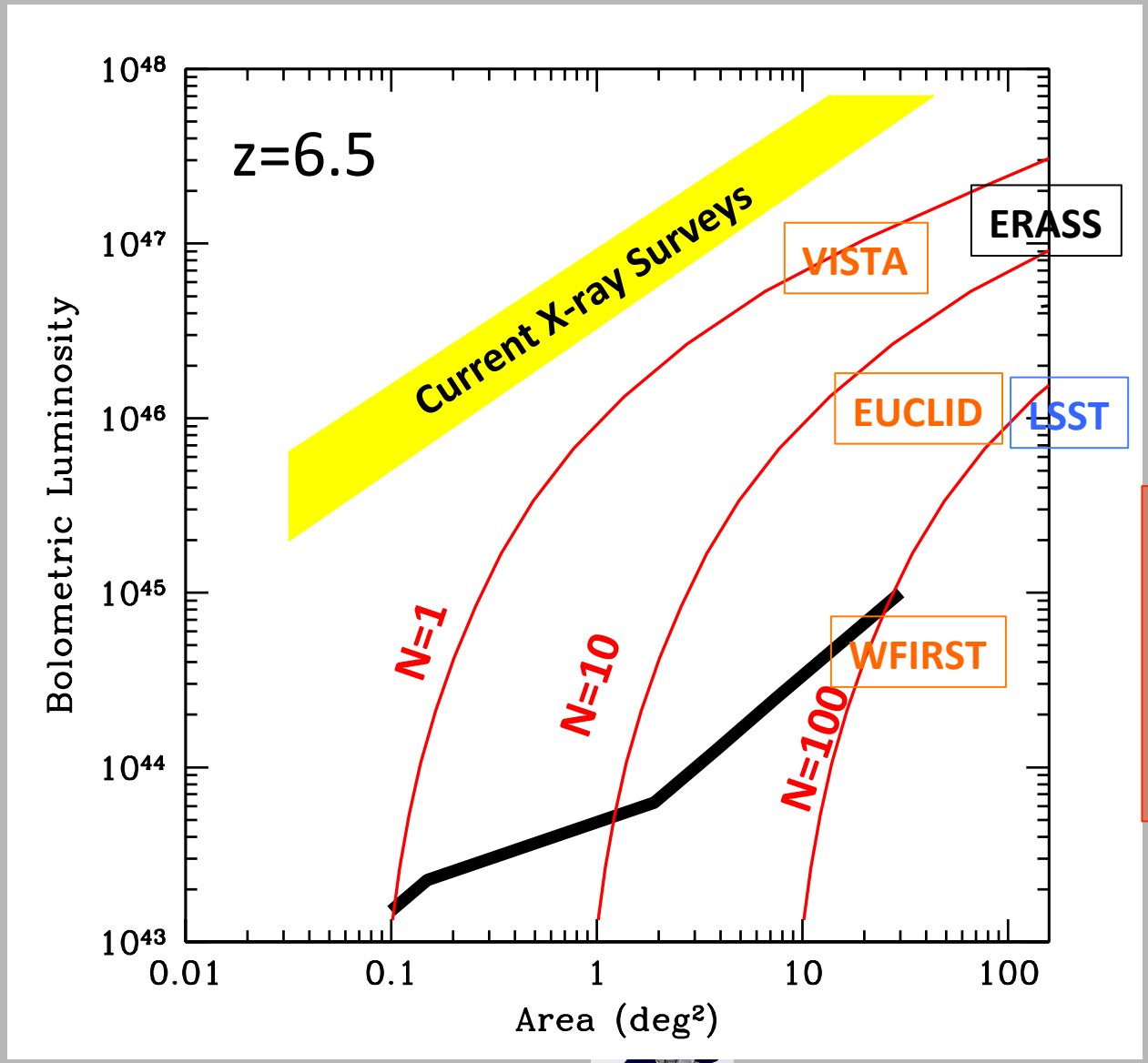
Adapted from Civano+ 2015

The First Black Holes



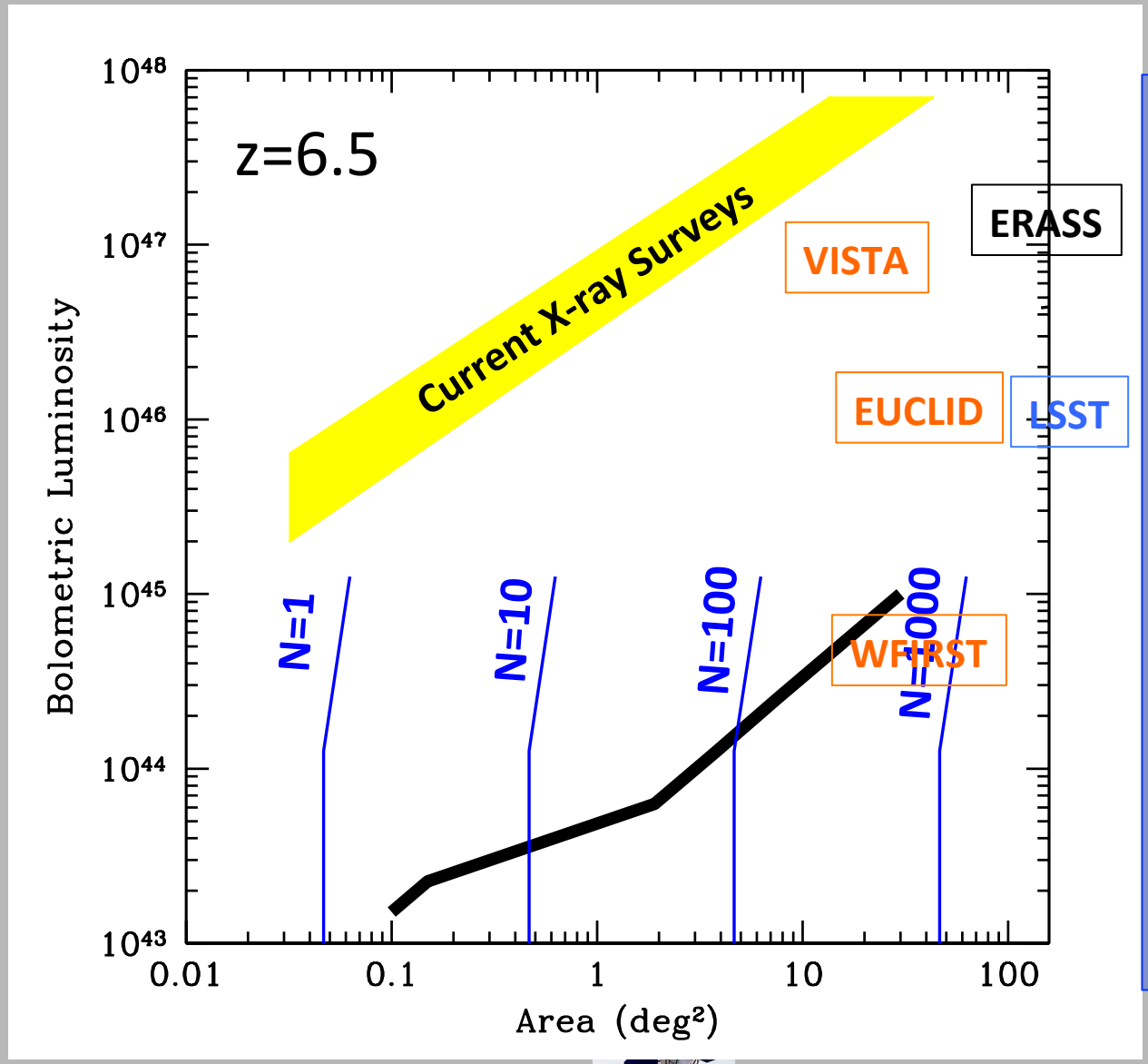


The First BHs: predictions (1)



Based on extrapolations of XRB population model *(Gilli+2007)*

The First BHs: predictions (2)



