AGN EVOLUTION:
OUSTANDING ISSUES AND PROSPECTS FOR IXO

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Imperial College London

Thanks to: James Aird, Mitesh Patel, Xavier Barcons, Andrea Comastri, George Chartas, Yuichi Terashima…
and the IXO team

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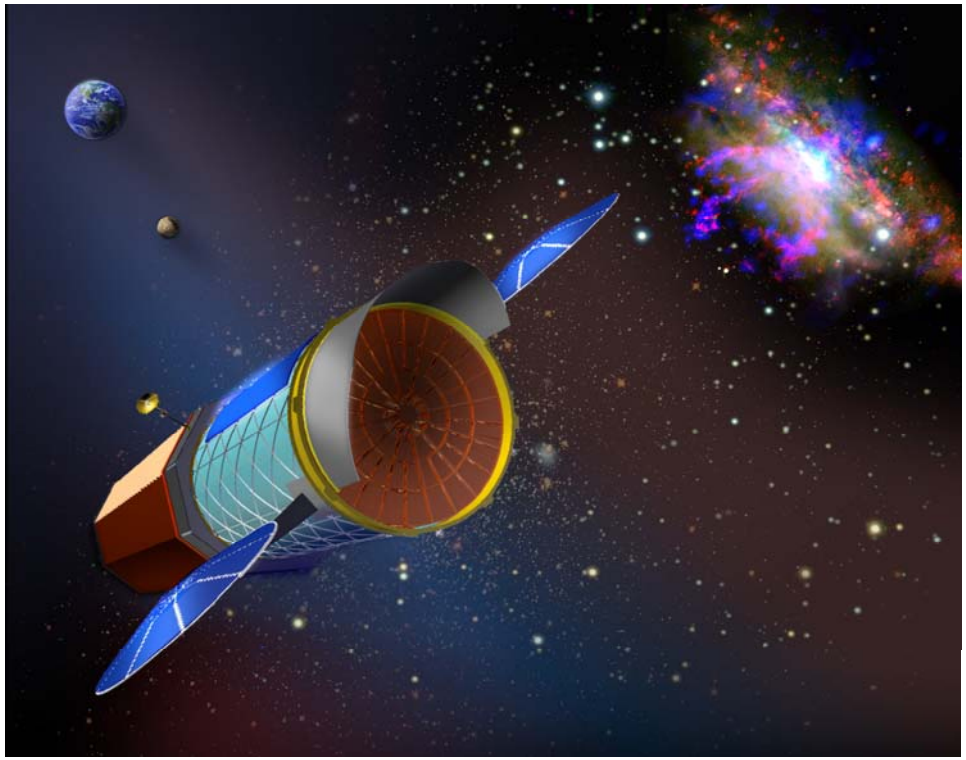
OUTSTANDING QUESTIONS

How do AGN evolve?



OUTSTANDING QUESTIONS

- Are AGN important in the early universe (z>6) and do they affect galaxy formation?
- How do they affect the subsequent evolution of galaxies (co-evolution)?
- Do we have a complete census (e.g. is there a significant population of CT AGN?)
- Why did the accretion power in the universe decline since z~1?
- What triggers AGN activity?

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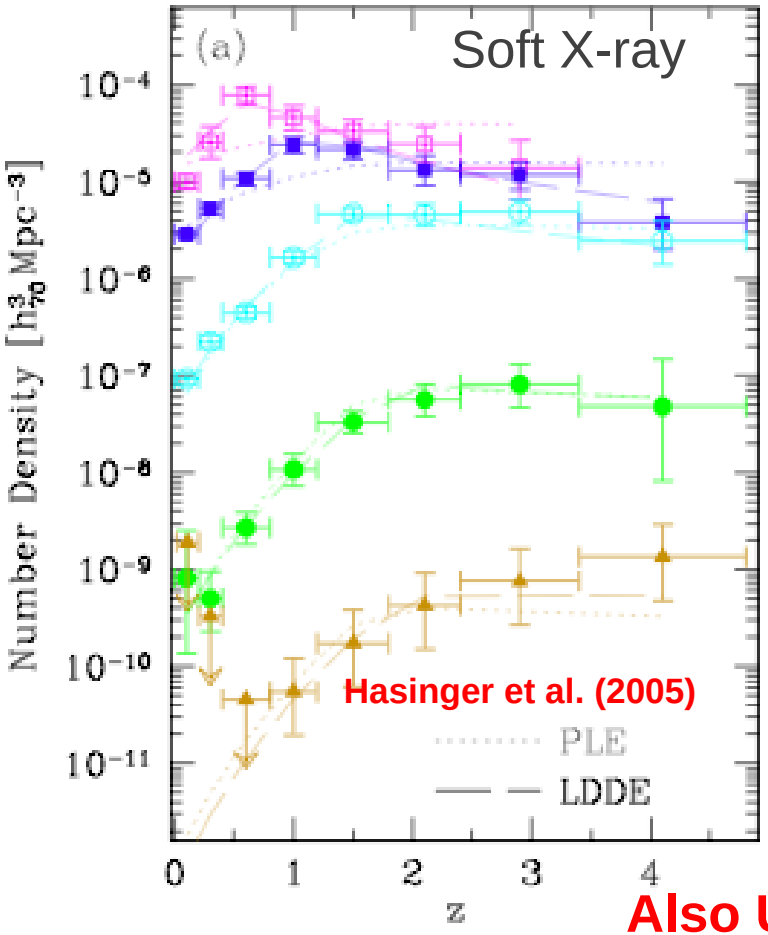
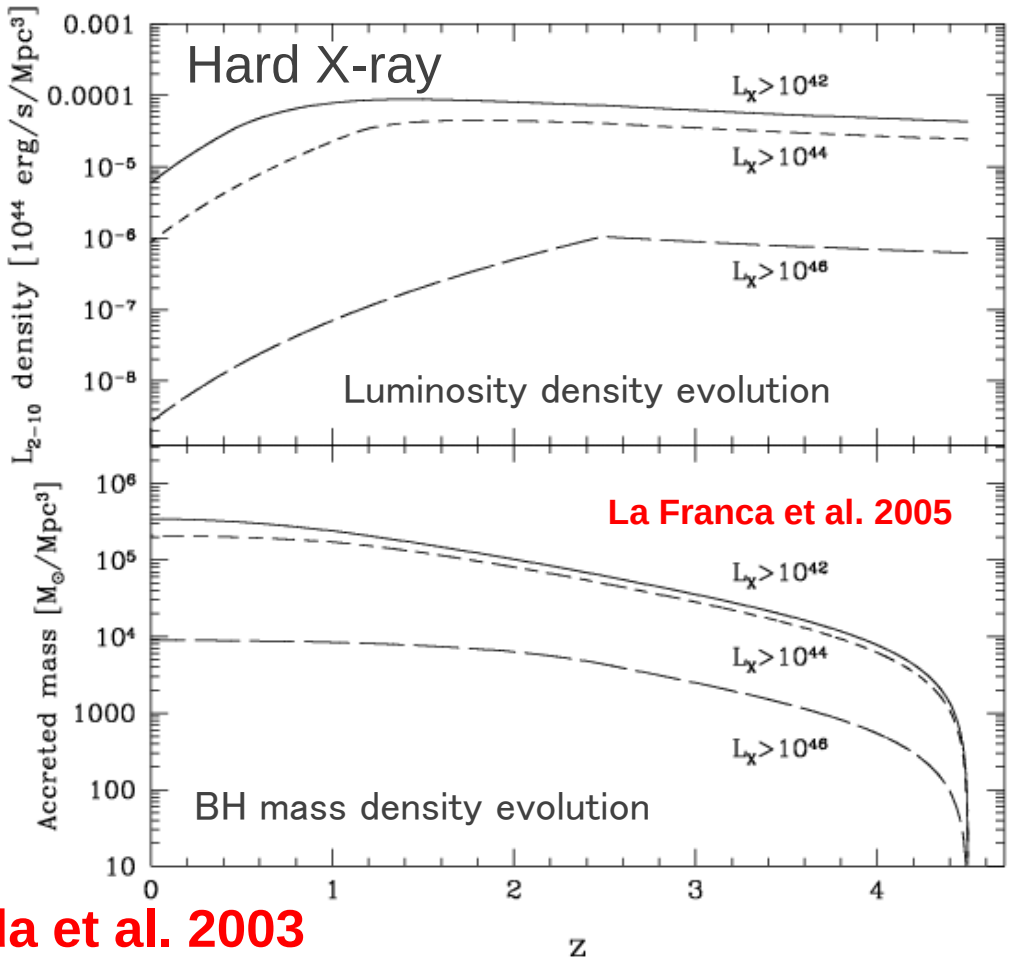
AGN EVOLUTION

Luminosity-dependent Density Evolution (LDDE)

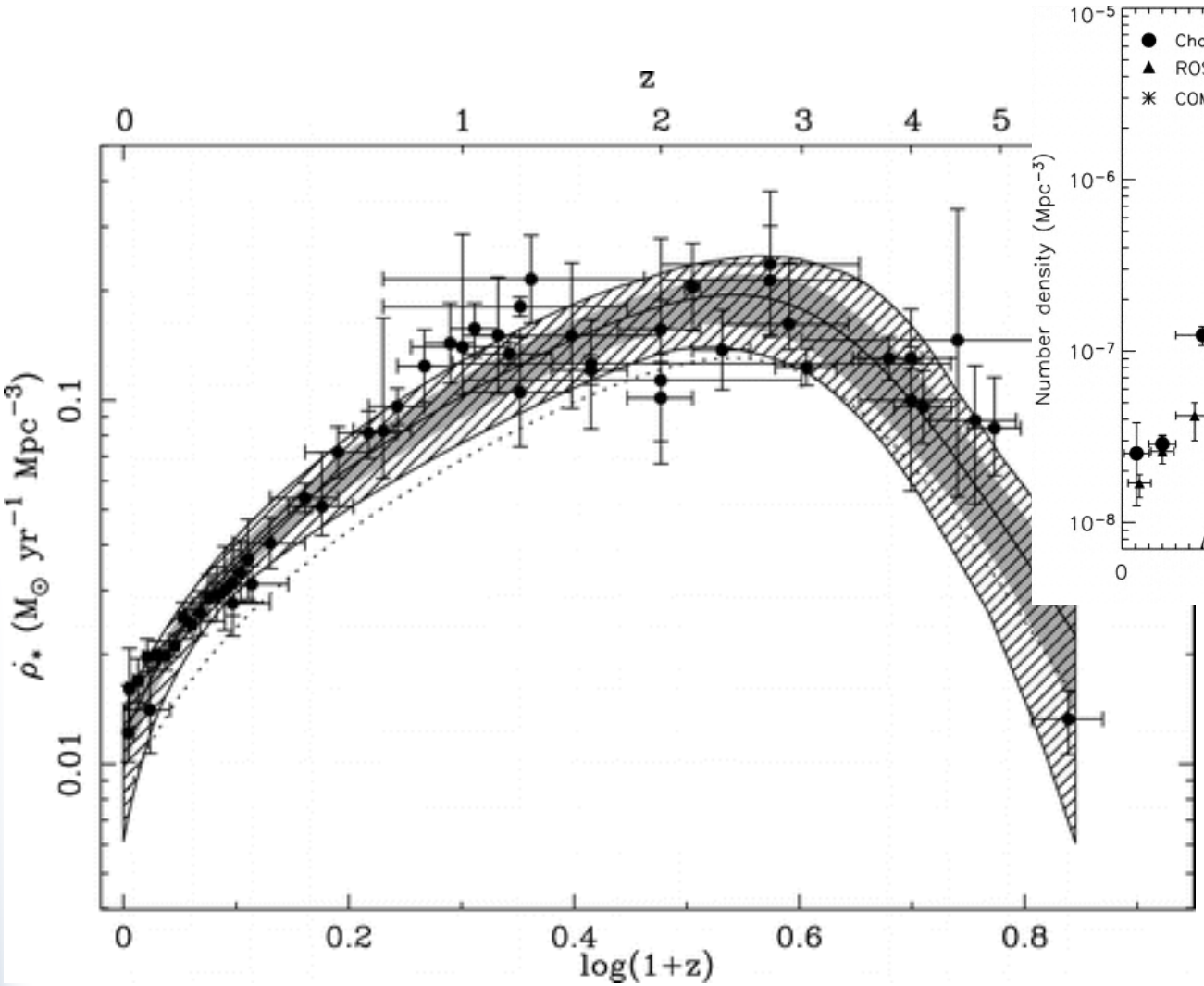




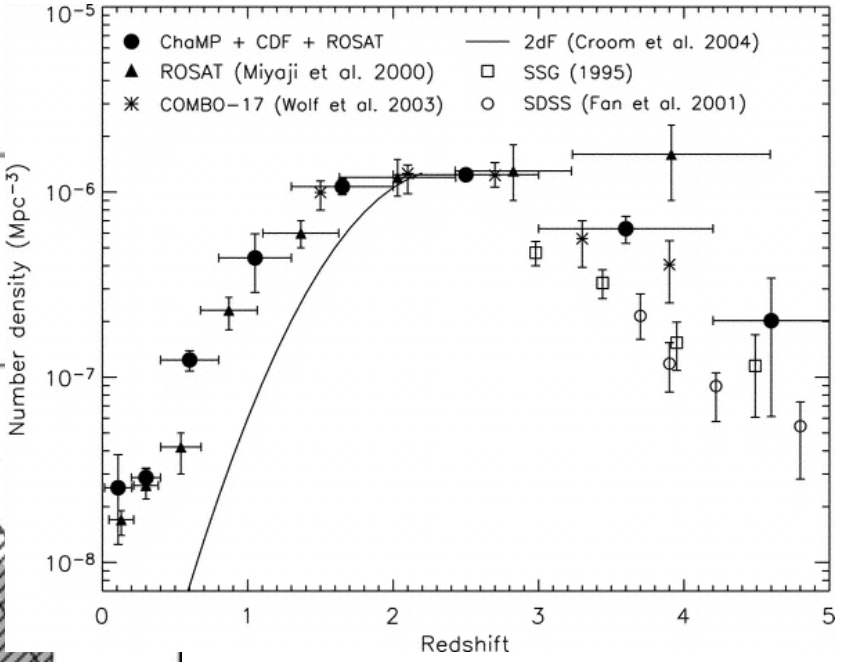
Also Ueda et al. 2003

AGN "Downsizing" Typical BH mass or accretion rate reduces with *z*?
Galaxy "downsizing": most massive galaxies formed their stars early

