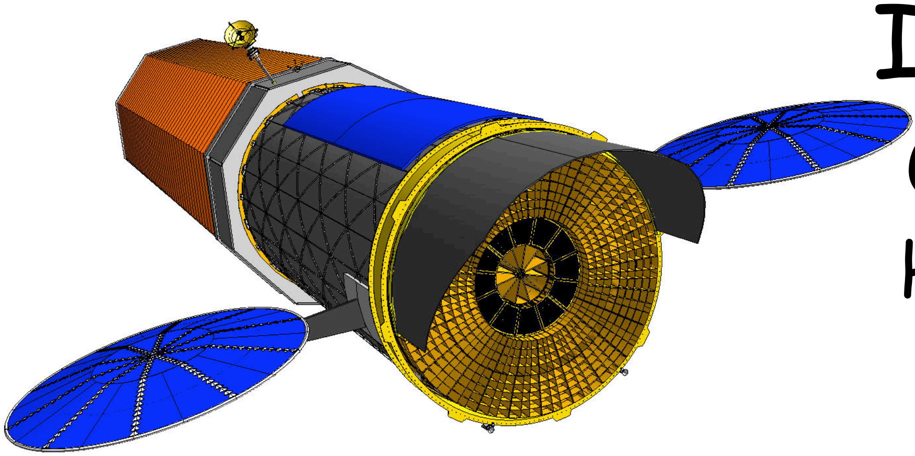


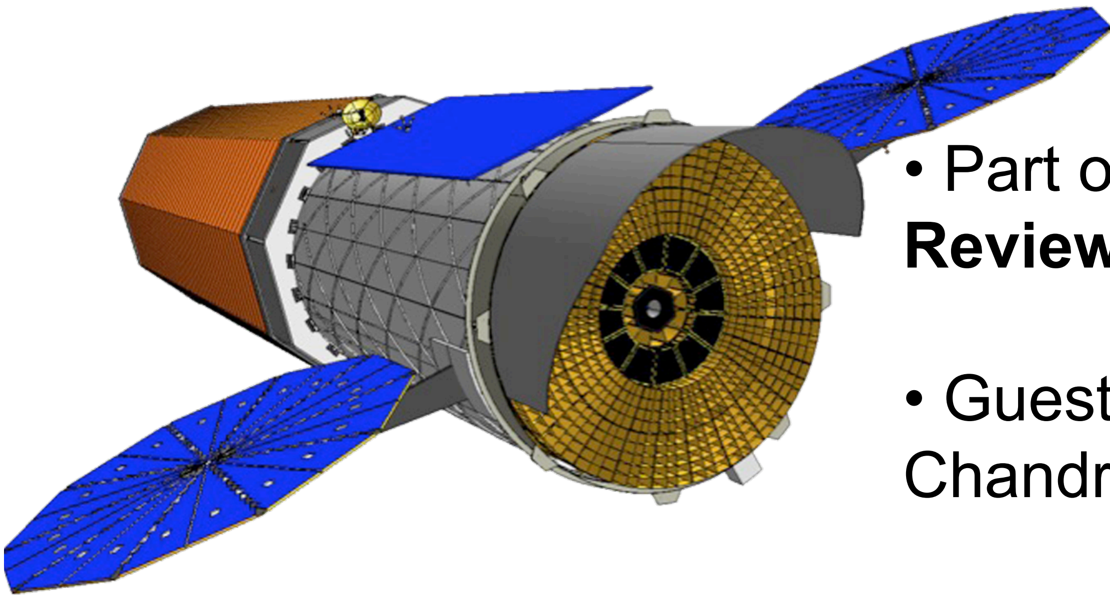
International X-RAY Observatory (IXO)

High-z obscured accretion

Andrea Comastri (INAF-OA-Bologna)

Piero Ranalli (Bologna University-INAF), Roberto Gilli (INAF-OABO), Cristian Vignali (Bologna University-INAF), Kazushi Iwasawa (INAF-OABO), Elisabeta Lusso (Bologna University-INAF), Marcella Brusa (MPE), Fabrizio Fiore (INAF-OAR), ...

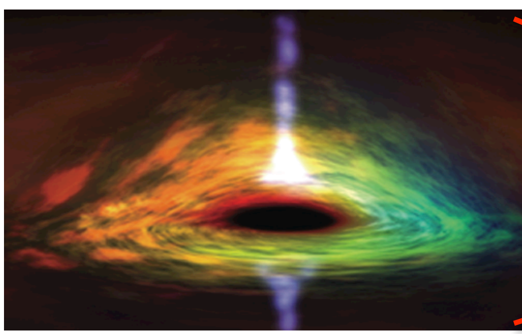
Basic Facts about IXO



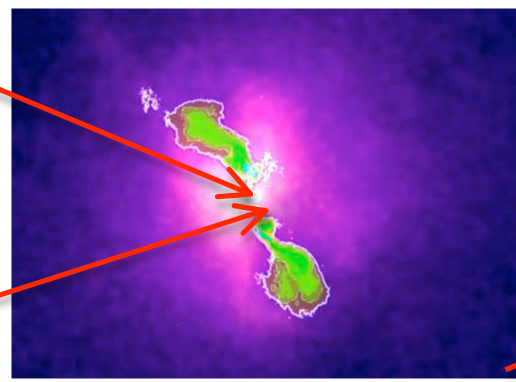
- Merger of ESA/JAXA XEUS and NASA's Constellation-X missions
- Part of US Astro2010 **Decadal Review** and ESA **Cosmic Visions**
- Guest Observatory, like Hubble, Chandra, Spitzer, Suzaku, Astro-H
- Launch: No Earlier Than ~2021

The International X-Ray Observatory (IXO) will address fundamental and timely questions in astrophysics:

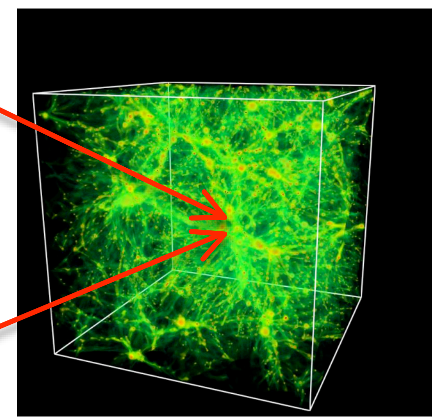
- What happens close to a black hole?
- When and how did super-massive black holes grow?
- How does large scale structure evolve?
- What is the connection between these processes?