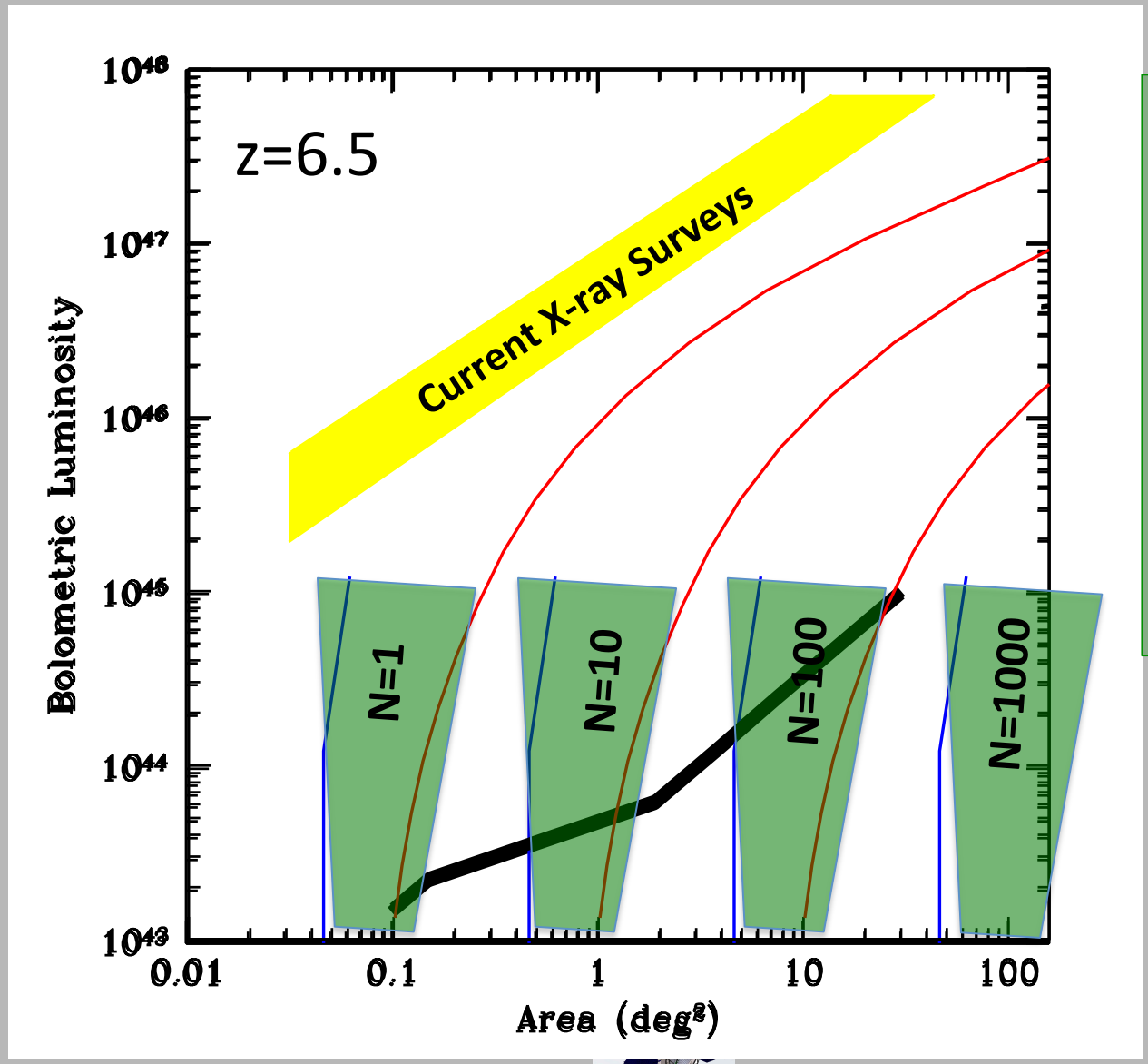
Cosmological Hydro-Simulations

Lbol>10^{44} erg/s
Horizon-AGN
(70 Mppc Box low-resolution)

Lbol<10^{44} erg/s
Chubby
(10 Mpc box
10 pc res)

Courtesy of Habouzit, Volonteri & Dubois

The First BHs: predictions (3)



Many tens at Lbol~$10^{43.5}$ erg/s BH masses of **10^6 -10^7**

Many hundreds Lbol~$10^{44.5}$ erg/s BH masses of **10^7 -10^8**

Summary

- BIG Q: Estimate of the volume density of faint AGN/QSO at high z have important implications concerning the abundance and mass of BH seeds and their early growth
- Current view of z>6 active BH: optical/IR bright surveys
- Biased towards bright and unobscured sources ➔ Biased AGAINST less massive BHs
- Missing a significant component detectable exclusively in the X-ray band
- **Deep & Wide** X-ray Surveys in conjunction with future optical/IR surveys
- Spatial resolution to pin-point the λλλ counterpart