AGN-GALAXY CO-EVOLUTION



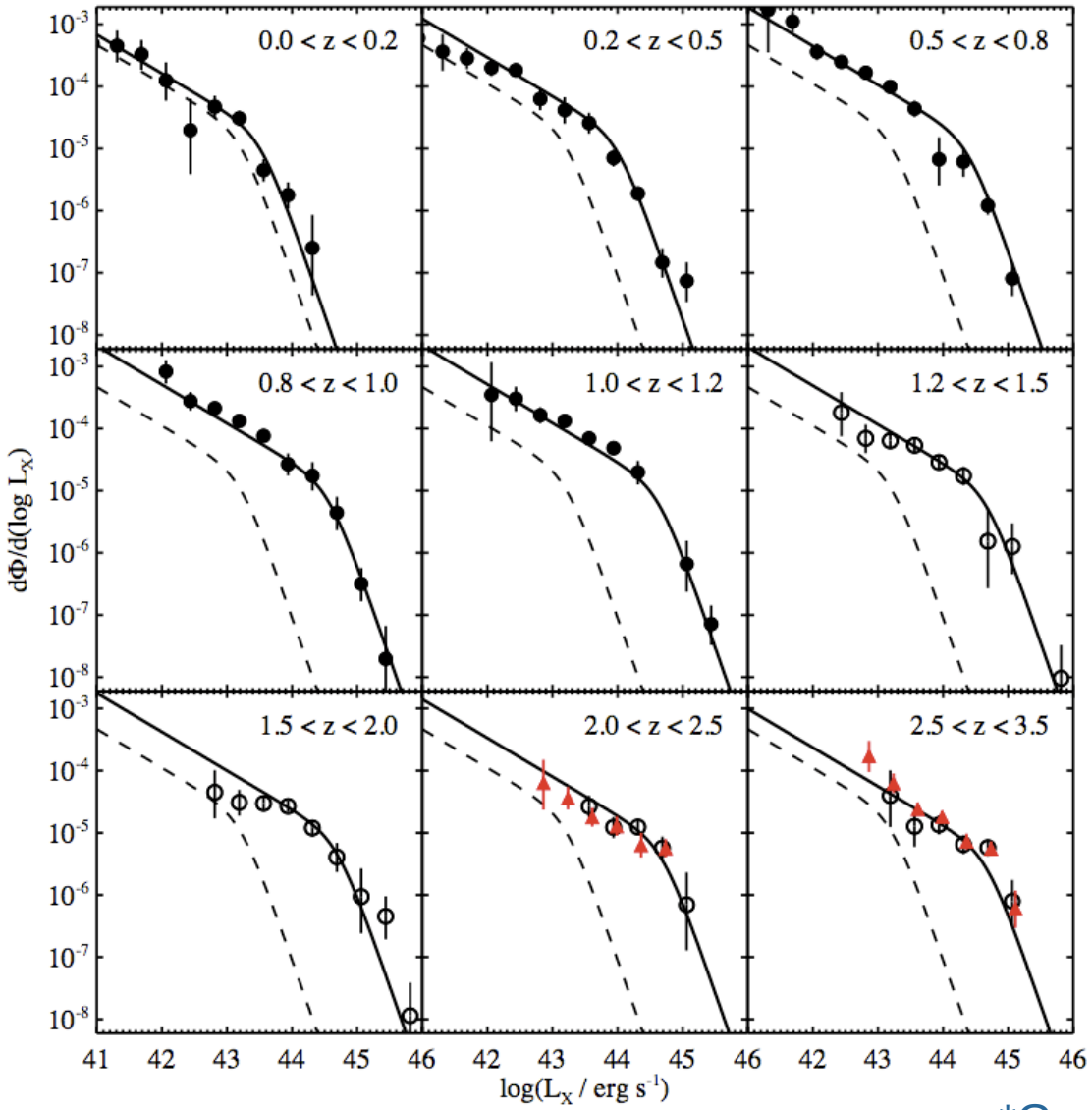
SFRD: Hopkins & Beacom (2006)



AGN number density:
Silverman et al. (2005)

Similar evolution:
Boyle & Terlevich 1998

NEW HARD X-RAY LF



Methodology:

- X-ray completeness and bias correction*
- Spectro completeness
- Photo-z errors
- Colour selection vs photz
- Bayesian model comp

RESULTS

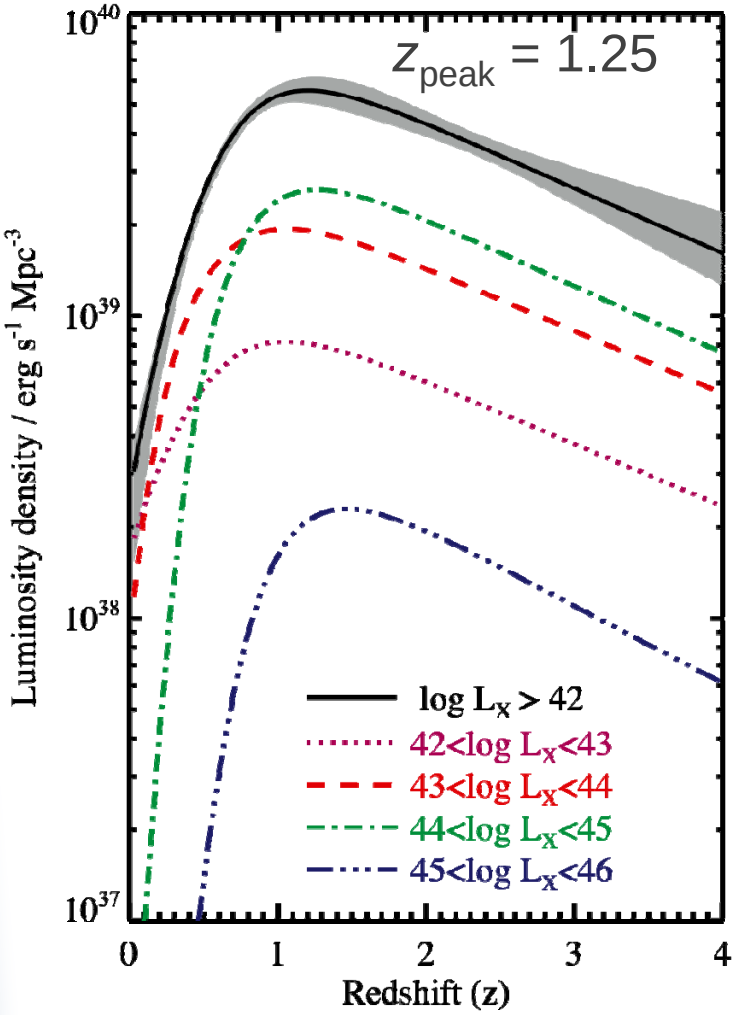
- L* evolves +ve to z~1
- Φ* mildly -ve above
- LDDE NOT preferred

Aird et al. (2009)

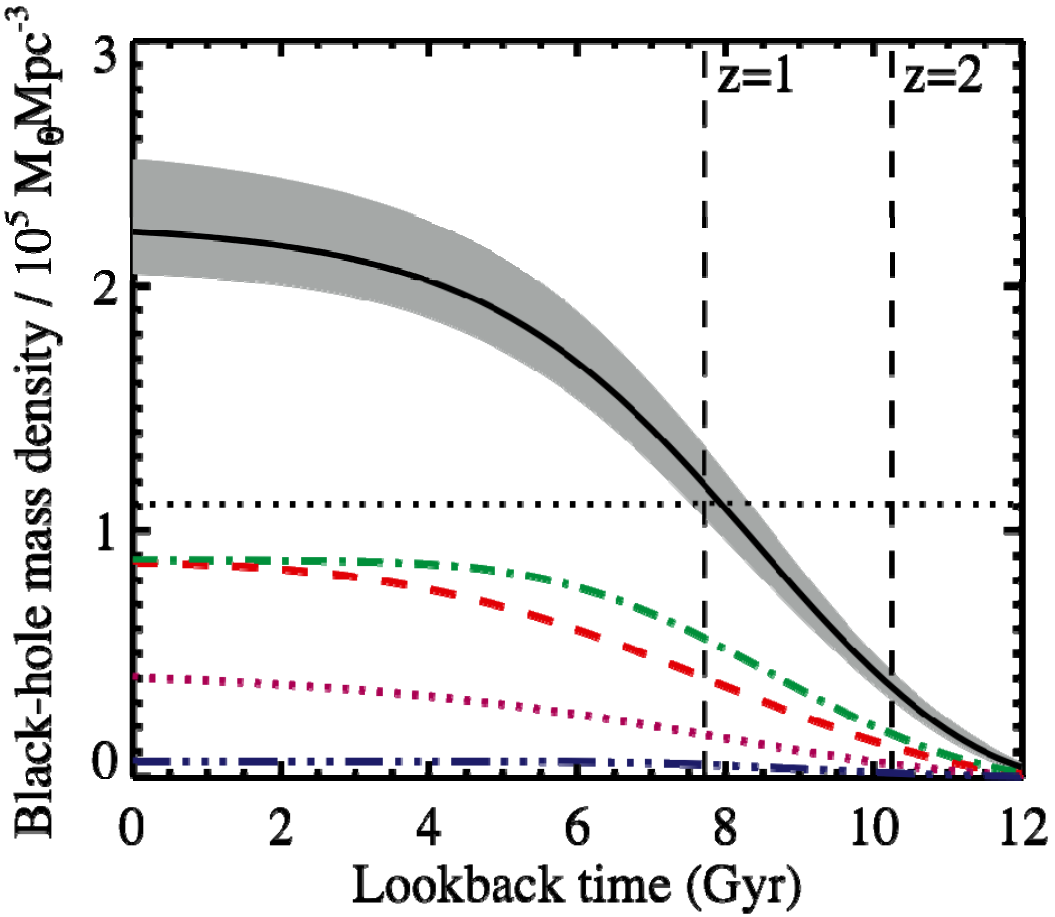
*Georgakakis et al. 2008

BLACK HOLE GROWTH HISTORY

Luminosity density

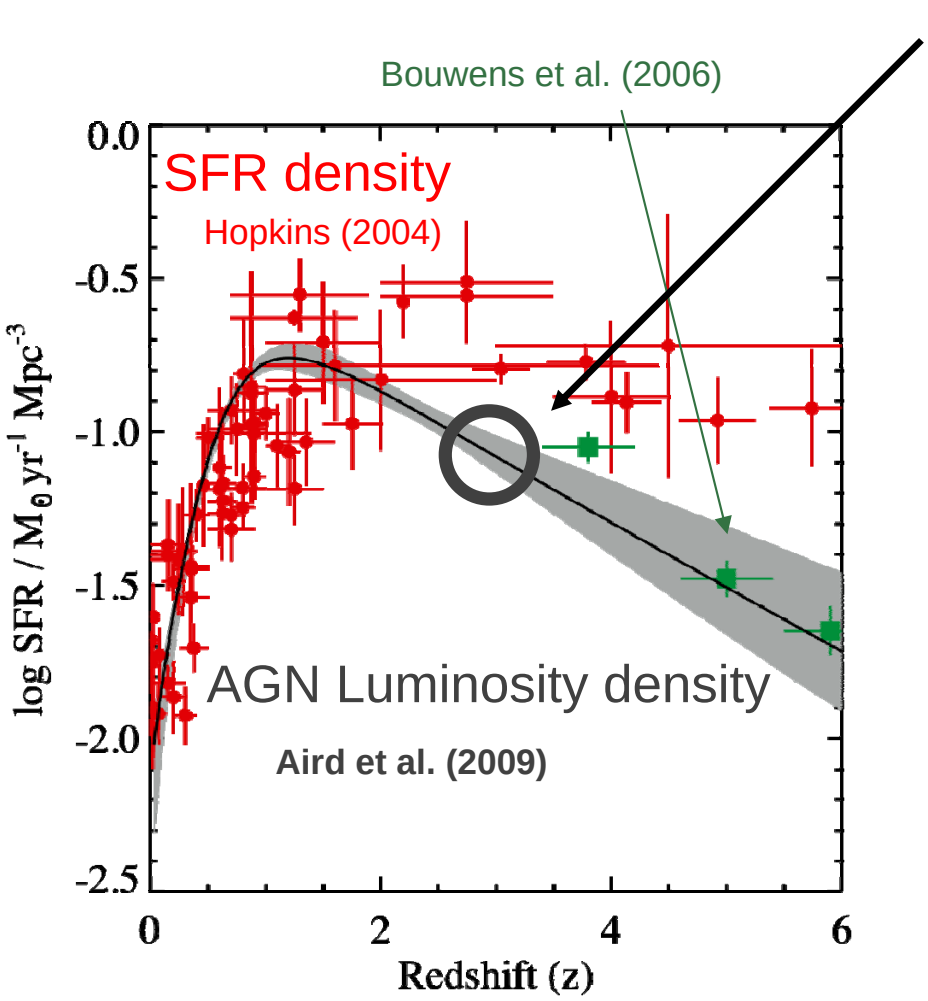


Black Hole Growth

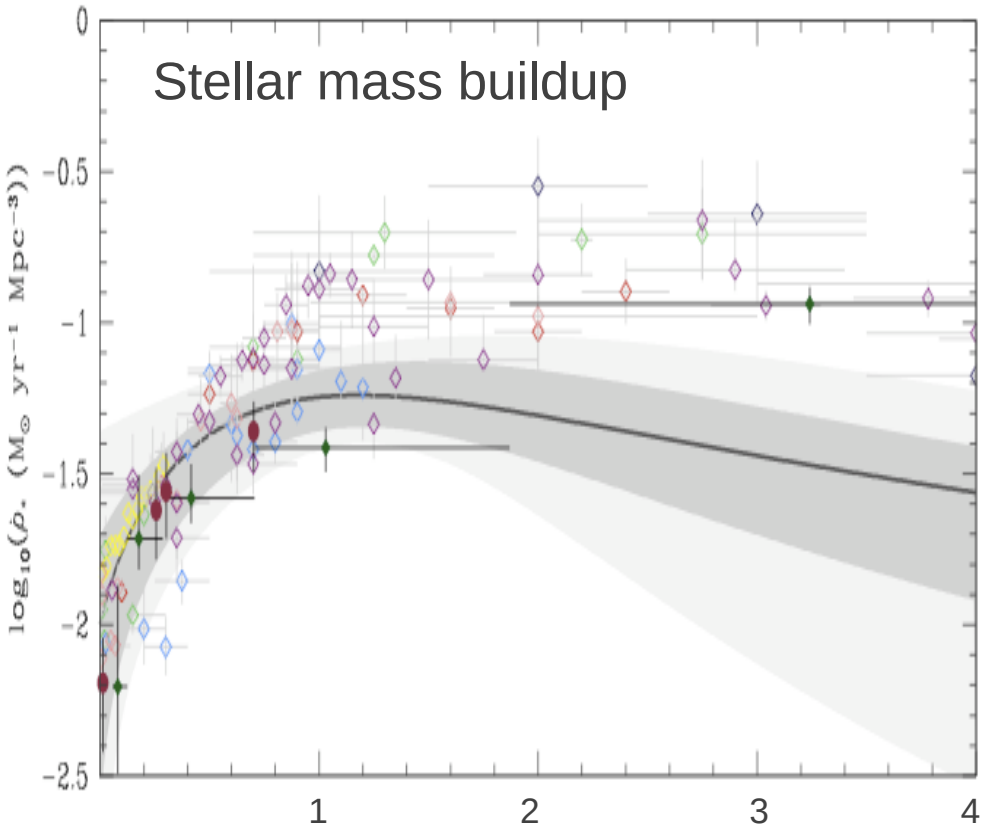


Aird et al. (2009)