Black Hole Accretion



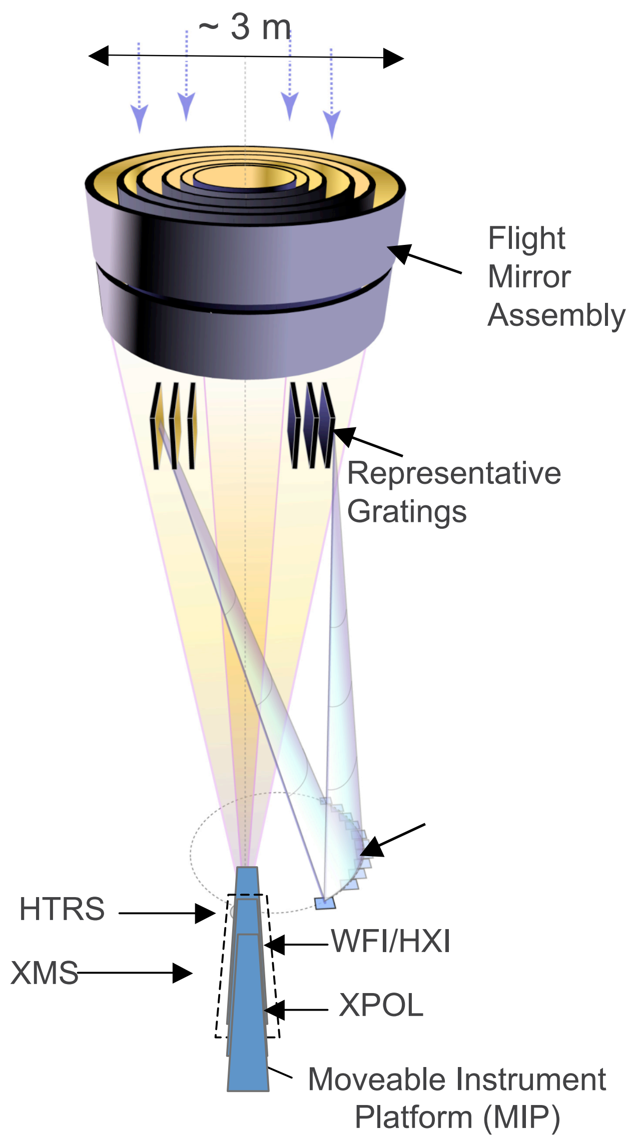
Hydra A Galaxy Cluster



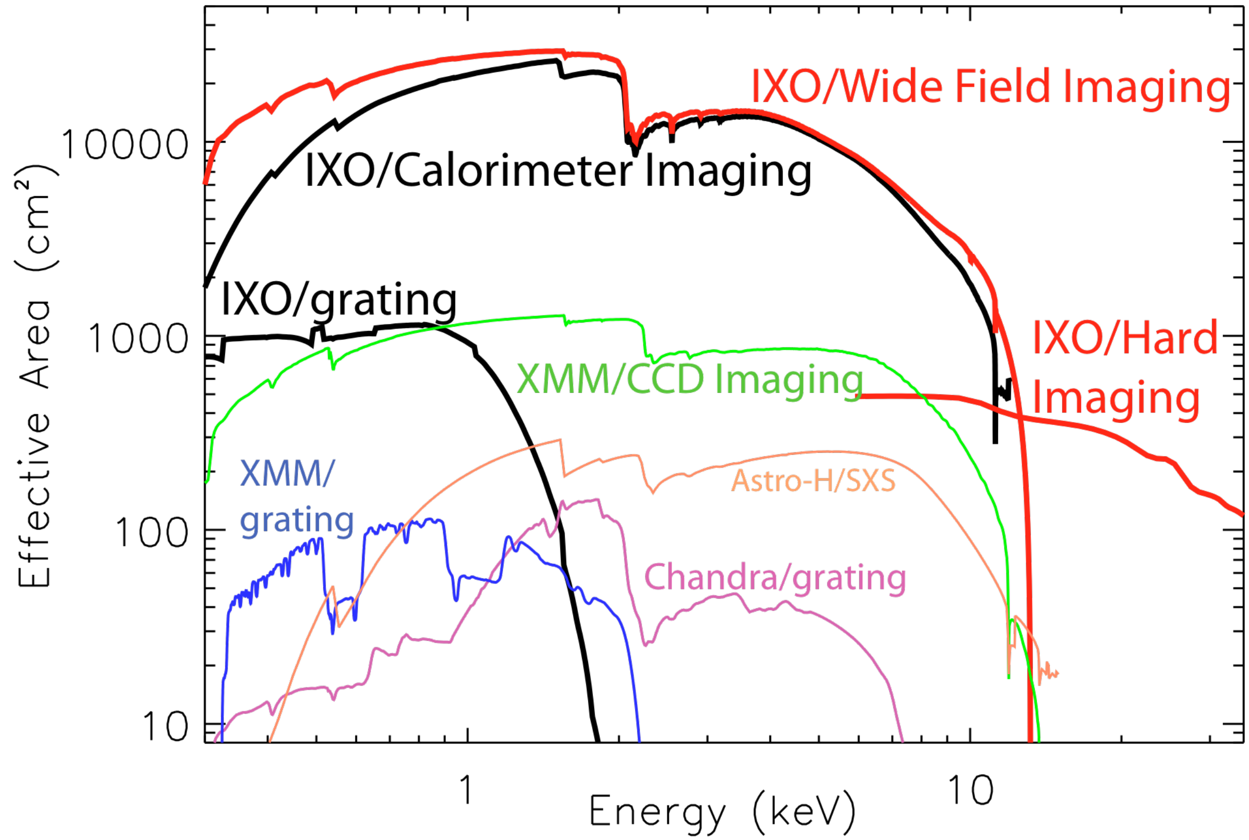
Cosmic Web

IXO Payload

- Flight Mirror Assembly (FMA)
  - Highly nested grazing incidence optics
  - 3 sq m @ 1.25 keV with a 5'' PSF
- Instruments
  - X-ray Micro-calorimeter Spectrometer (XMS)
    - 2.5 eV with 5 arc min FOV
  - X-ray Grating Spectrometer (XGS)
    - R = 3000 with 1,000 sq cm
  - Wide Field Imager (WFI) and Hard X-ray Imager (HXI)
    - 18 arc min FOV with CCD-like resolution
    - 0.3 to 40 keV
  - X-ray Polarimeter (X-POL)
  - High Time Resolution Spectrometer (HTRS)



IXO is a Vast Improvement over Existing Missions

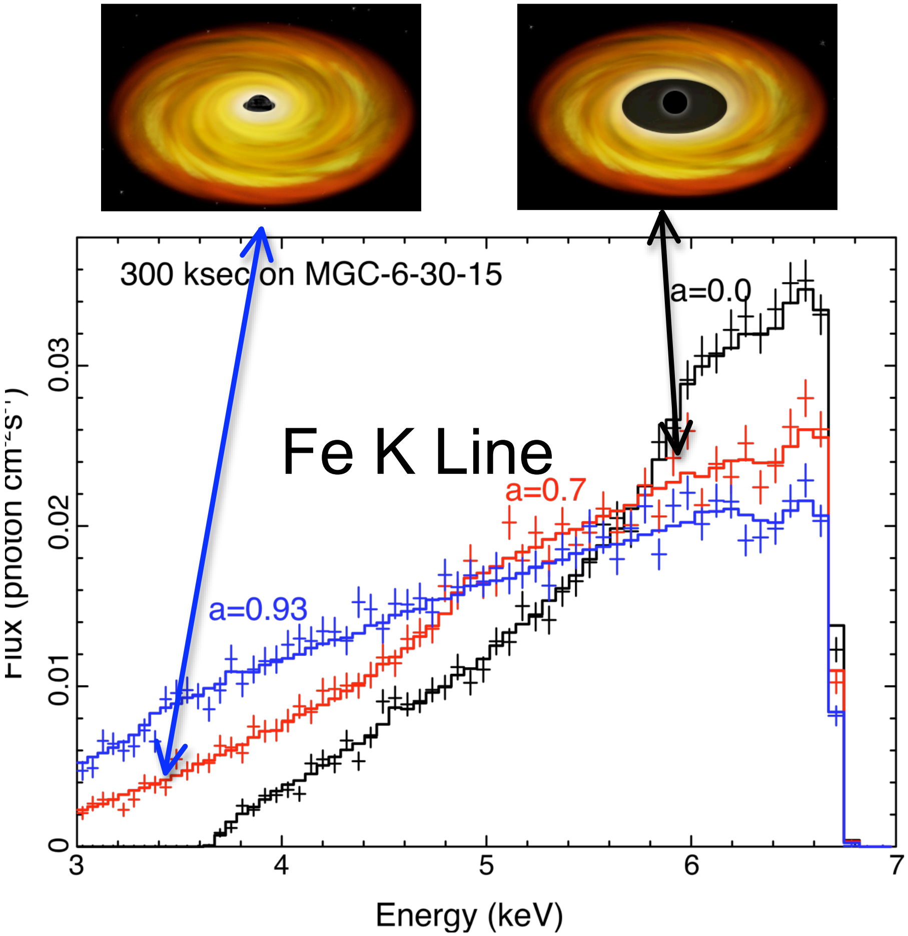


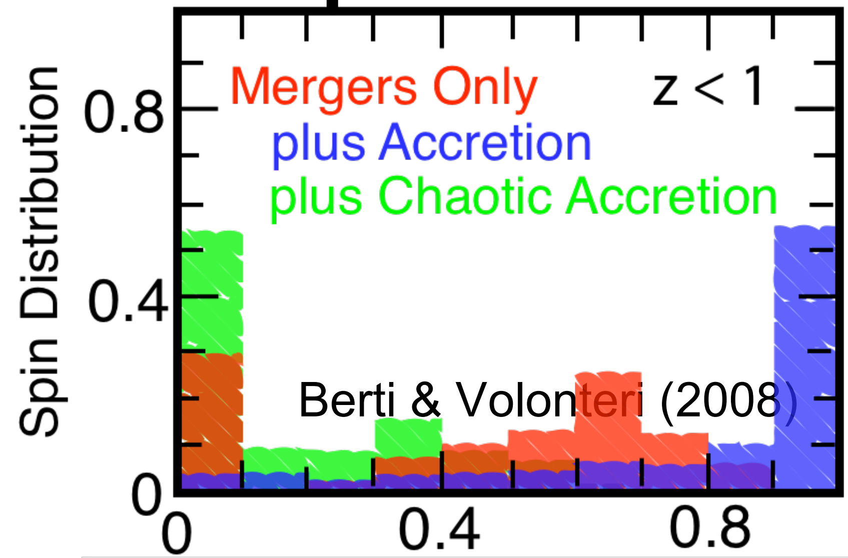
Effective area a factor of >10x of current missions
Spectroscopy capabilities >100x of current missions

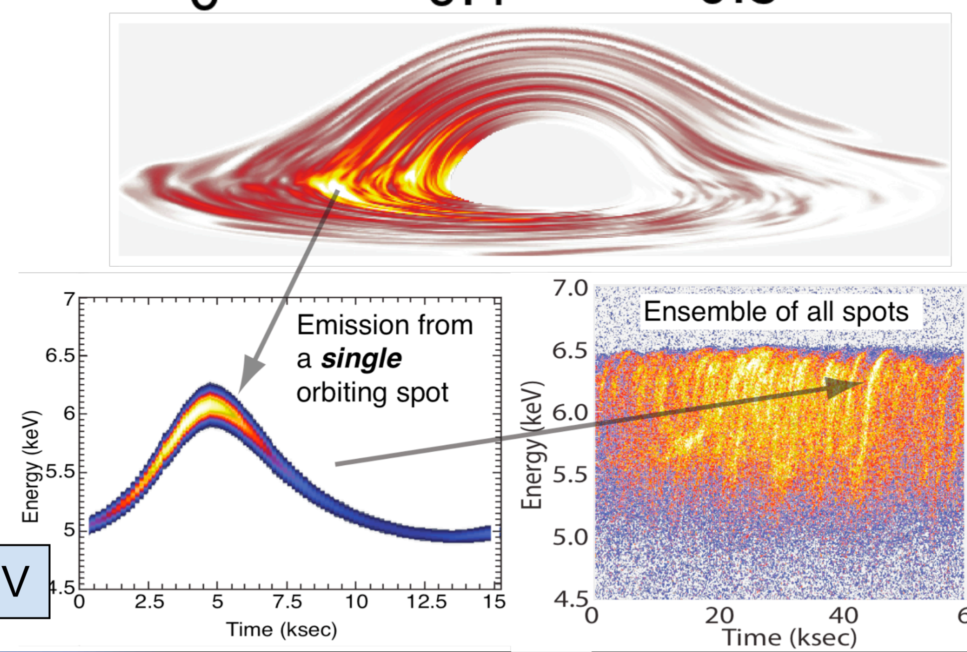
Key Performance Requirements

Mirror Effective Area	3 m^2 @1.25 keV 0.65 m^2 @ 6 keV with a goal of 1 m^2 150 cm^2 @ 30 keV with a goal of 350 cm^2	Black hole evolution, large scale structure, cosmic feedback, EOS Strong gravity, EOS Cosmic acceleration, strong gravity
Spectral Resolution	ΔE = 2.5 eV within 2 x 2 arc min (0.3 – 7 keV) . ΔE = 10 eV within 5 x 5 arc min (0.3 - 7 keV) ΔE < 150 eV @ 6 keV within 18 arc min diameter (0.1 - 15 keV) E/ΔE = 3000 from 0.3–1 keV with an area of 1,000 cm^2 with a goal of 3,000 cm^2 for point sources ΔE = 1 keV within 8 x 8 arc min (10 – 40 keV)	Black Hole evolution, Large scale structure Missing baryons using tens of background AGN
Mirror Angular Resolution	≤5 arc sec HPD (0.1 – 7 keV) ≤30 arc sec HPD (7 - 40 keV) with a goal of 5 arc sec	Large scale structure, cosmic feedback, black hole evolution, missing baryons Black hole evolution
Count Rate	1 Crab with >90% throughput. ΔE < 200 eV (0.1 – 15 keV)	Strong gravity, EOS
Polarimetry	1% MDP (3 sigma) on 1 mCrab in 100 ksec (2 - 6 keV)	AGN geometry, strong gravity
Astrometry	1 arcsec at 3σ confidence	Black hole evolution
Absolute Timing	50 μsec	Neutron star studies

Super-massive Black Hole Spin & Growth



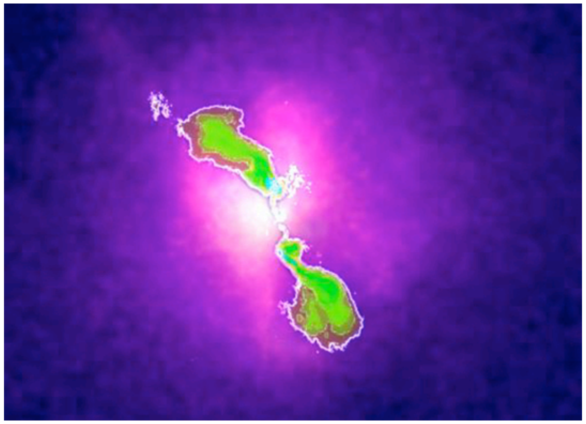




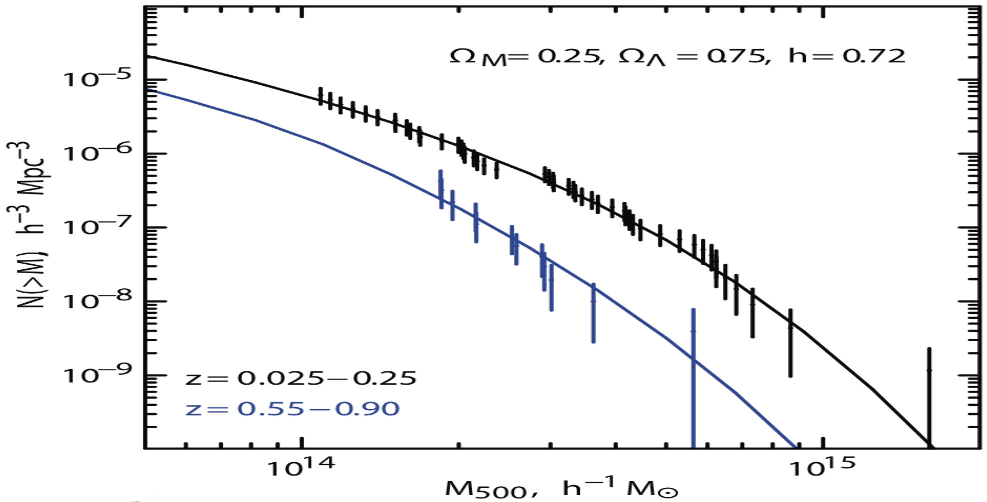
~300 AGN z < 0.2 constrain
The SMBH merger History

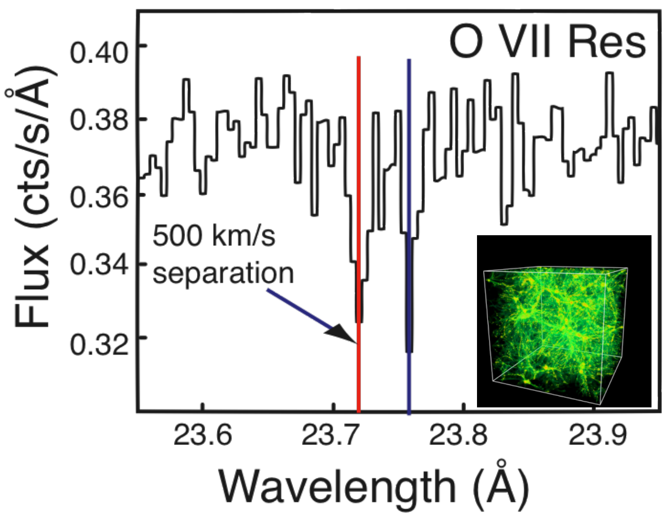
0.7sq m @ 6-7 keV

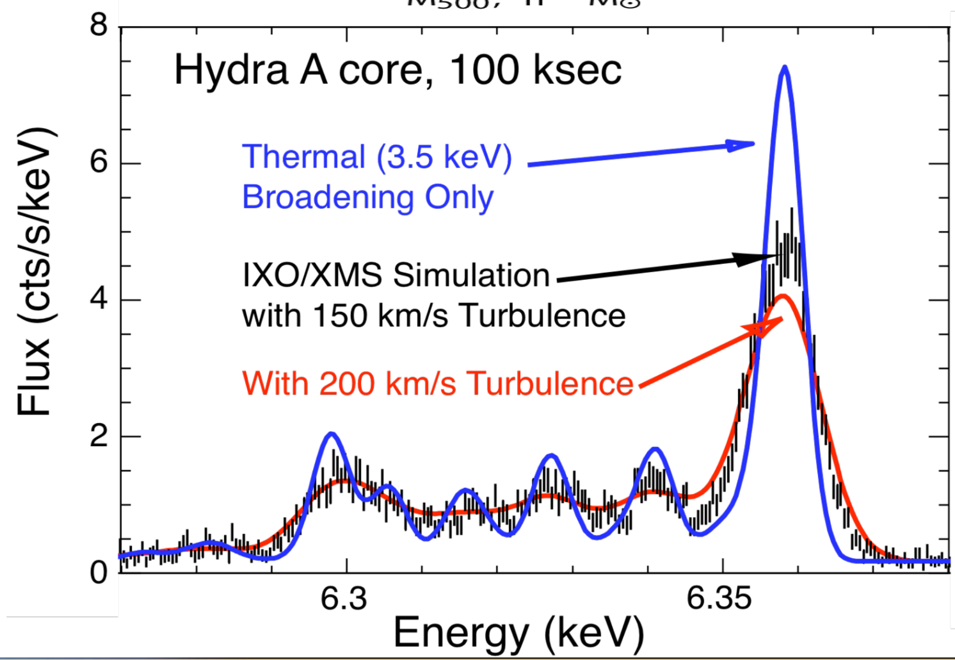
Hot and Warm Baryons Physics & Evolution



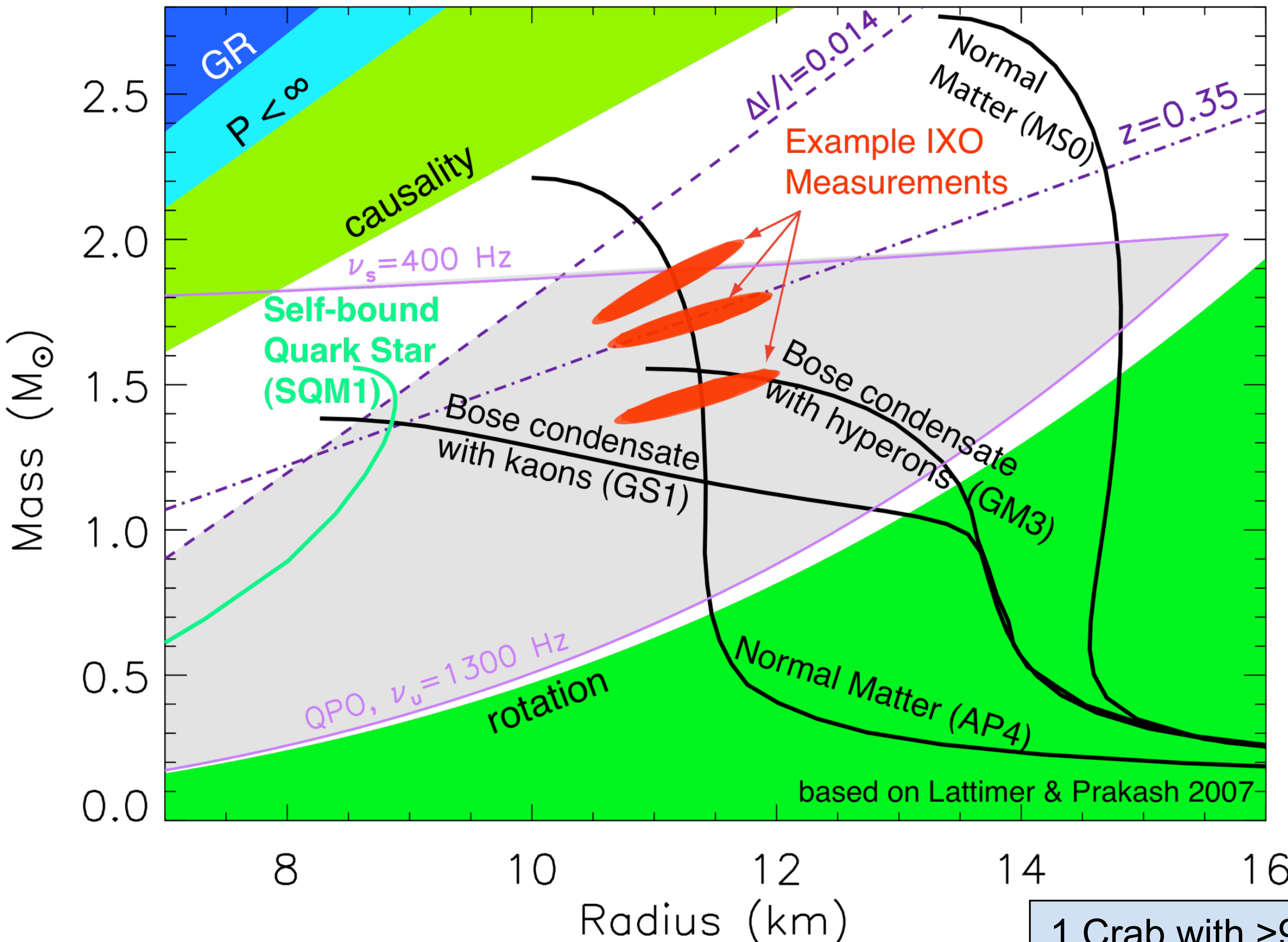
2.5 – 5 eV @ 6.4 keV
5 arc sec
5 arc min FOV