ACCRETION VS STAR FORMATION

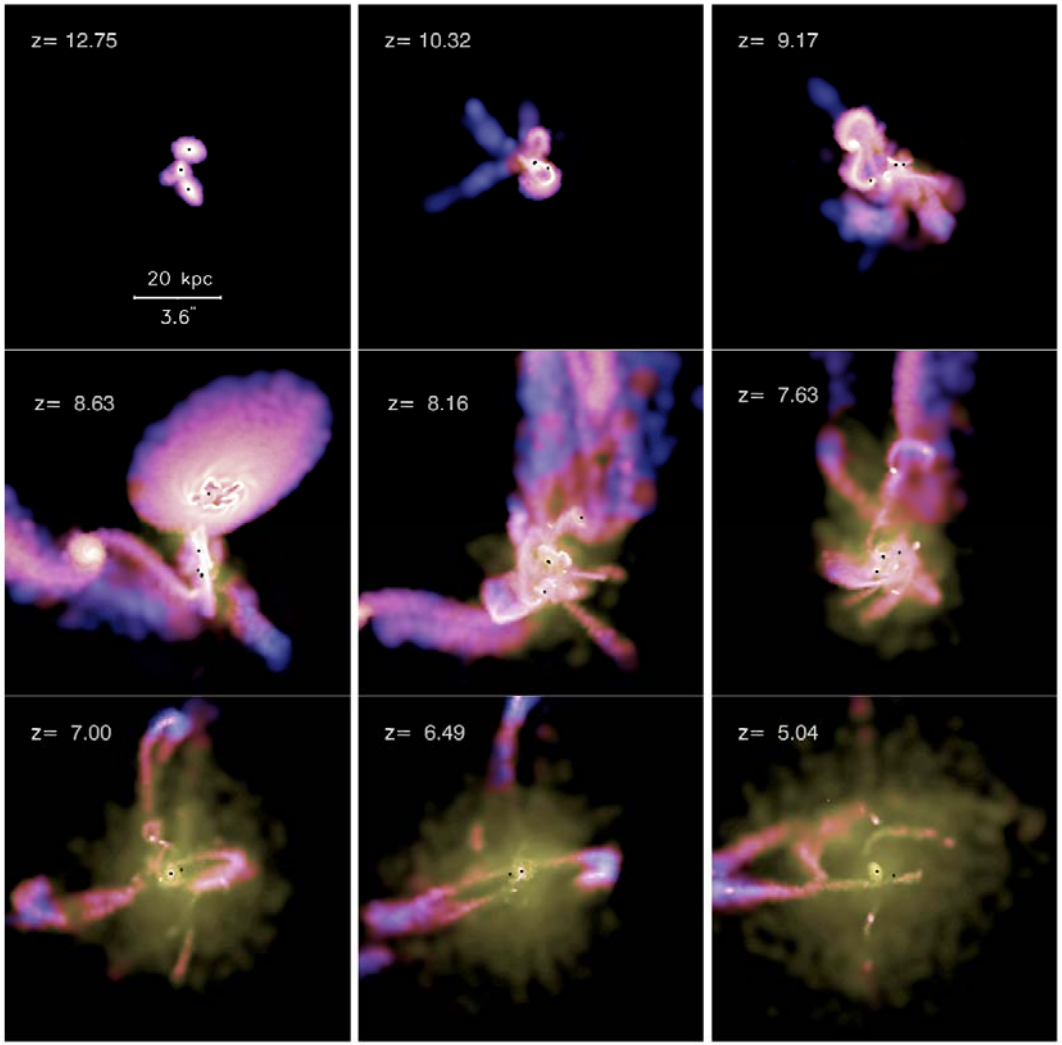


XLF only known to here so far!



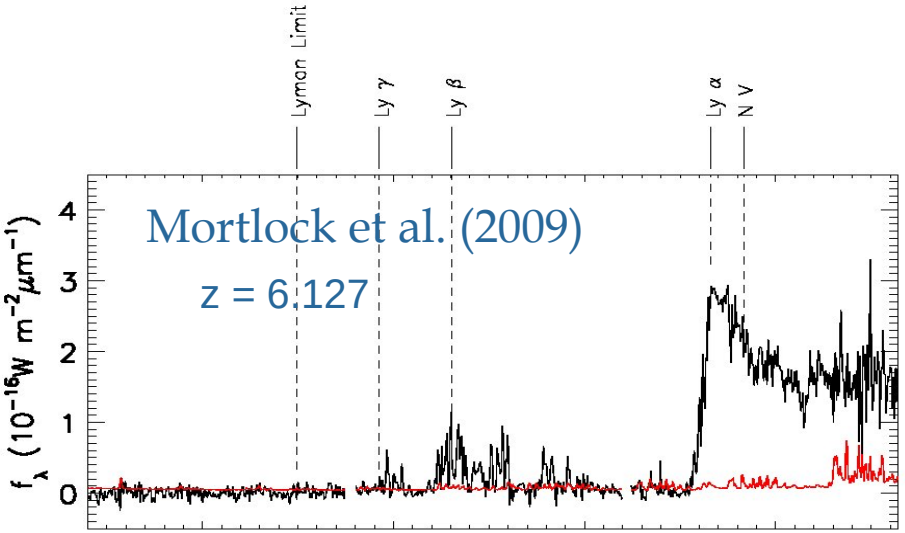
Wilkins et al. (2008)

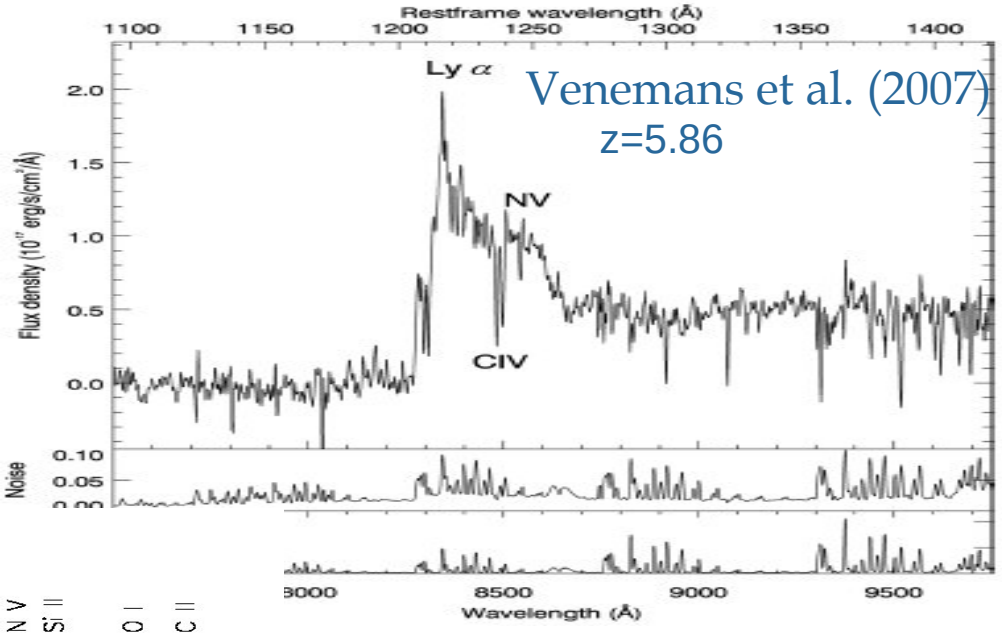
FORMATION OF THE FIRST SMBH

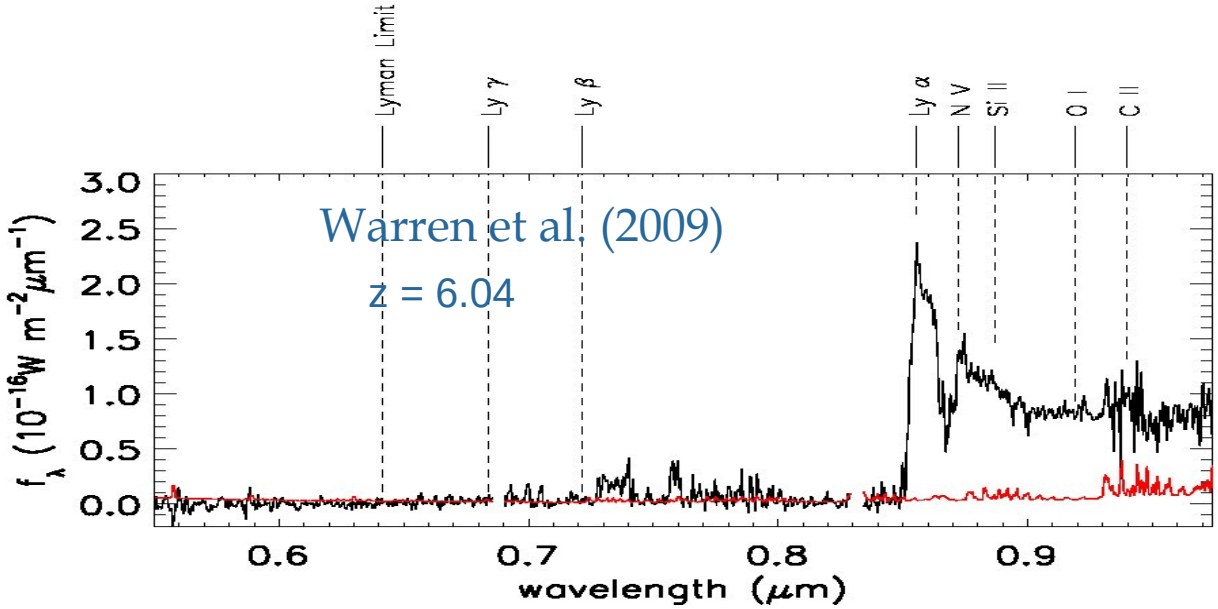


Li et al. 2007

Z=6 QUASARS: SDSS+UKIDSS







Credit: Mitesh Patel, Daniel Mortlock, Steve Warren

SDSS: Fan et al. 2001, 2003, 2006
CFHQS: Willott et al. 2005, 2007

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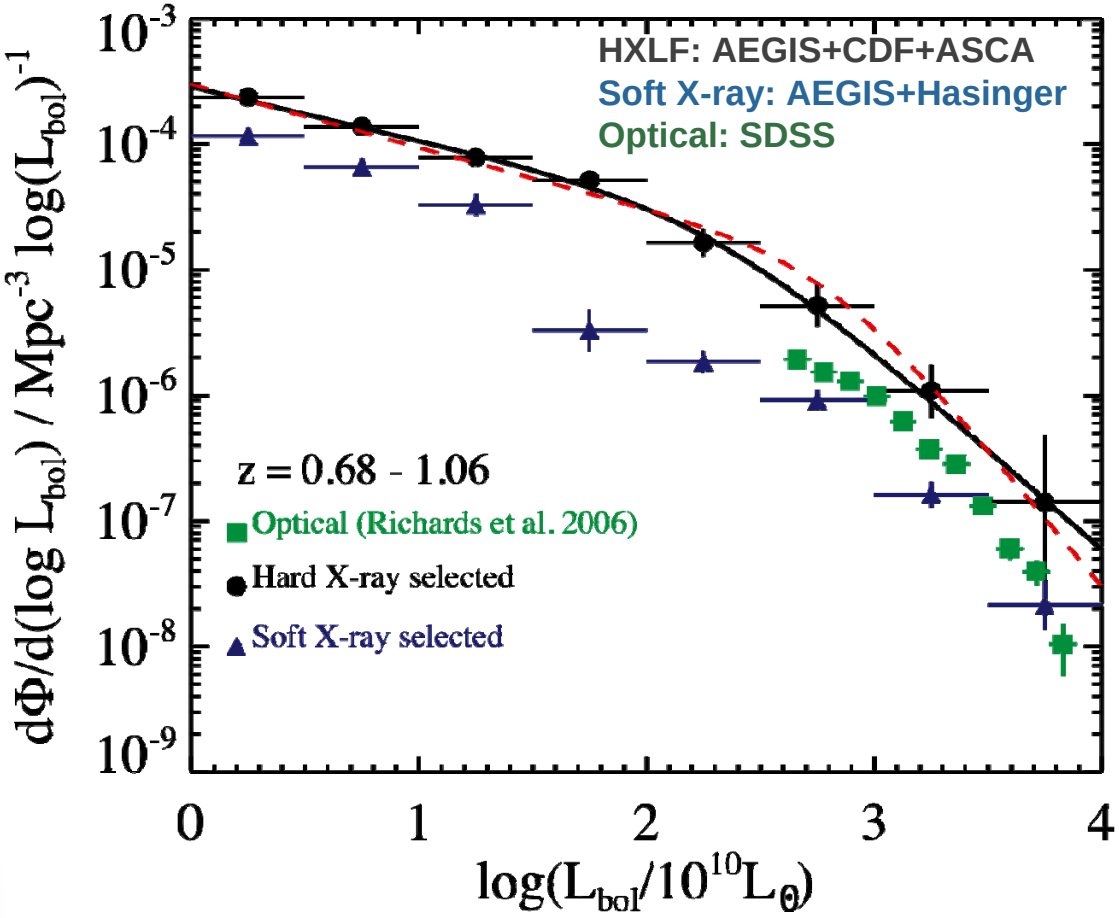
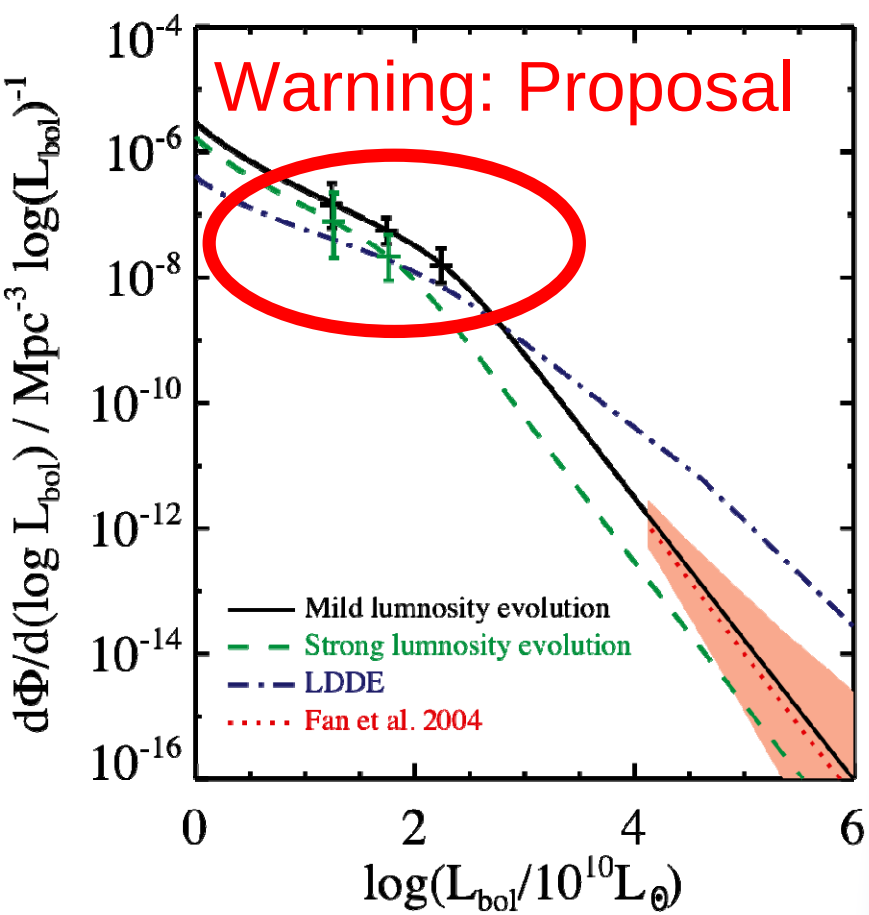
THE NEED FOR X-RAYS

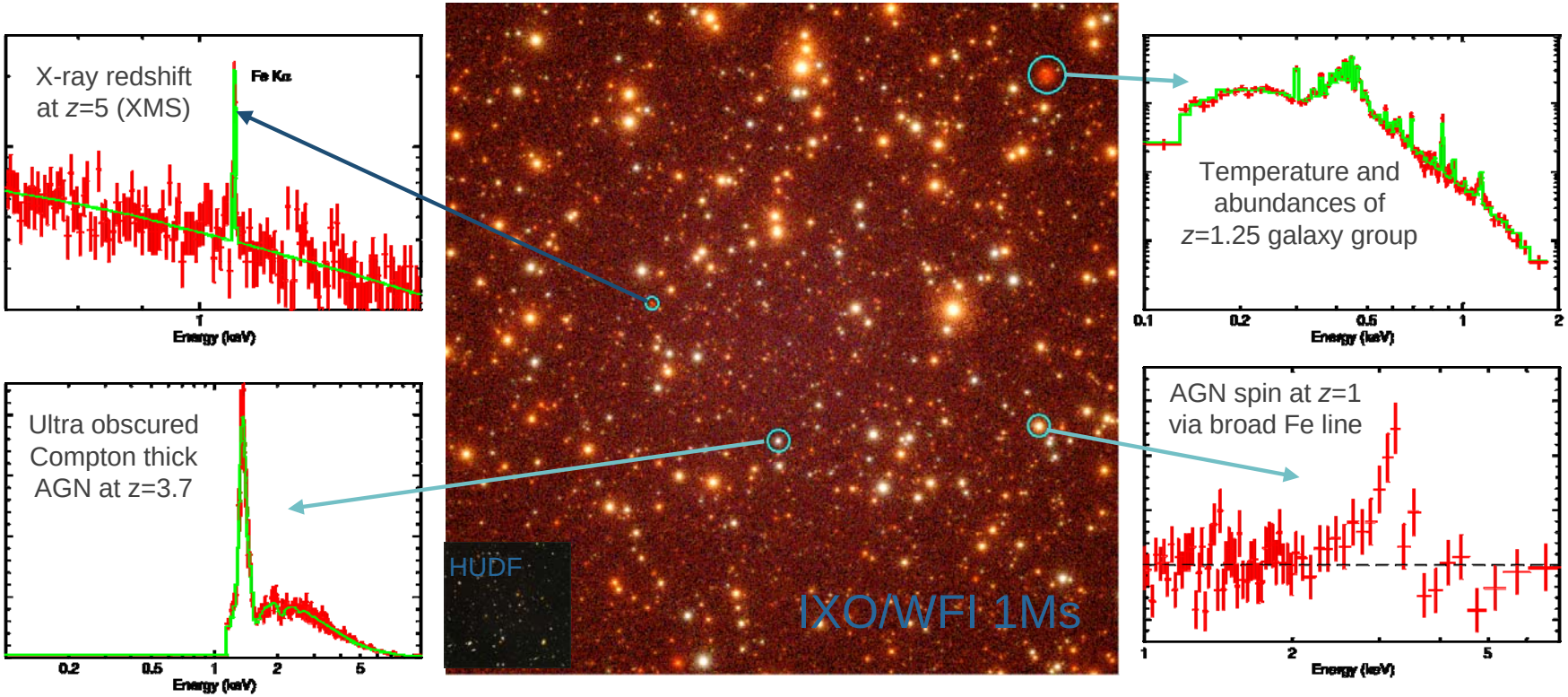
BOLOMETRIC LUMINOSITY FUNCTIONS





QSOs sample ~30% of accretion power:
obscuration and host galaxy dilution

WHAT CAN IXO DO?



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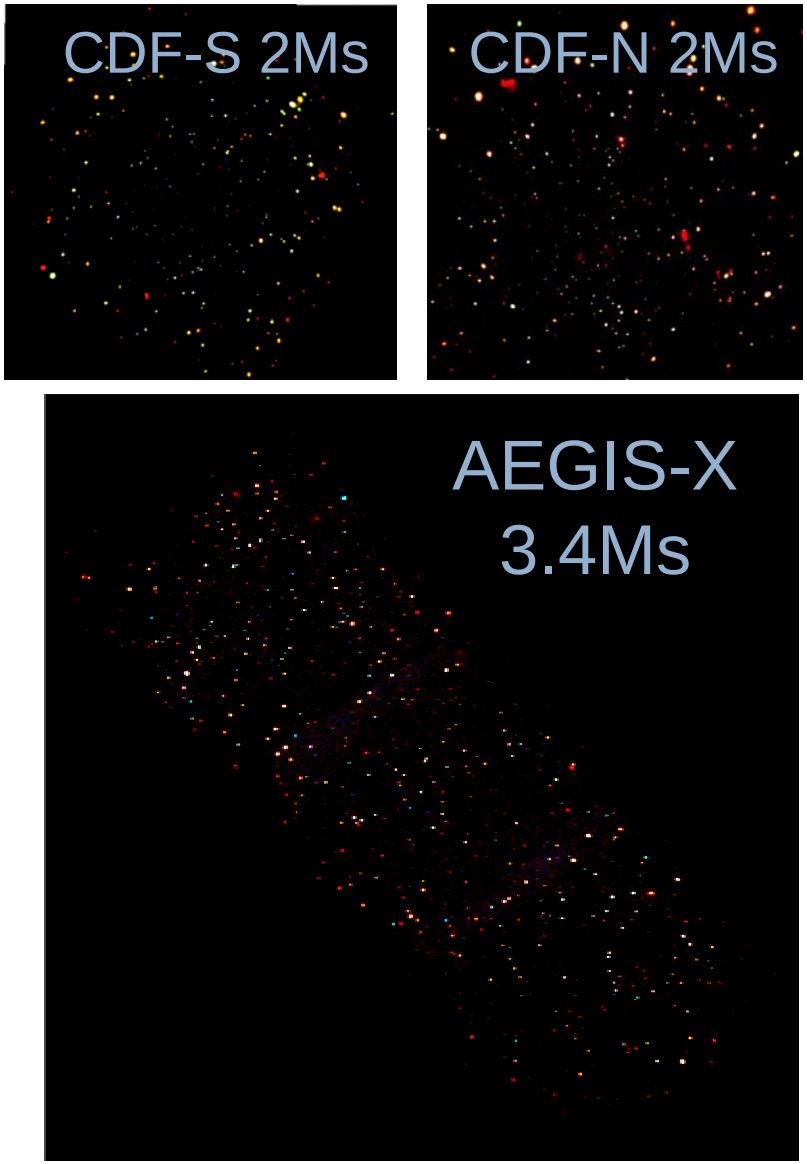
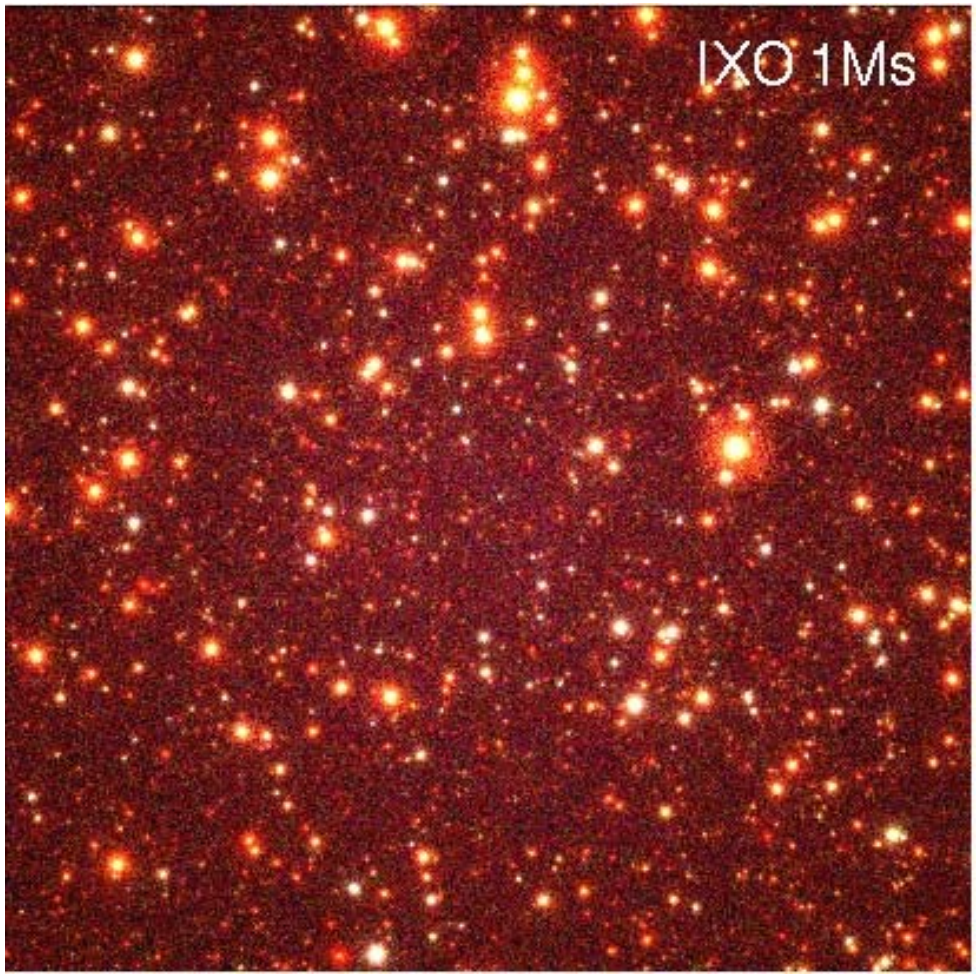
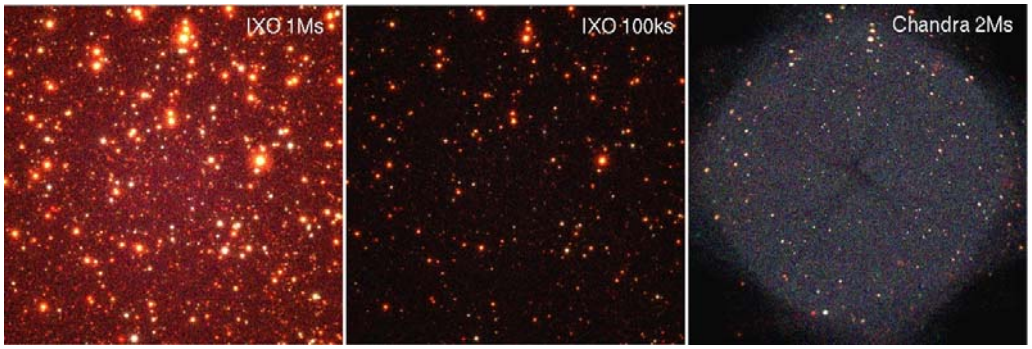
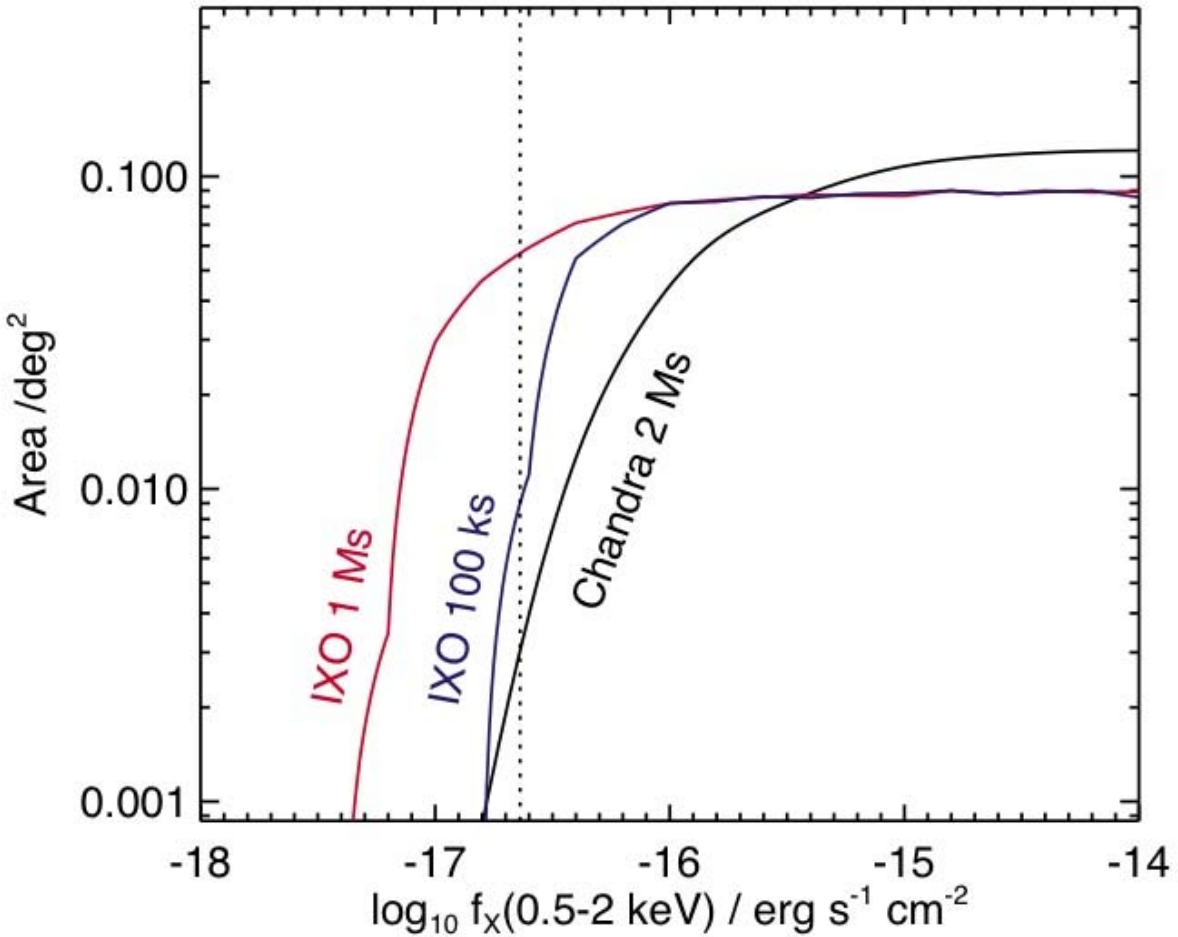




Simulations: James Aird

IXO: SENSITIVITY





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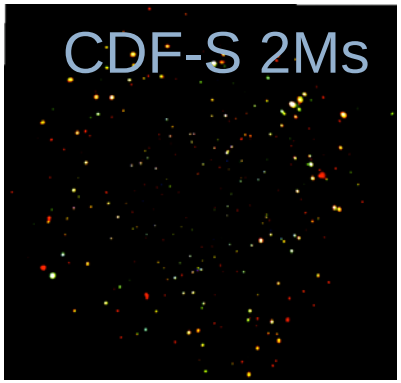