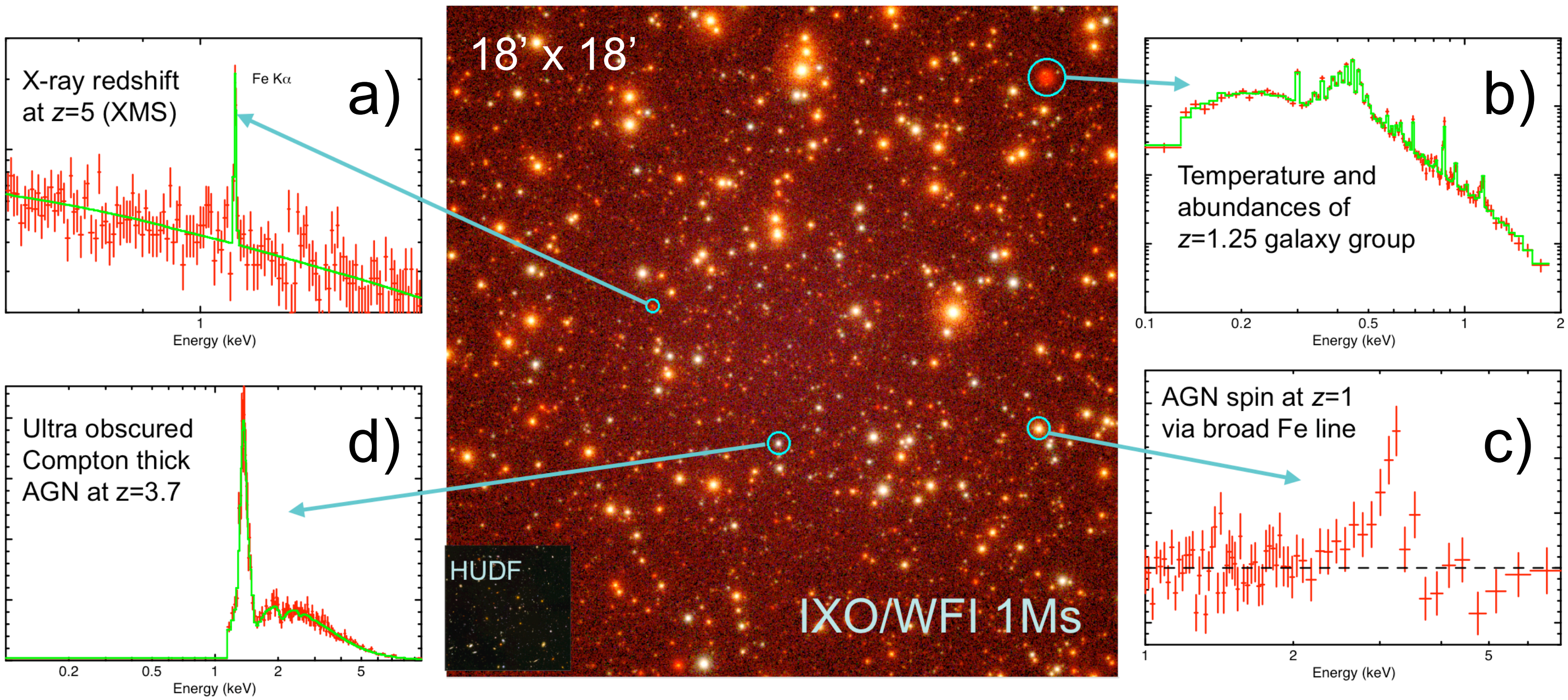


Neutron Star Equation of State



1 Crab with >90% throughput.
ΔE < 200 eV (0.1 – 15 keV)

Black Hole and Large Scale Structure Evolution with IXO

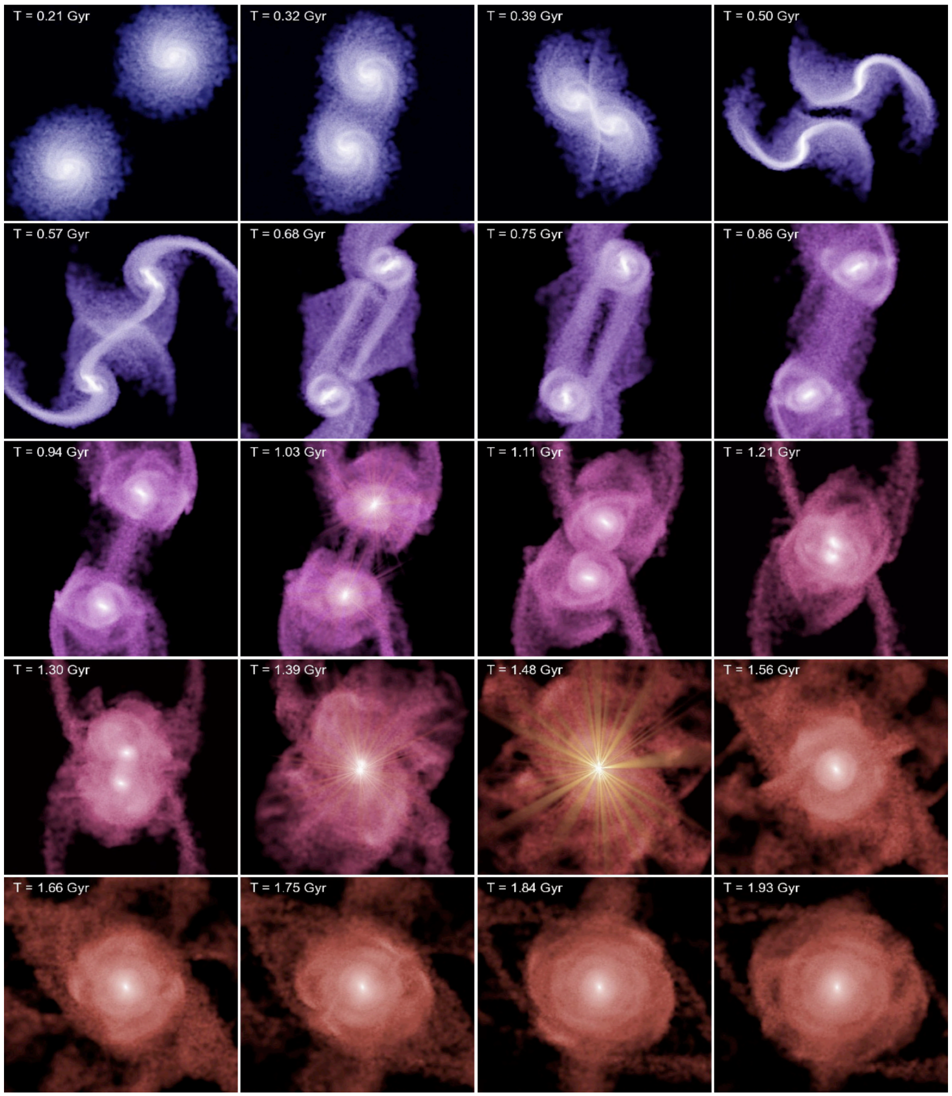


IXO will be 20 times faster than Chandra to make wide and deep surveys:

a) determine redshift autonomously in the X-ray band
b) determine temperatures and abundances even for low luminosity galaxy groups
c) make spin measurements of AGN to a similar redshift
d) uncover the most heavily obscured, Compton-thick AGN