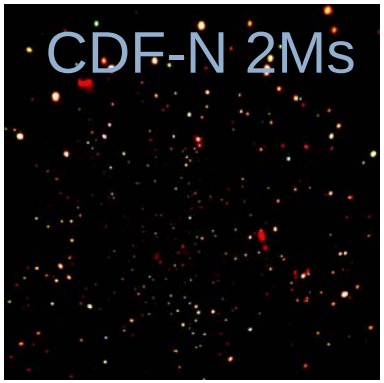

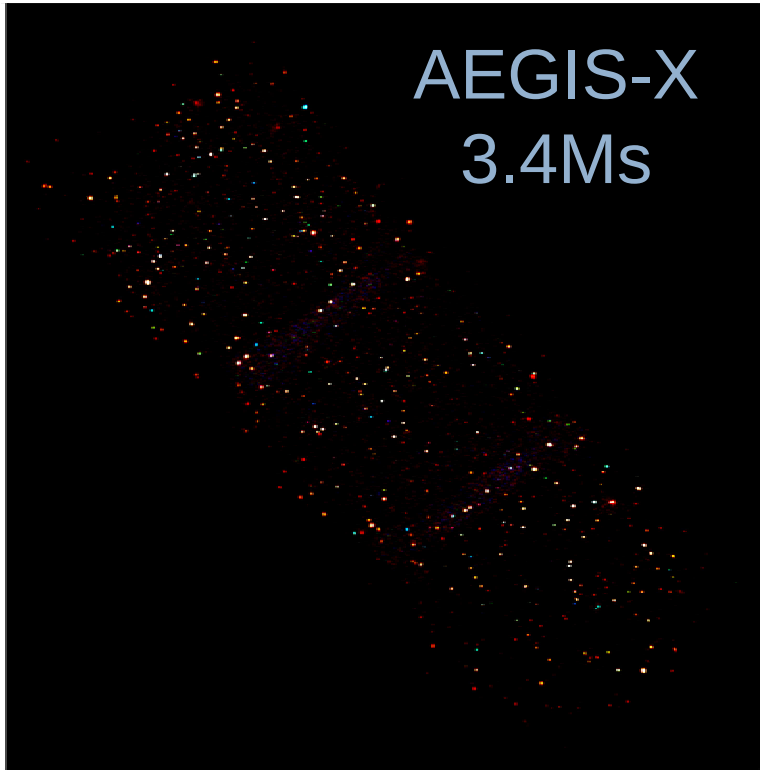

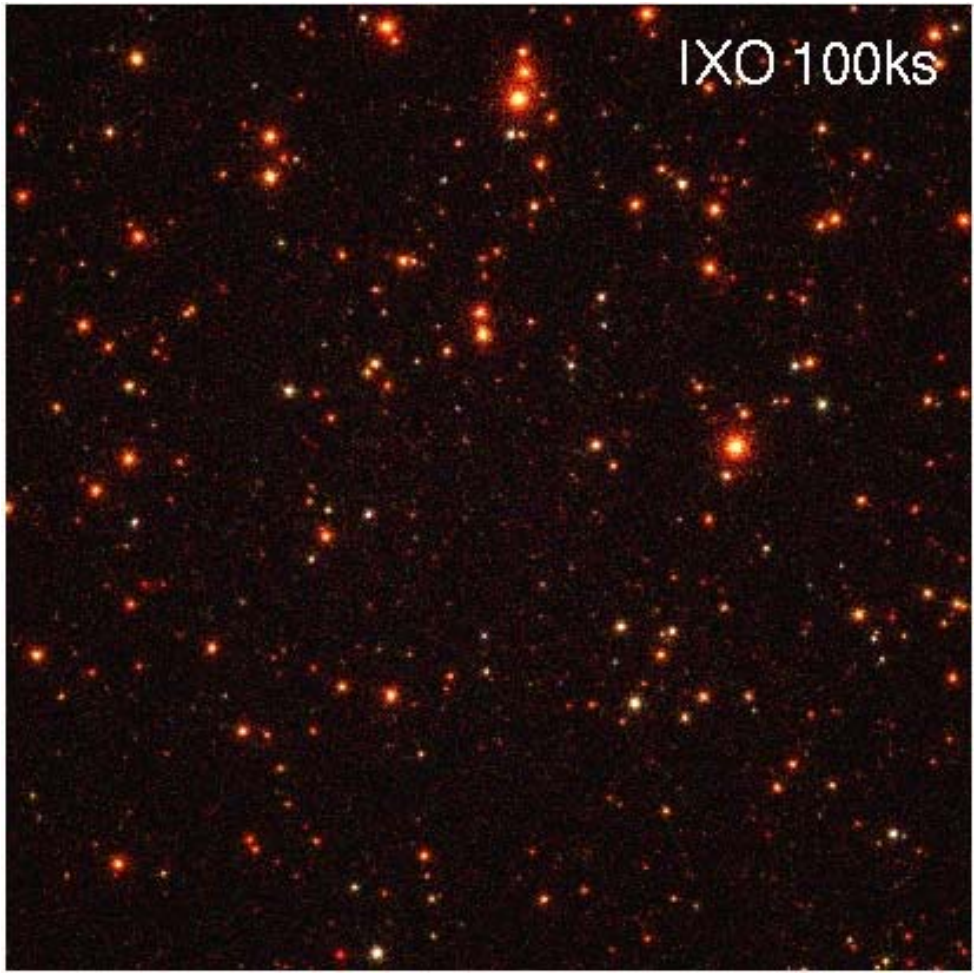

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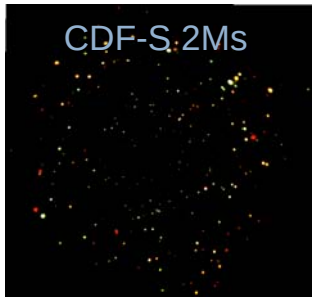
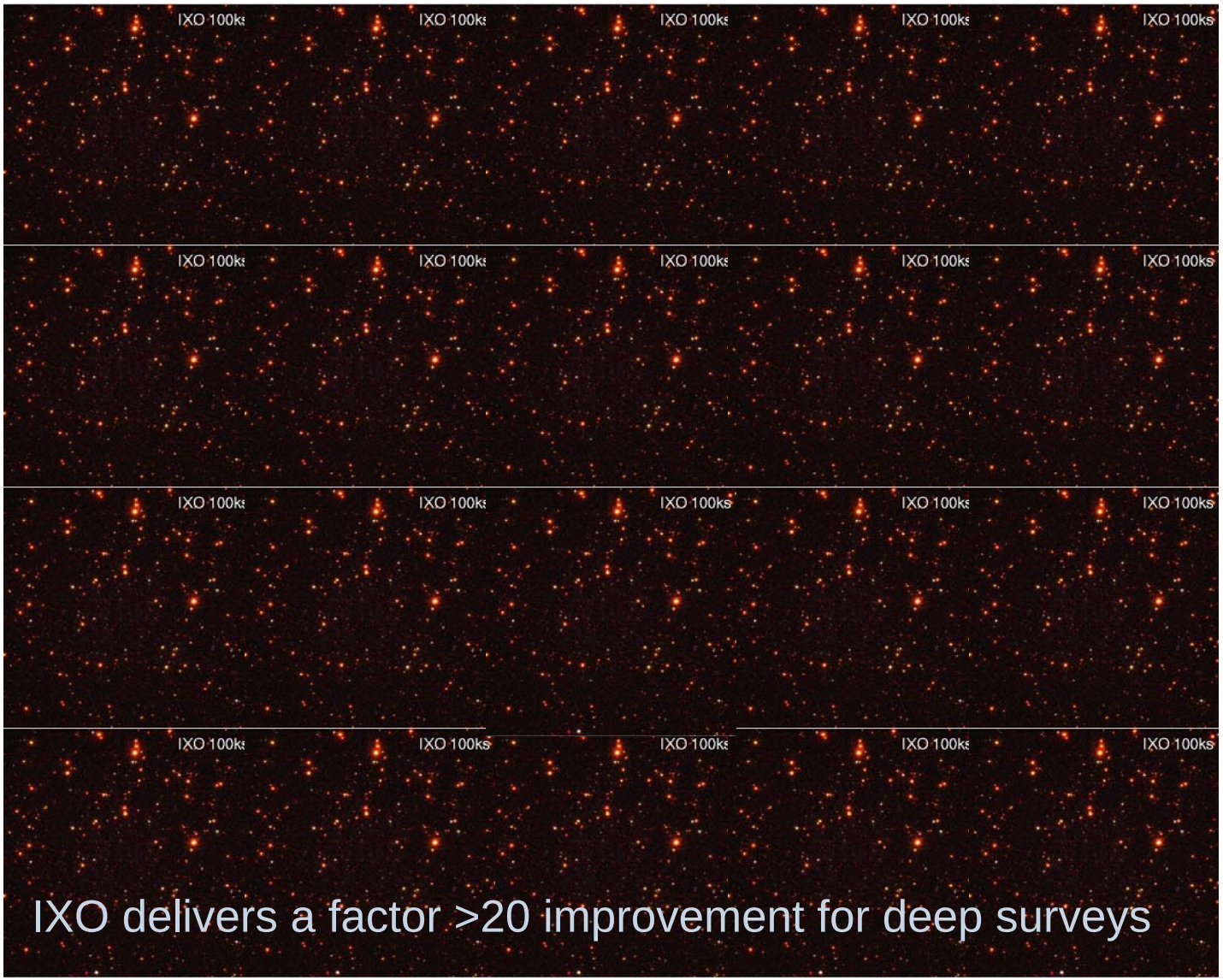
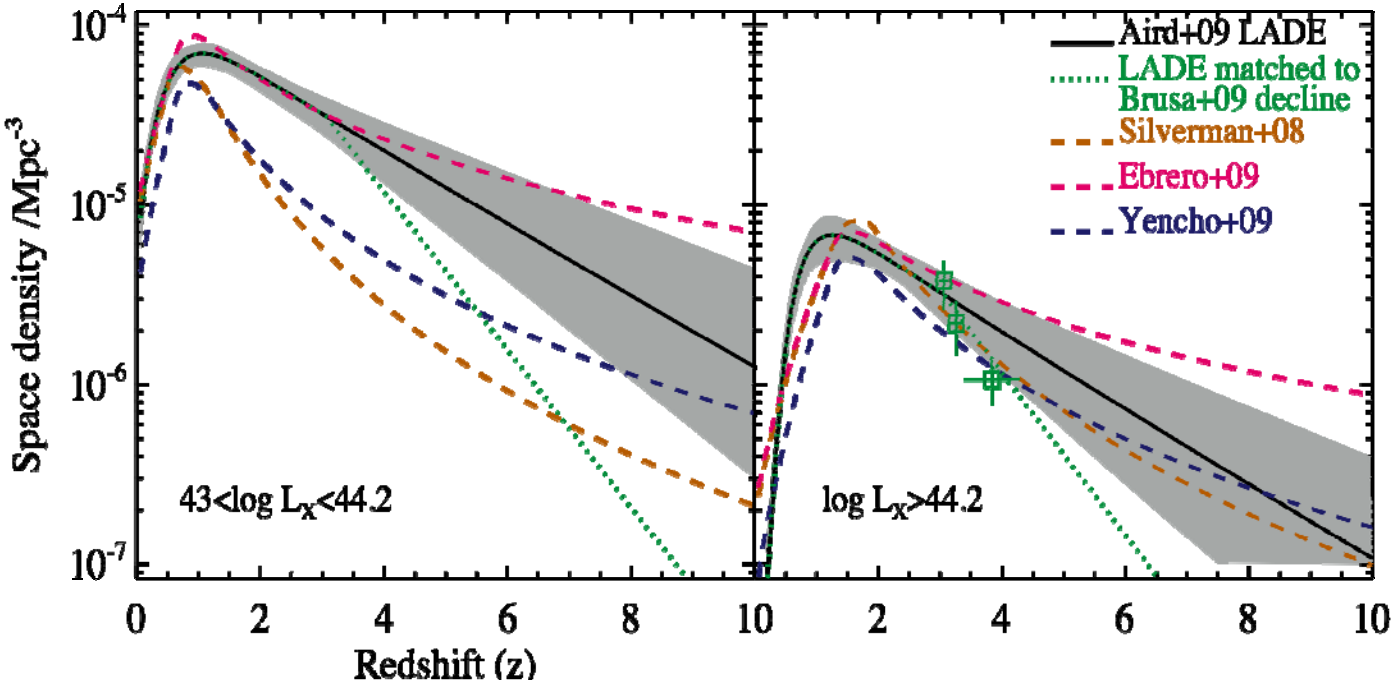
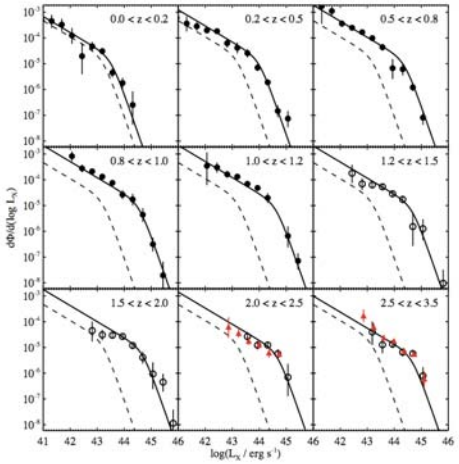




IXO: HIGH Z PREDICTIONS





➔Best ***observational*** estimate of high *z* numbers

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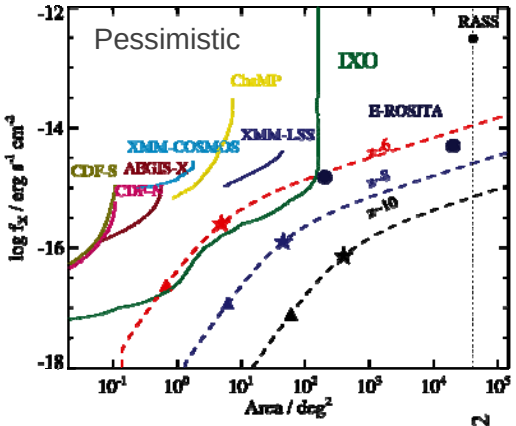
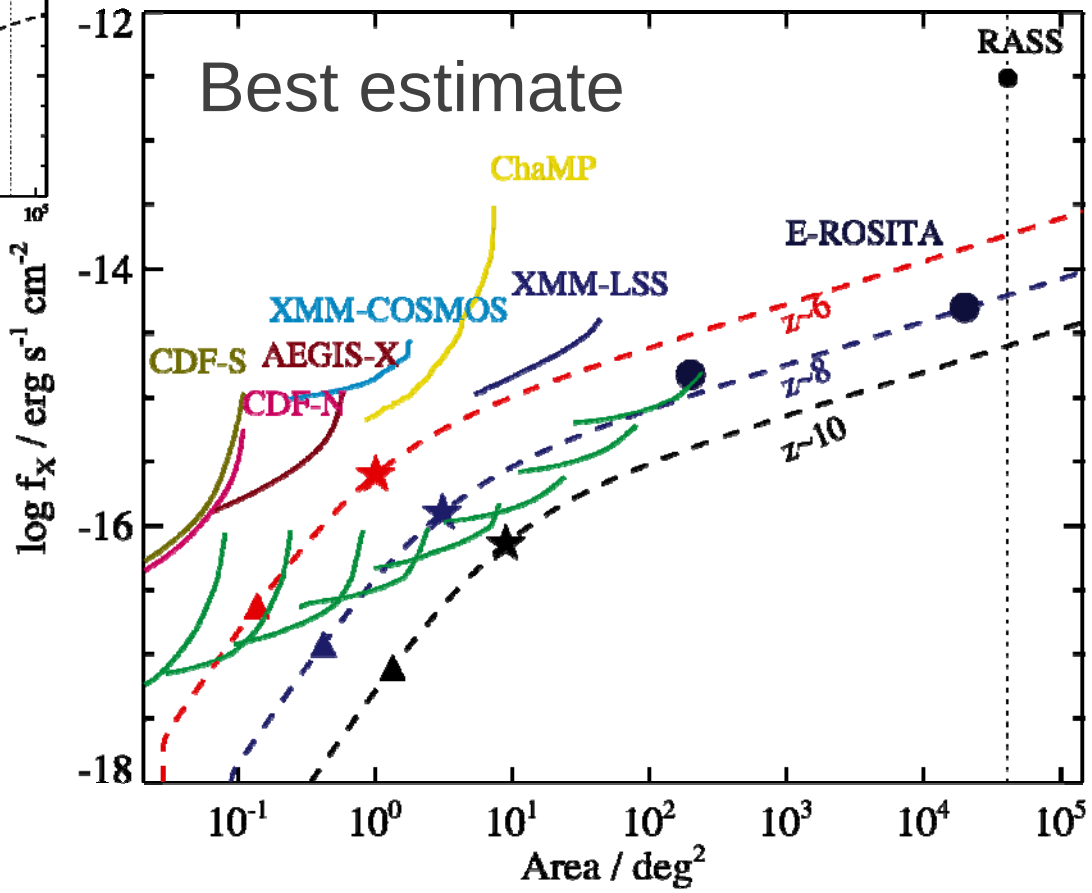
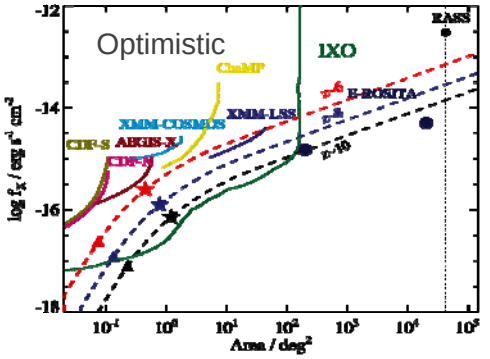
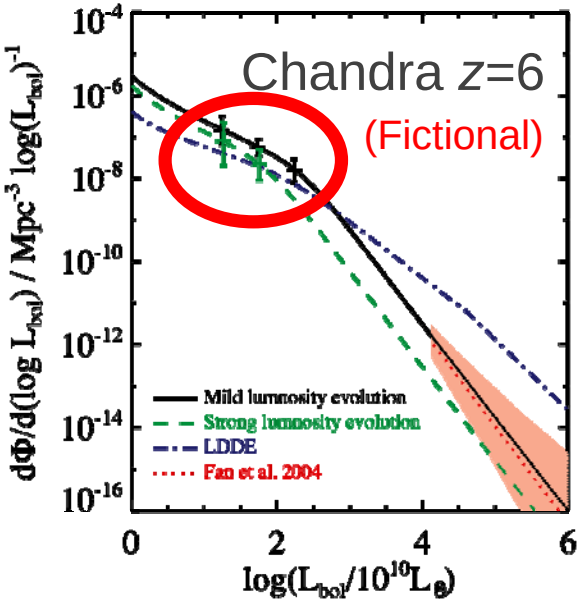
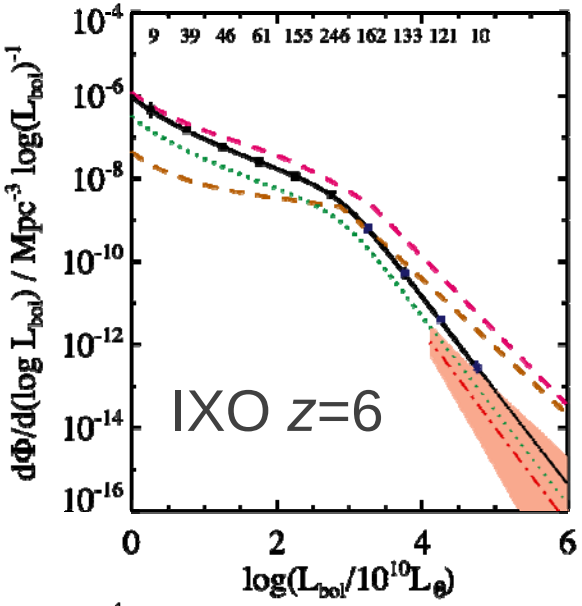


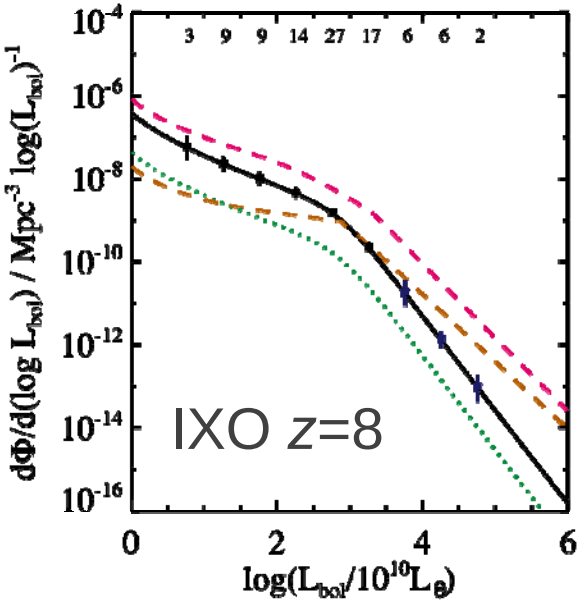


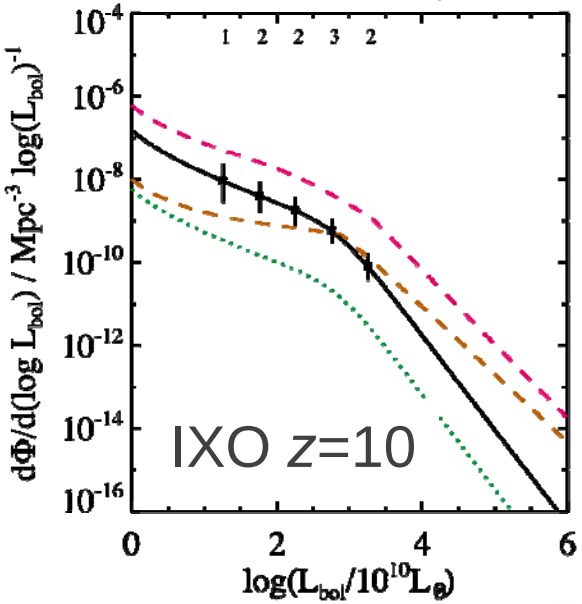


IXO: PREDICTED XLF

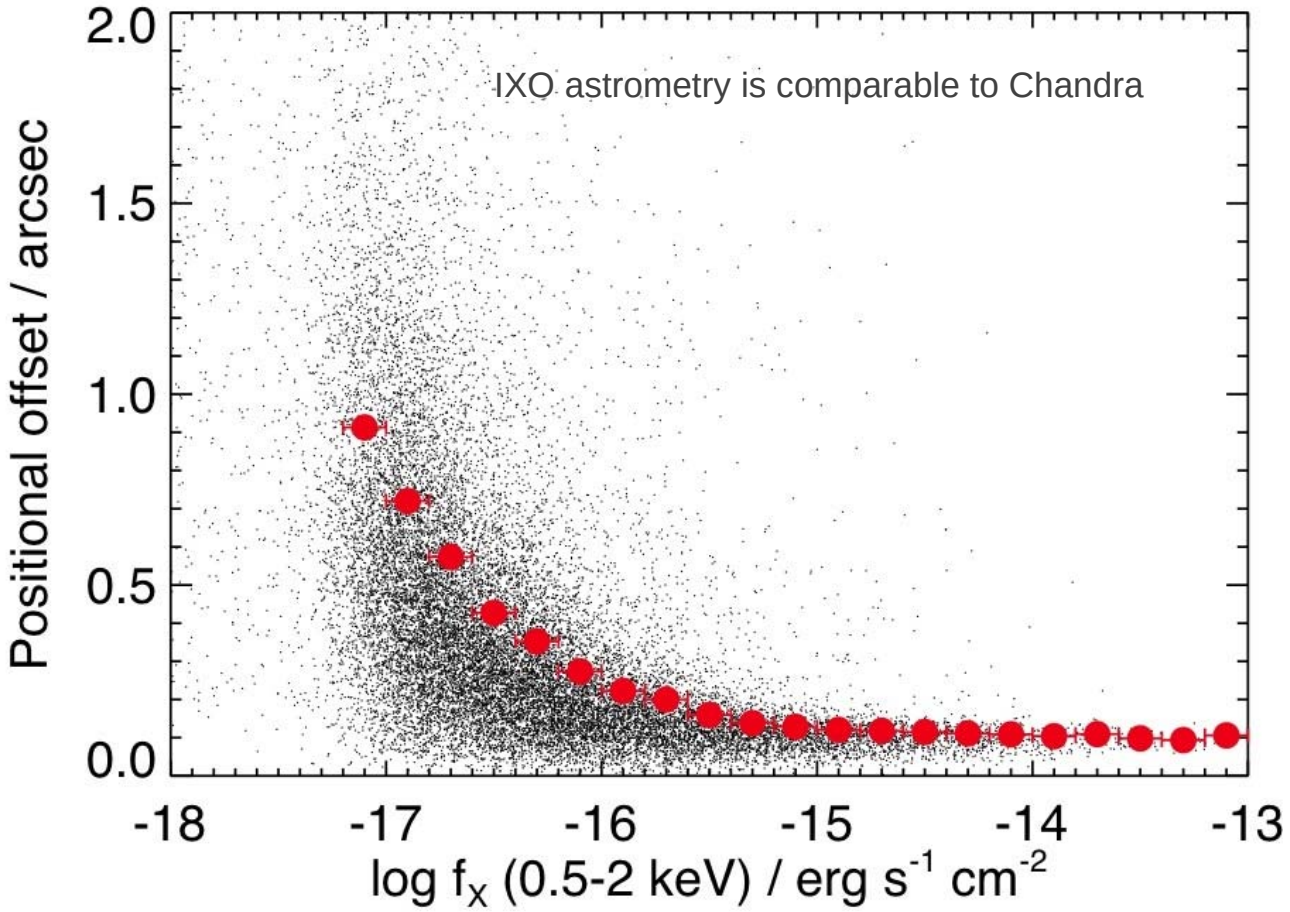






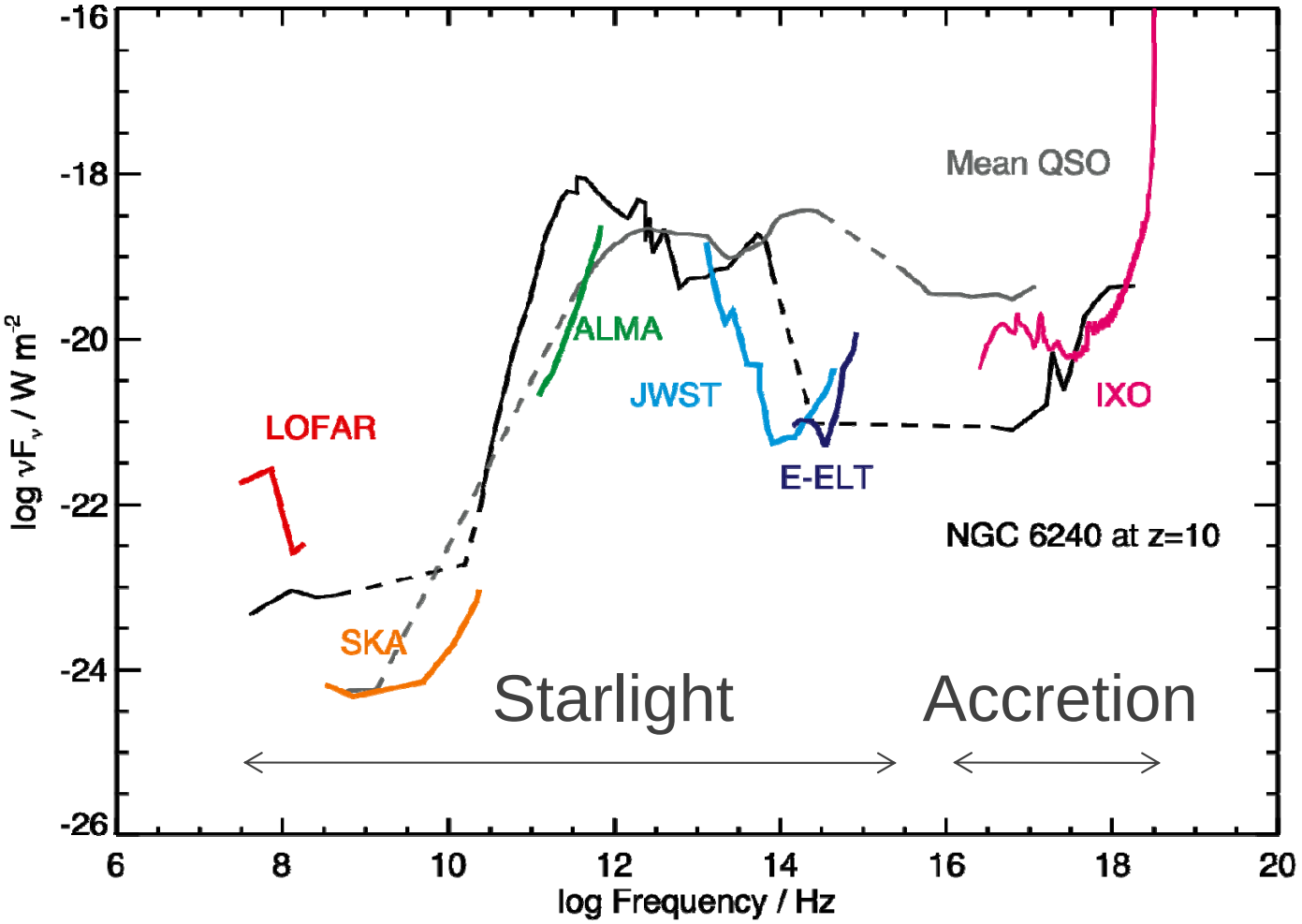


IDENTIFICATIONS



Redshifts can be determined by JWST or ELTs

MULTIWAVELENGTH FOLLOWUP



JWST, ELTs, ALMA will give host galaxy stellar ages, masses, populations etc. to constrain models of early SMBH formation

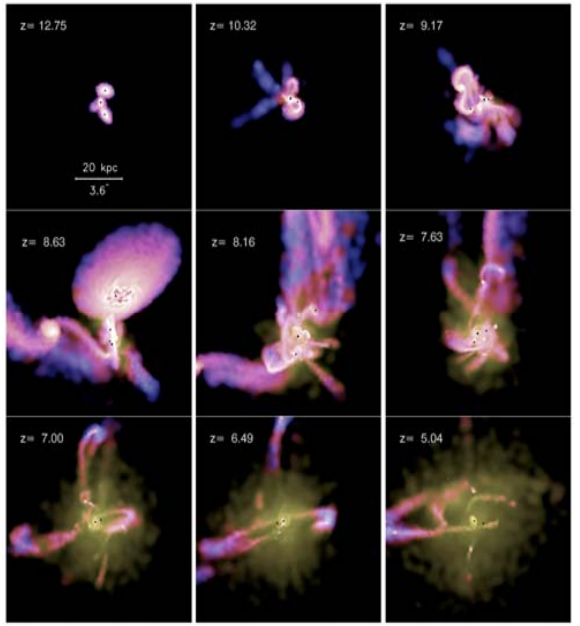
TESTING MODELS

- Do SMBH form by monolithic collapse?
  - No star formation
  - No stellar population

(e.g. Bromm & Leob 2003; Begelman et al. 2006)

- Or hierarchical merging?
  - Strong star formation
  - Significant stellar pop
  - Molecular gas
  - Dense environments