3 sq m @ 1.25 keV
5 arc sec

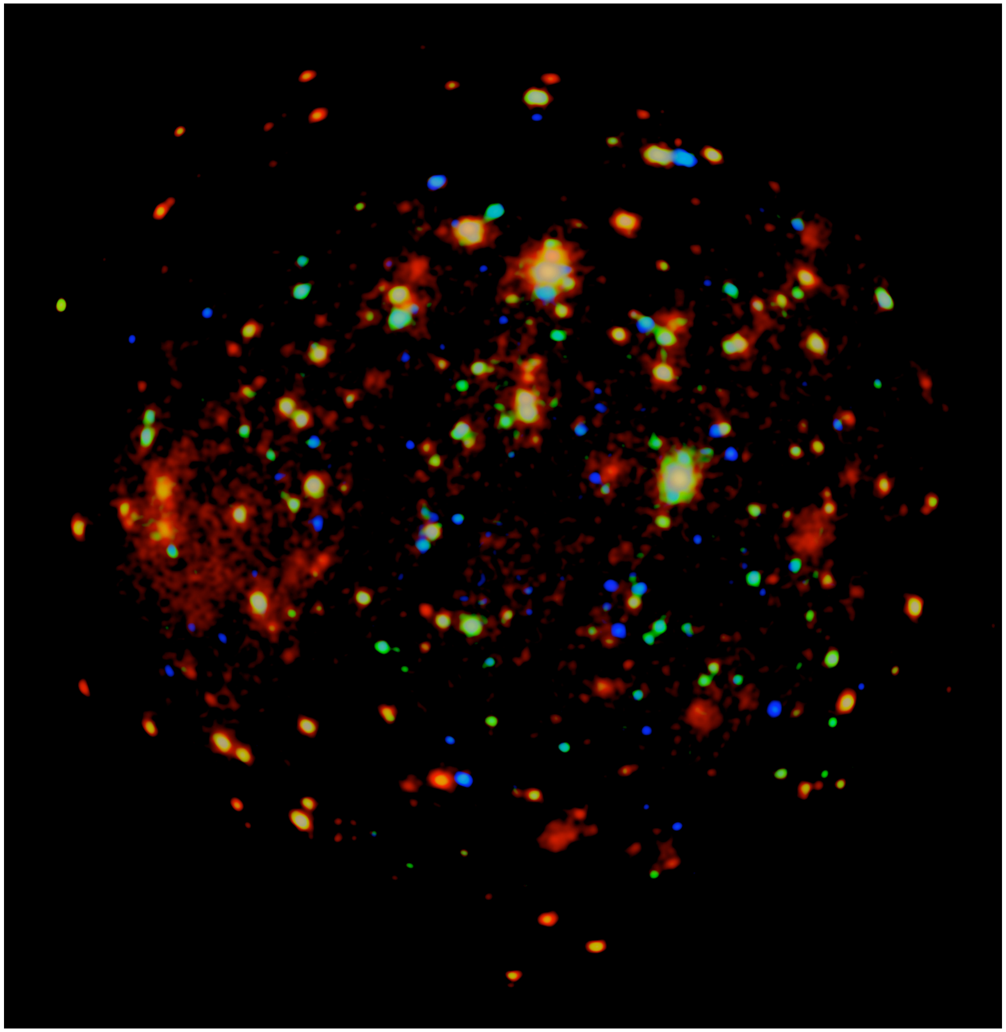
Building a ~10^9 $M_\odot$ BH at z ~ 6



- Gas rich major merger
- Inflows trigger BH accretion & starbursts
- Dust/gas clouds obscure AGN
- AGN wind sweeps away gas, quenching SF and BH accretion
- IXO well tuned to follow and confirm/constrain this process

Hernquist (1989)
Springel+(2005)
Hopkins+(2006)
Menci+(2008)
………..

Available Ultra-deep Fields



Chandra 2 Ms
(will be ~ 4 Ms
DDT time aims
at 10 ?)

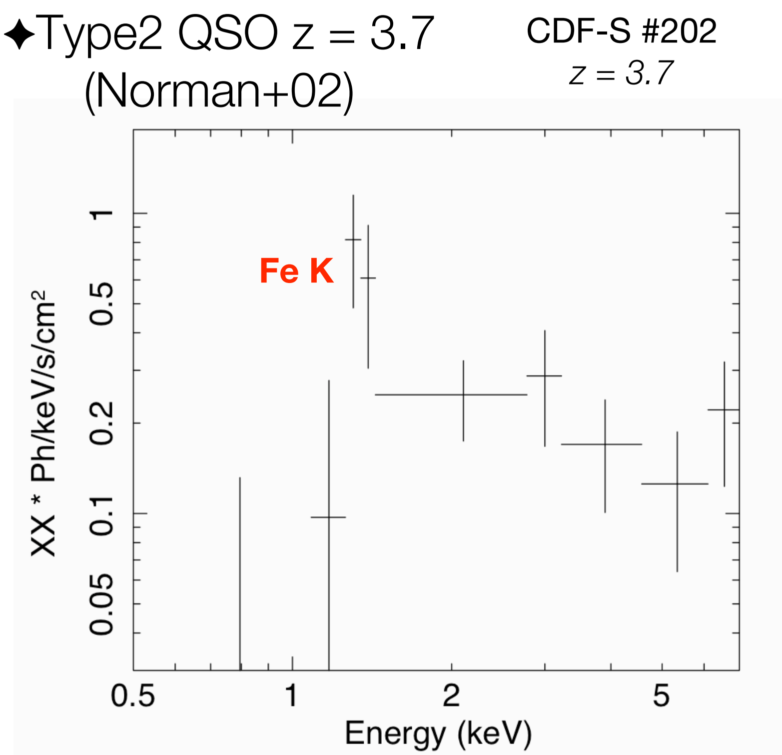
10^{-17} cgs over
50 arcmin^2

XMM ~ 1.5 Ms
(AO7+AO8 ~ 3 Ms)

Confusion limited
> 5 keV

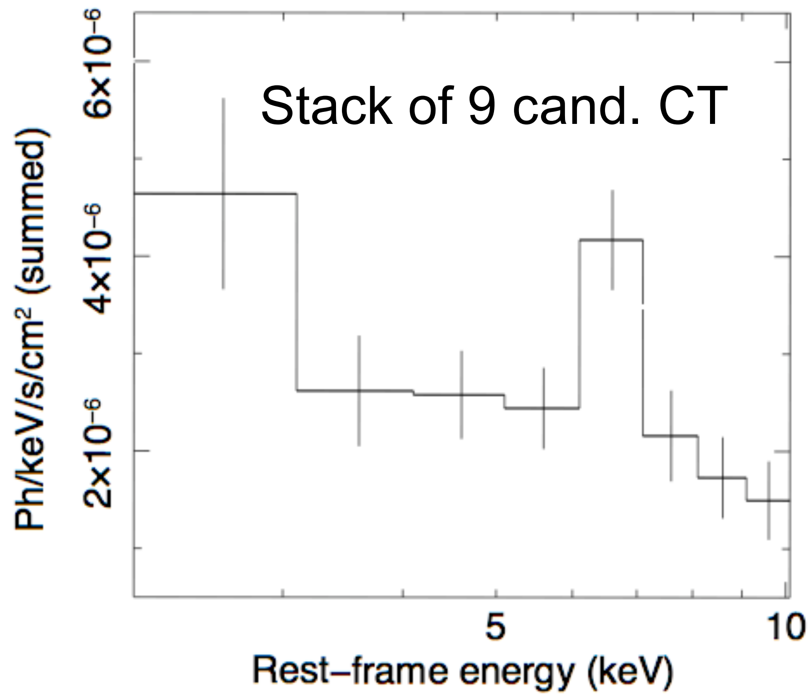
XMM observations of heavily obscured AGN in CDFS

✦Type2 QSO z = 3.7 (Norman+02)

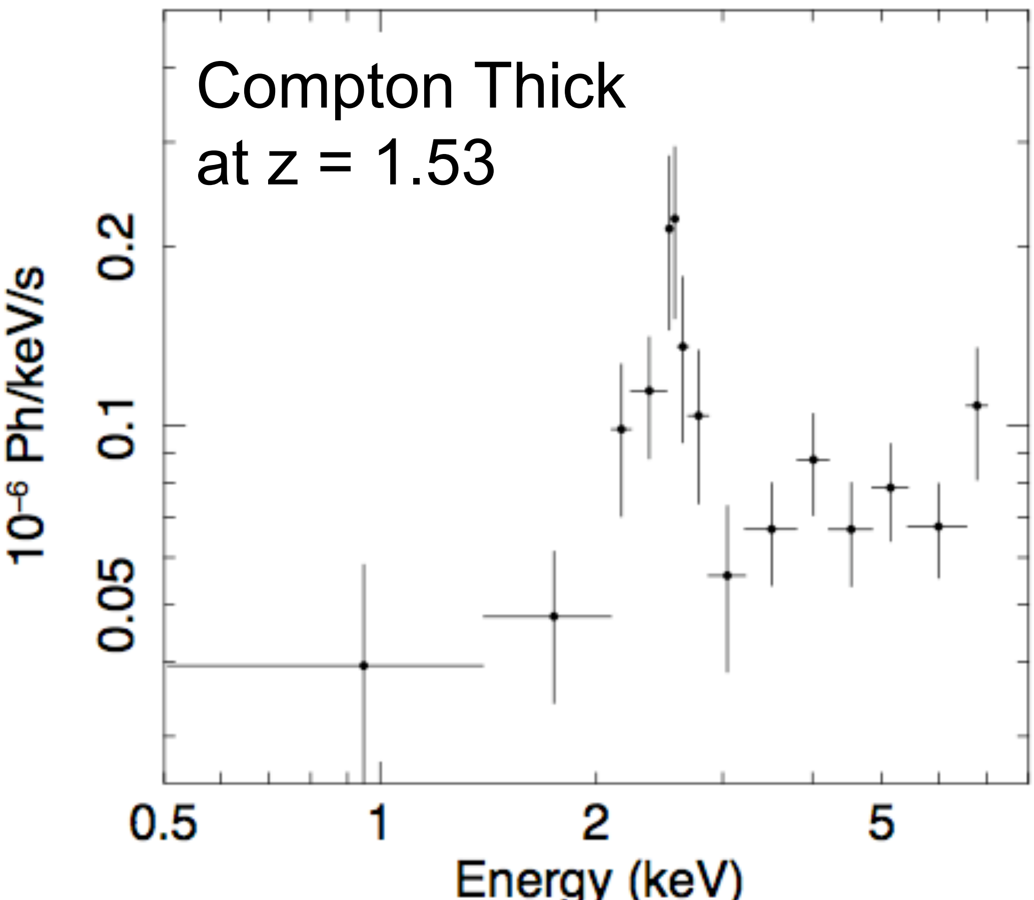


Fe K line sources

from Chandra observations (Tozzi+06)