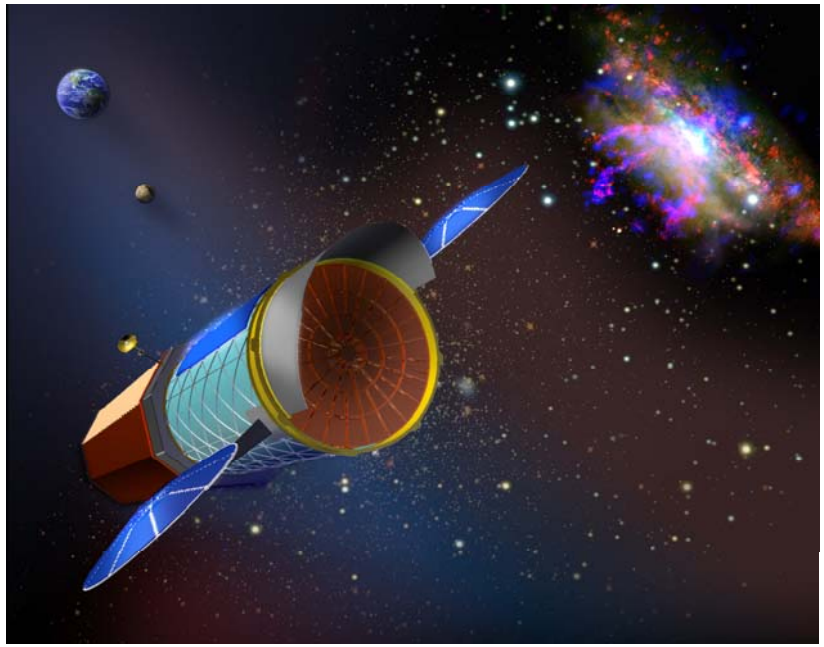
(e.g. Li et al. 2007)



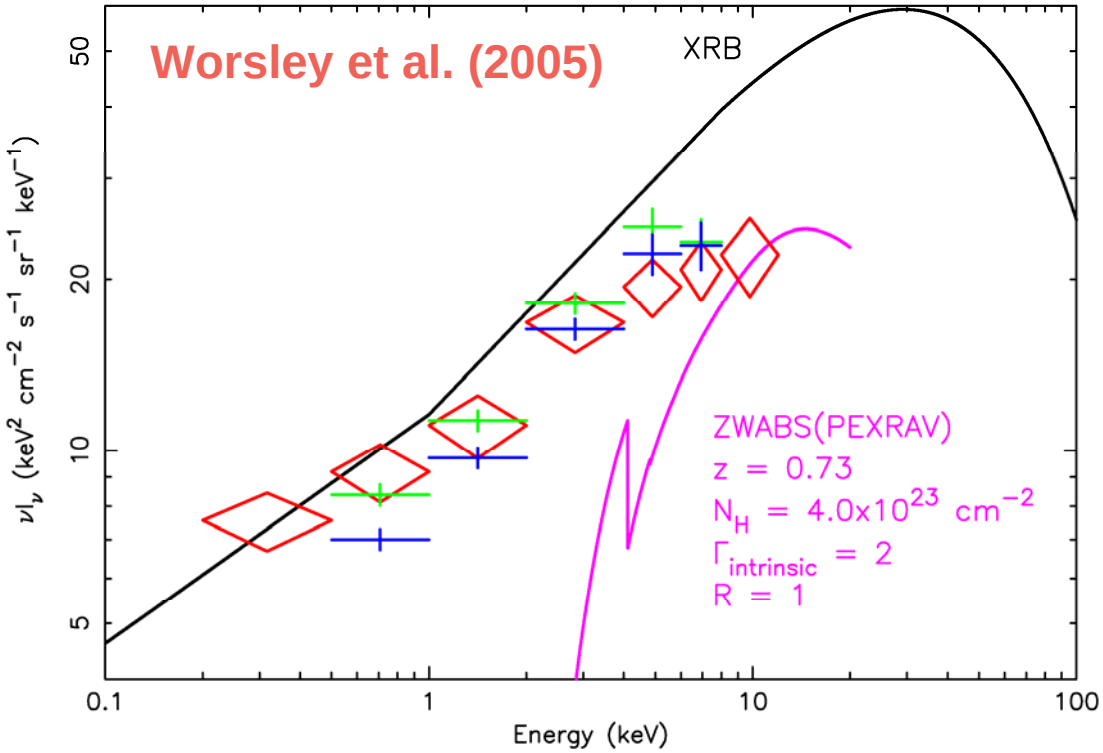
- Early Structure formation
  - Hard radiation affects cooling and physical state of IGM
  - Extended reionization

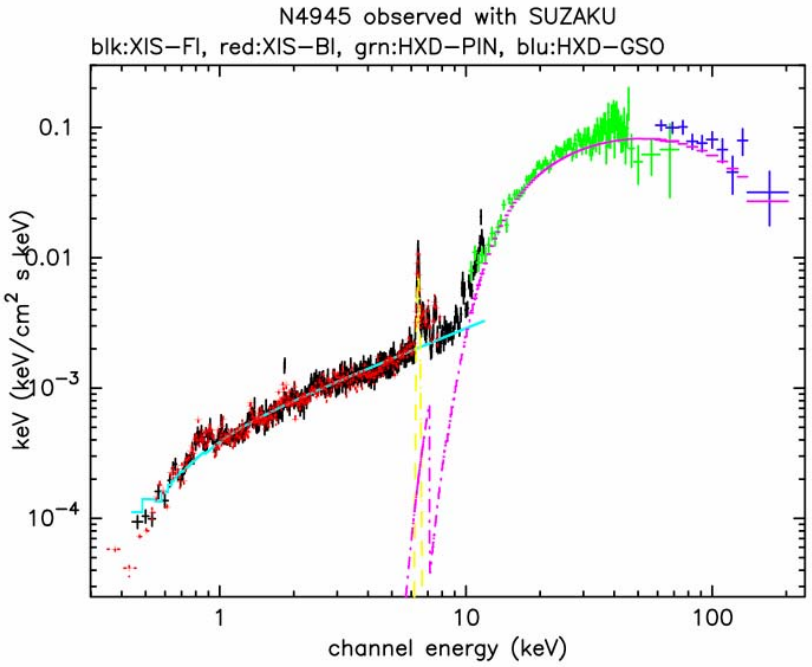
CONCLUSIONS

- IXO will Trace SMBH growth at z>6 (to z=8-10)
  - Total accretion power in early universe
  - Contribution to ionizing radiation
  - SMBH feedback in formation of first galaxies



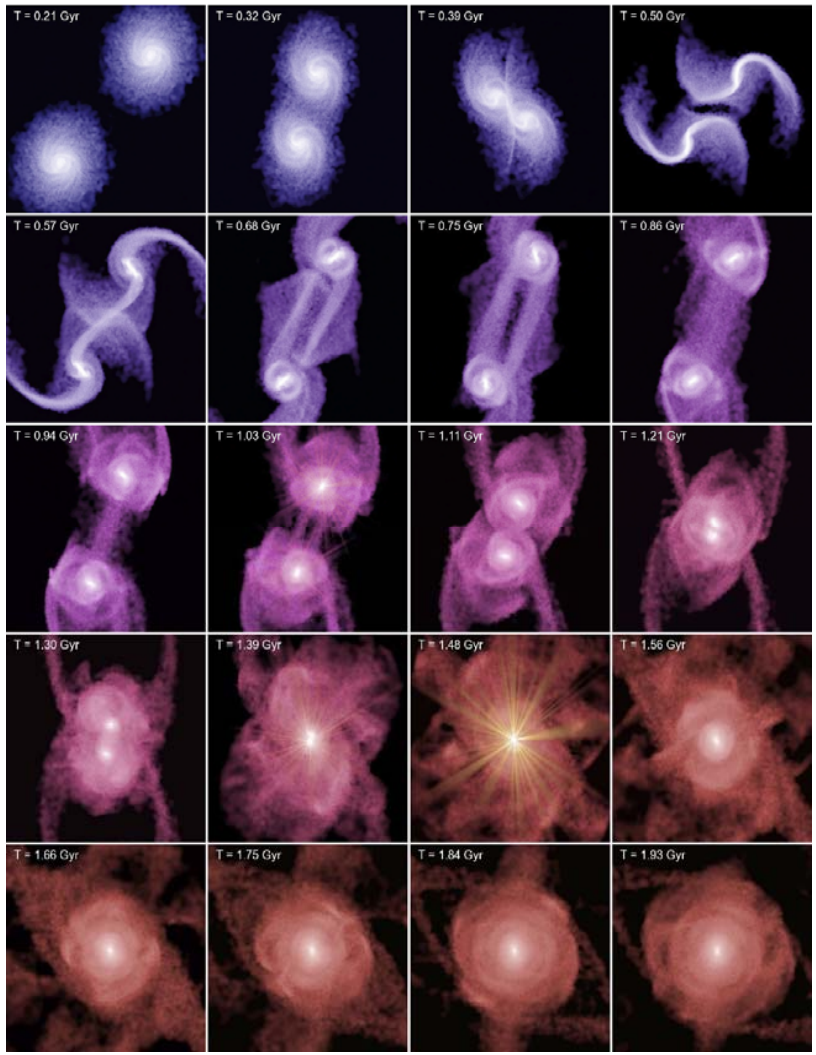
COMPLETING THE CENSUS





SOME OF THE X-RAY BACKGROUND IS MISSING
30 keV PEAK PROBABLY "COMPTON THICK" AGN

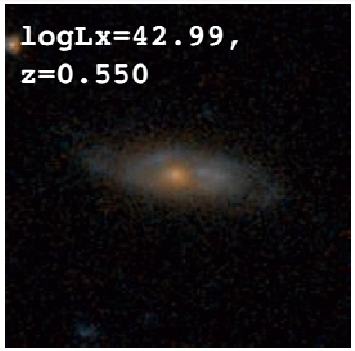
MERGER-DRIVEN FEEDBACK

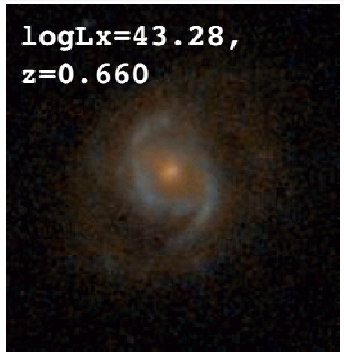


- Gas rich major merger
- Inflows trigger BH accretion & starbursts
- Dust/gas clouds obscure AGN
- AGN wind sweeps away gas, quenching SF and BH accretion.

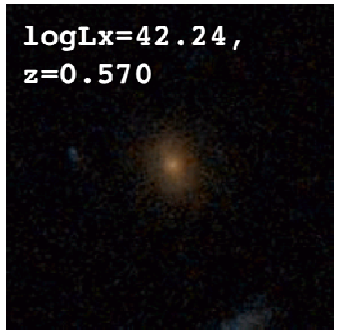
Hernquist (1989)
Springel et al. (2005)
Hopkins et al. (2006)

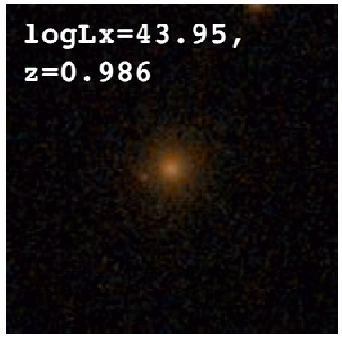
AEGIS: AGN HOST MORPHOLOGIES

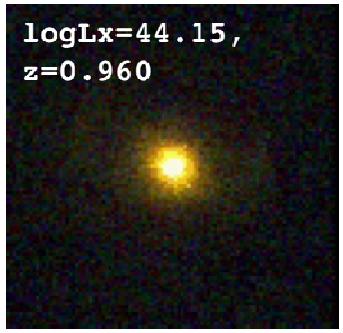




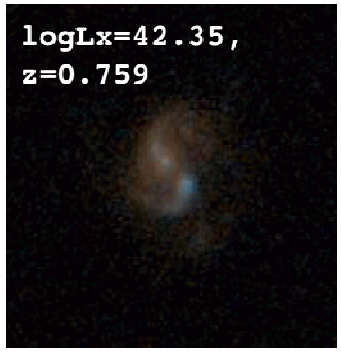
Disks/spirals

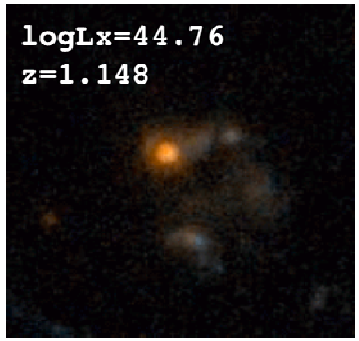






Bulges

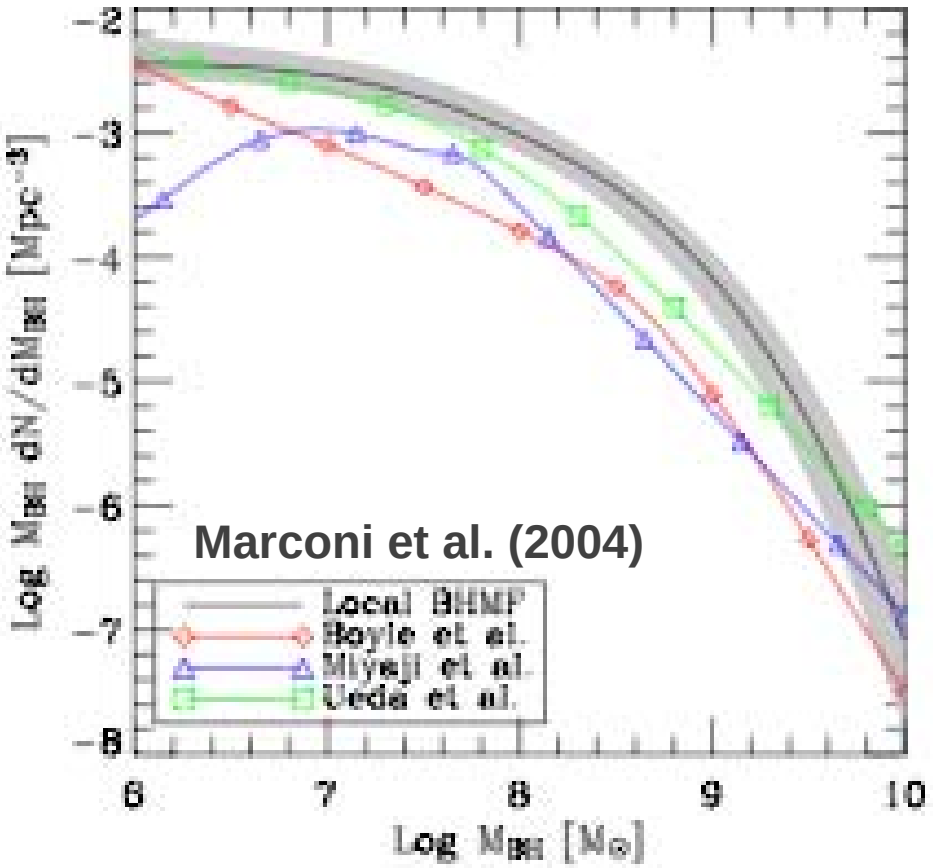




Peculiar/interacting

Georgakakis et al., MNRAS, in press

ACCRETION HISTORY: INTEGRAL LIMITS



Integral HXLF:

$$\rho_{BH} = 2.2 \pm 0.3 \times 10^5 \mathrm{M}_{\mathrm{sun}}\ \mathrm{Mpc}^{-1}$$

(Aird et al. 2009)

Local BH mass function

$$\rho_{BH} = 2.5 \pm 0.4 \times 10^5 \mathrm{M}_{\mathrm{sun}}\ \mathrm{Mpc}^{-1}$$

Yu & Tremaine (2002)

$$\rho_{BH} = 4.6^{+1.9}_{-1.4} \mathrm{M}_{\mathrm{sun}}\ \mathrm{Mpc}^{-1}$$

Marconi et al. (2004)

There may be a contribution from Compton thick AGN
(e.g. Worsley et al. 2005; Gilli et al. 2007; Daddi et al. 2007)

COMPTON THICK AGN POPULATION?