XMM observations of heavily obscured AGN in CDFS



Fe K line sources

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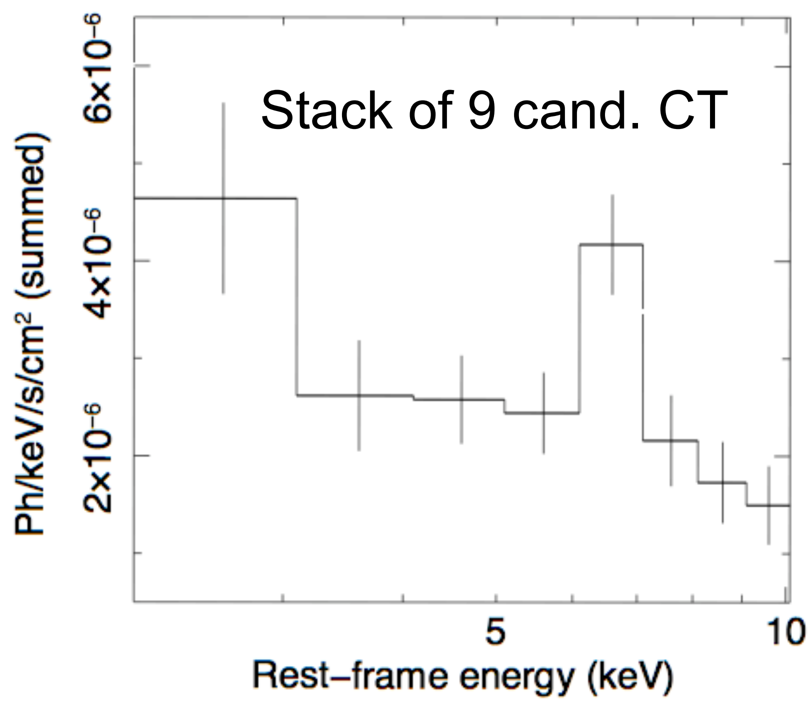
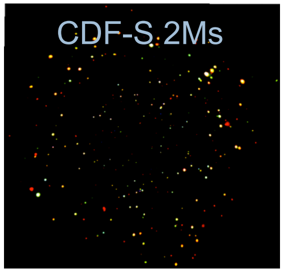
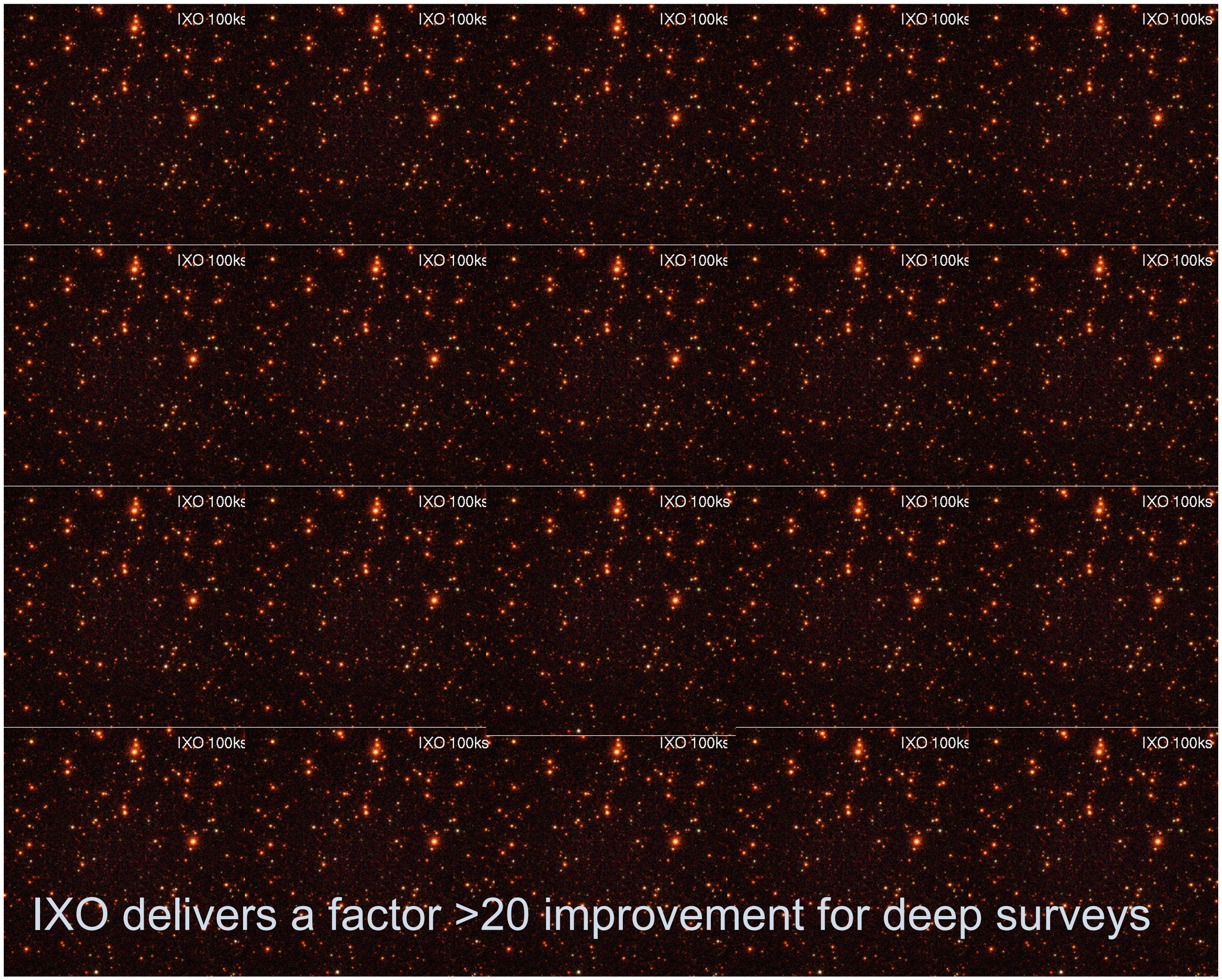


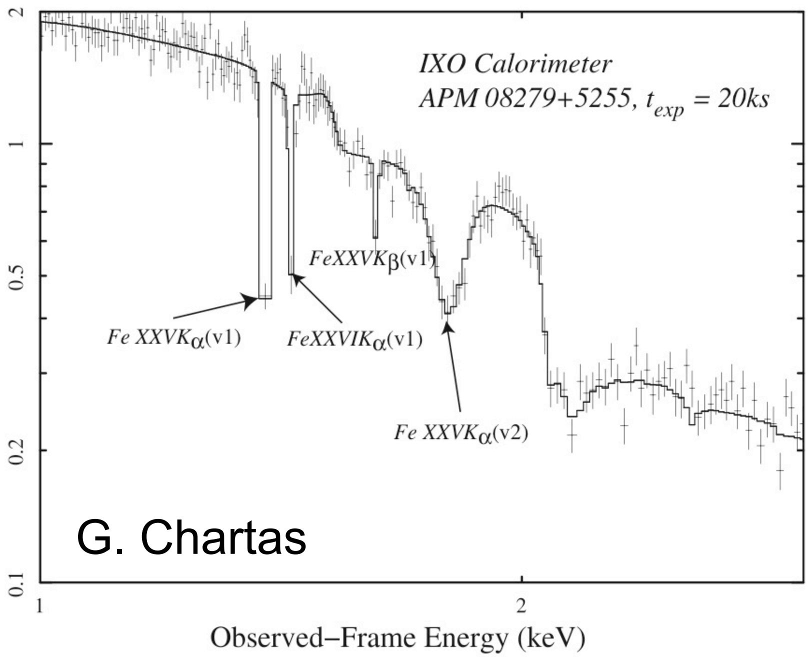
WHAT CAN IXO DO?





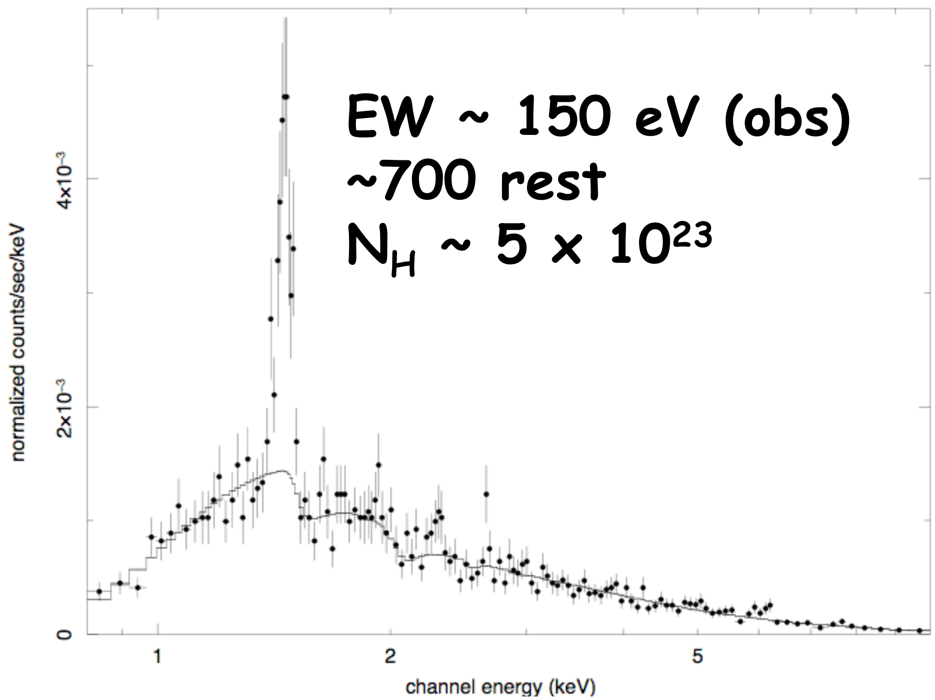
IXO SIMULATIONS

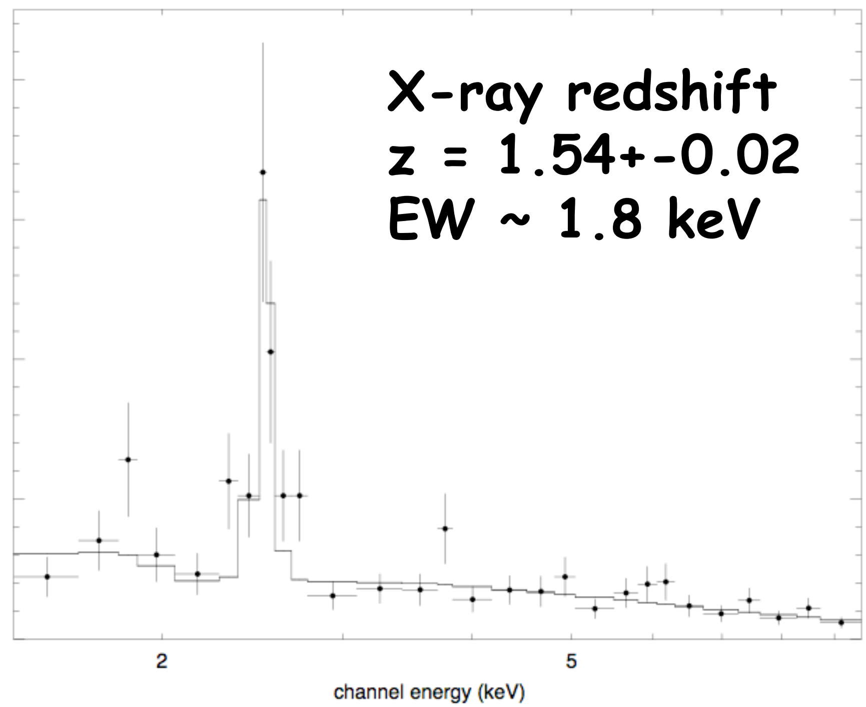
Feedback in Action?



IXO SIMULATIONS

Buried AGN revealed

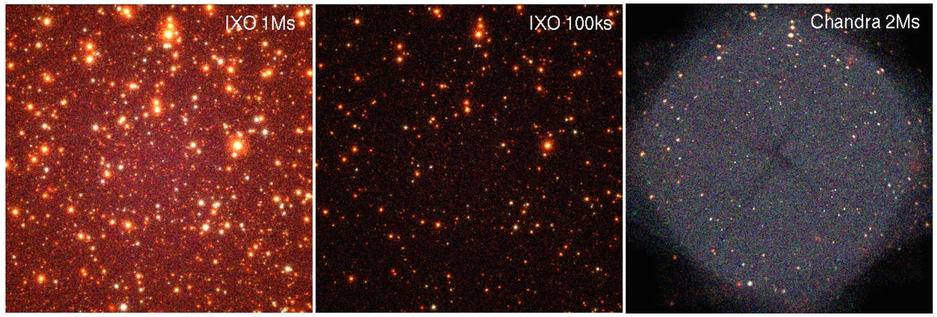


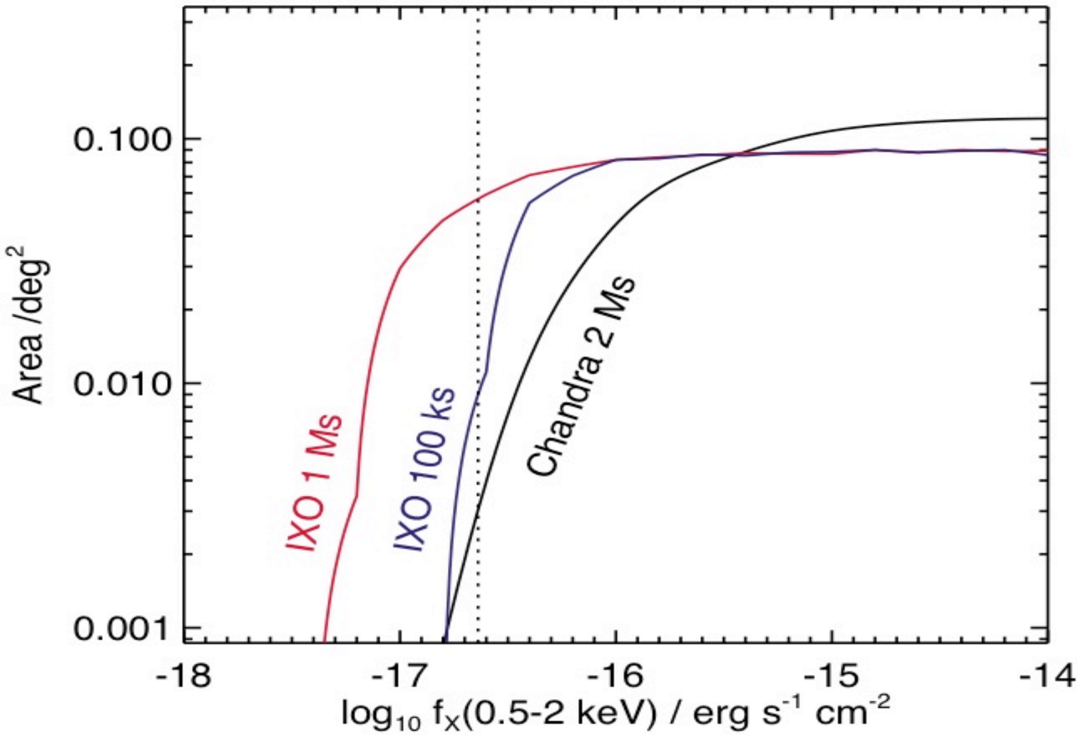


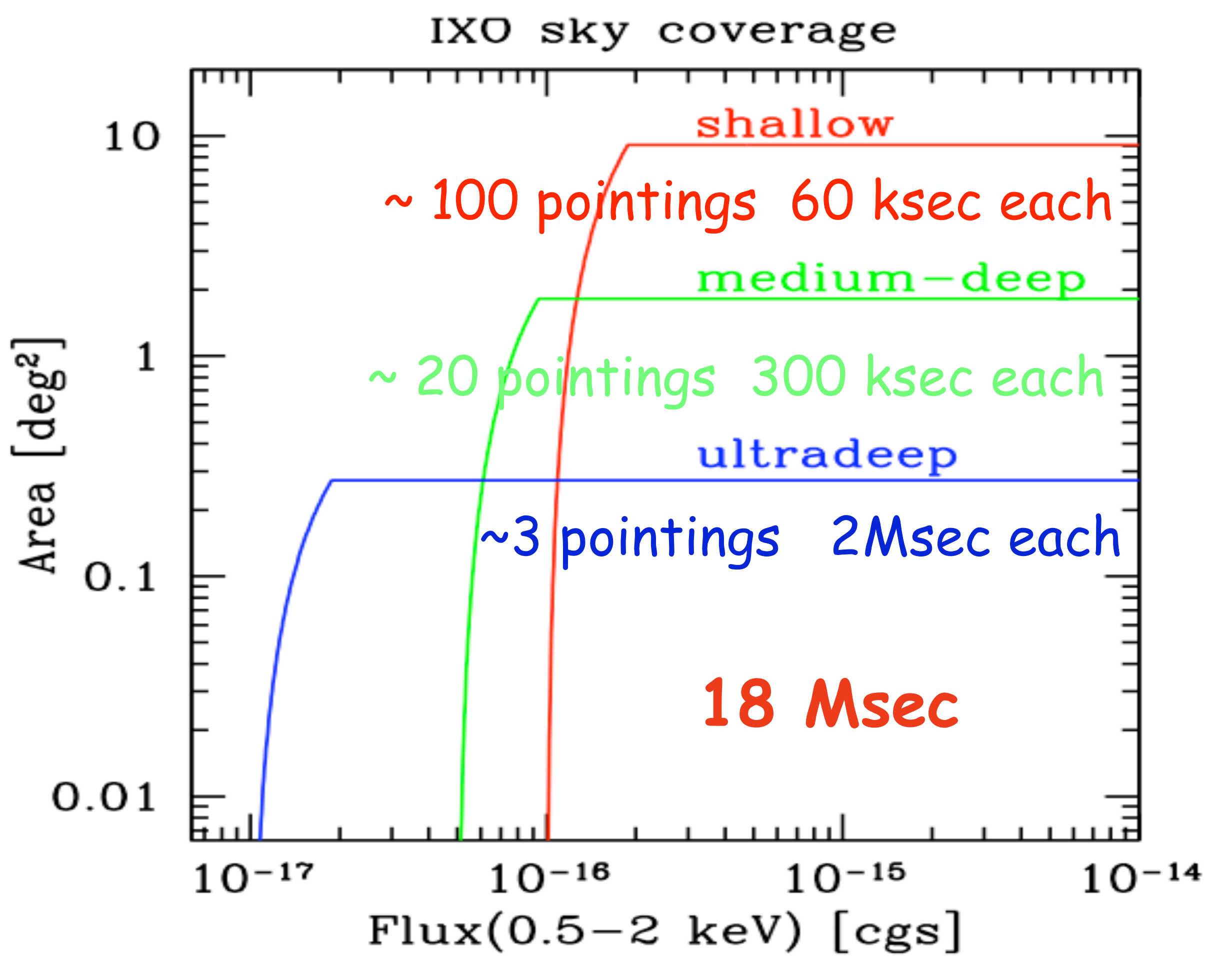
XMM CDFS202 z = 3.7
1 Ms F_{2-10} ~ 10^{-15}