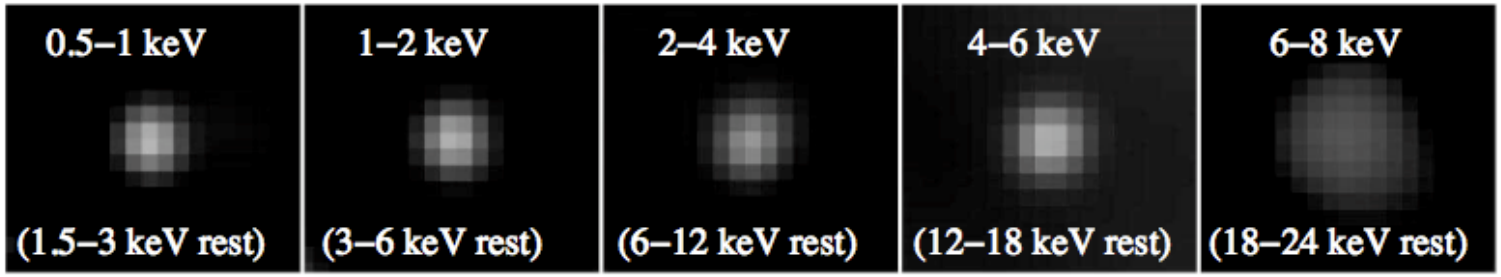
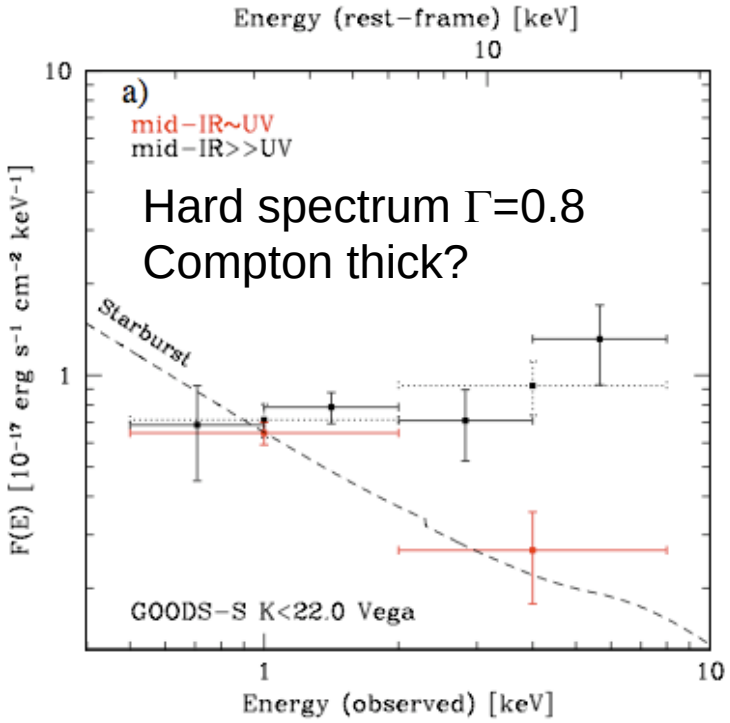
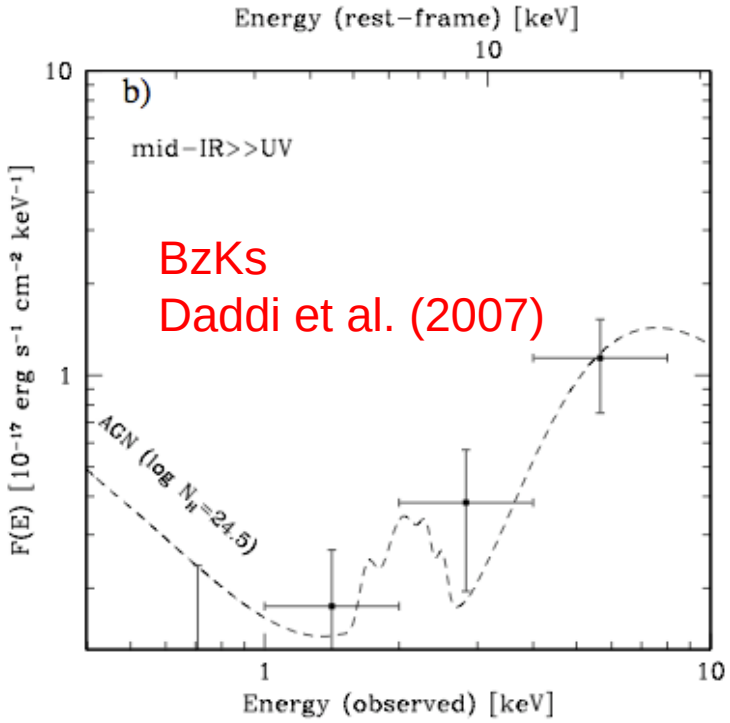
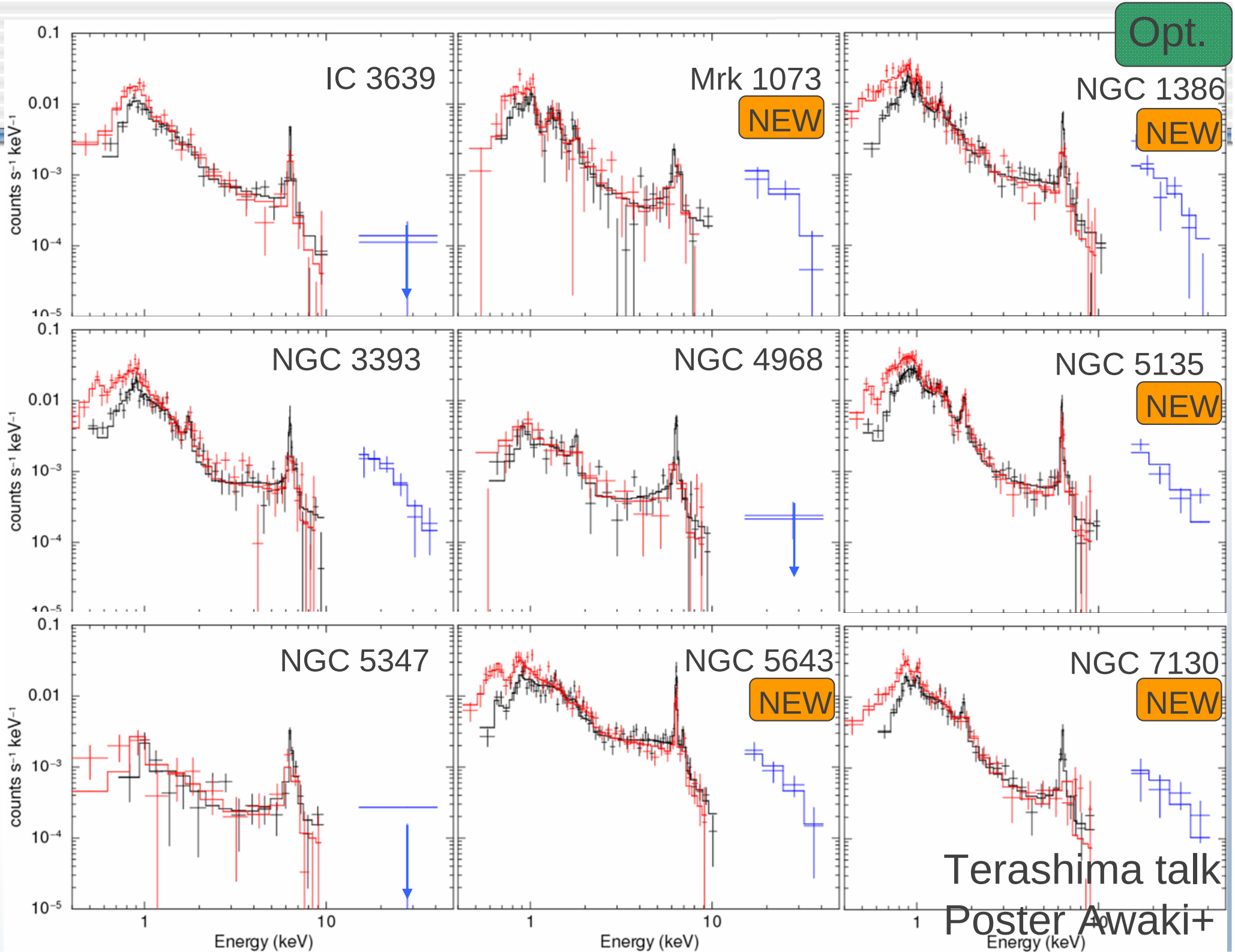


FIG. 8.— *Chandra* sub-band stacking detections of mid-IR excess $z \sim 2$ galaxies. The images have been smoothed with the PSF of the band, to enhance the signal visibility. Each panel size is 12″.



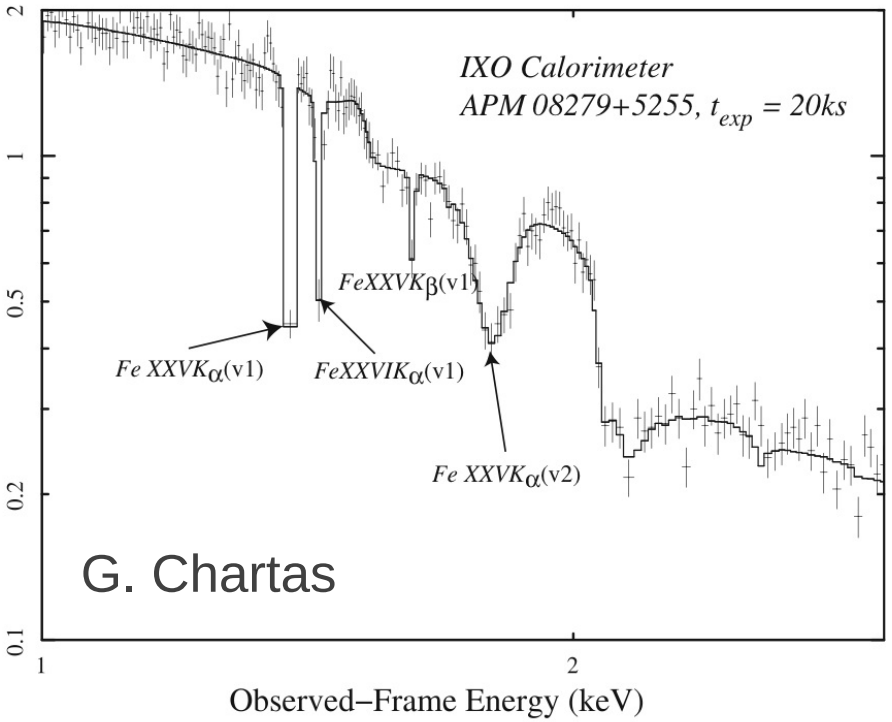


also Fiore et al. (2008); Georgantopoulos et al. (2008)
BUT see Donley et el. 2008; Georgakakis et al. 2008, 2009

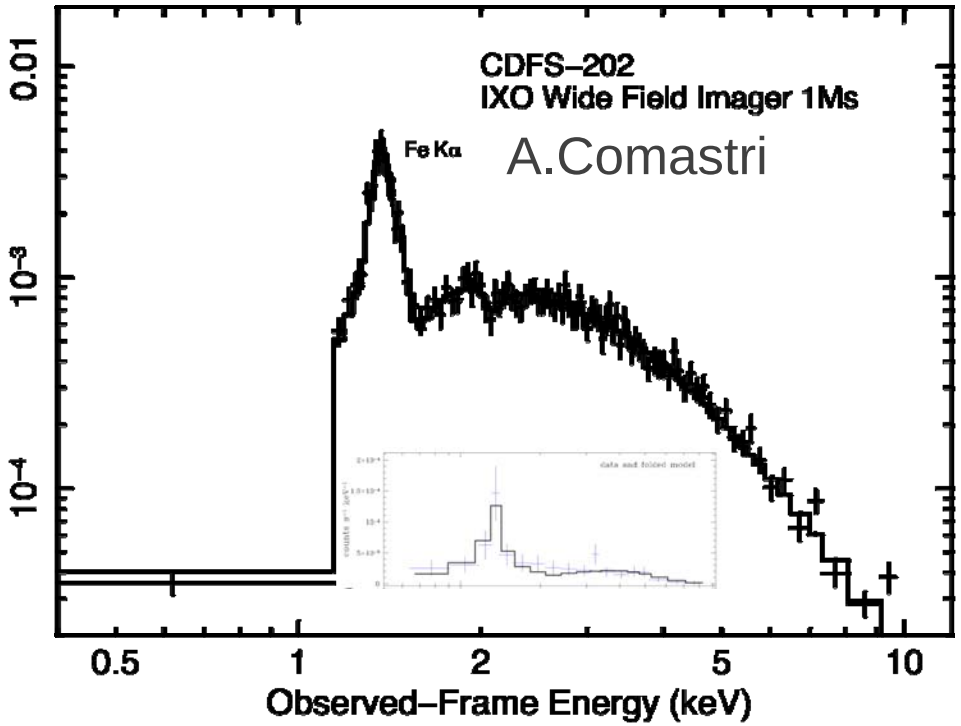

Opt.
IC 3639
Mrk 1073
NEW
NGC 1386
NEW
NGC 3393
NGC 4968
NGC 5135
NEW
NGC 5347
NGC 5643
NEW
NGC 7130
NEW
counts s⁻¹ keV⁻¹
Energy (keV)
Terashima talk
Poster Awaki+

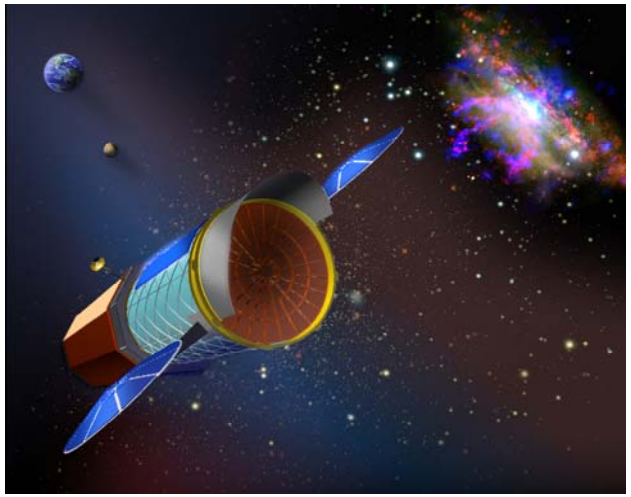
IXO SIMULATIONS

Feedback in Action?



Buried AGN revealed



CONCLUSIONS

- Trace SMBH growth at z>6 (to z=8-10)
  - Total accretion power in early universe
  - Contribution to ionizing radiation
  - SMBH feedback in formation of first galaxies
- Provide complete census at z<3
  - Major epoch of galaxy growth
  - Compton thick objects
  - SMBH regulation of star formation
  - AGN/Galaxy Co-evolution