XMM CT z = 1.53
100 ks F_{2-10} ~ 3 x 10^{-15}

IXO: SENSITIVITY







high-z AGN yields:

$N_{tot} \approx S^{1-\alpha}$

if $\alpha > 1$

deep in a single field

if $\alpha<1$

wider areas

Confusion

at $N(>S) \sim 2x10^4$ deg^{-2},

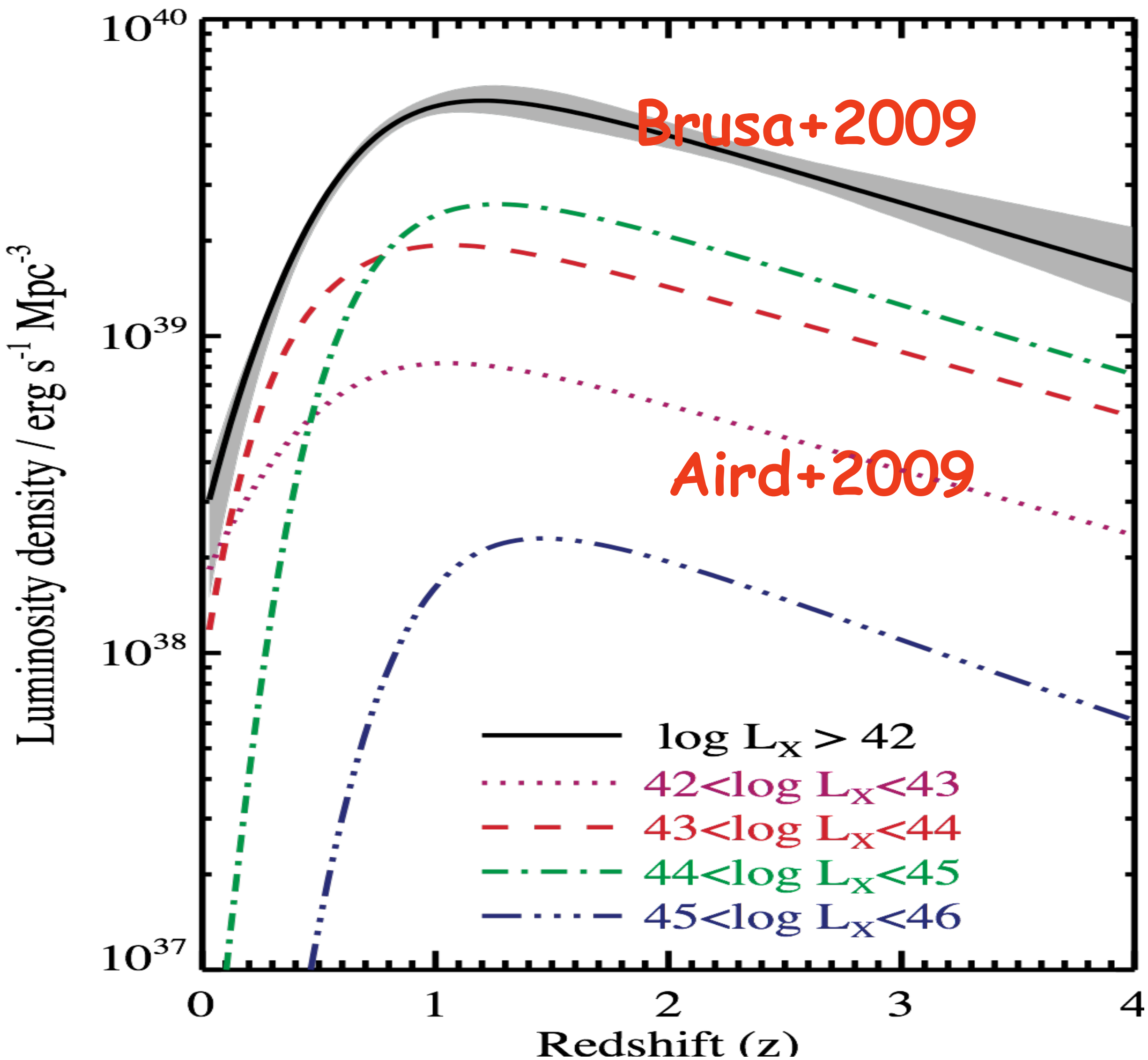
i.e. $S < 10^{-17}$ $erg/cm^2/s$

in ~ 2 Msec (depending on the bkg level)

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

FOV ~ 18'x18'

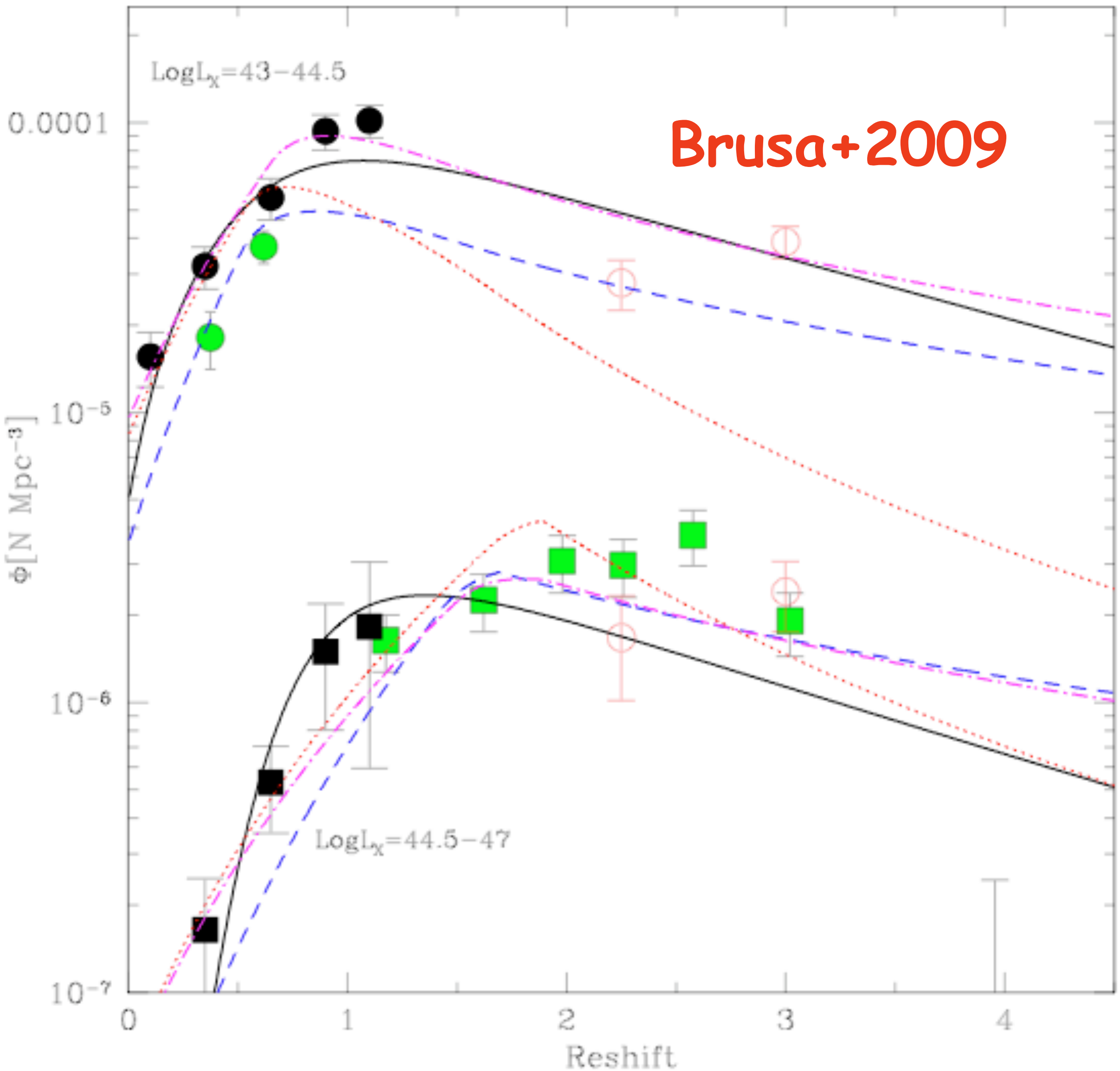
(Vignetting Included)



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

BH seeds mass function, accretion mechanisms

EXTRAPOLATION !!!



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

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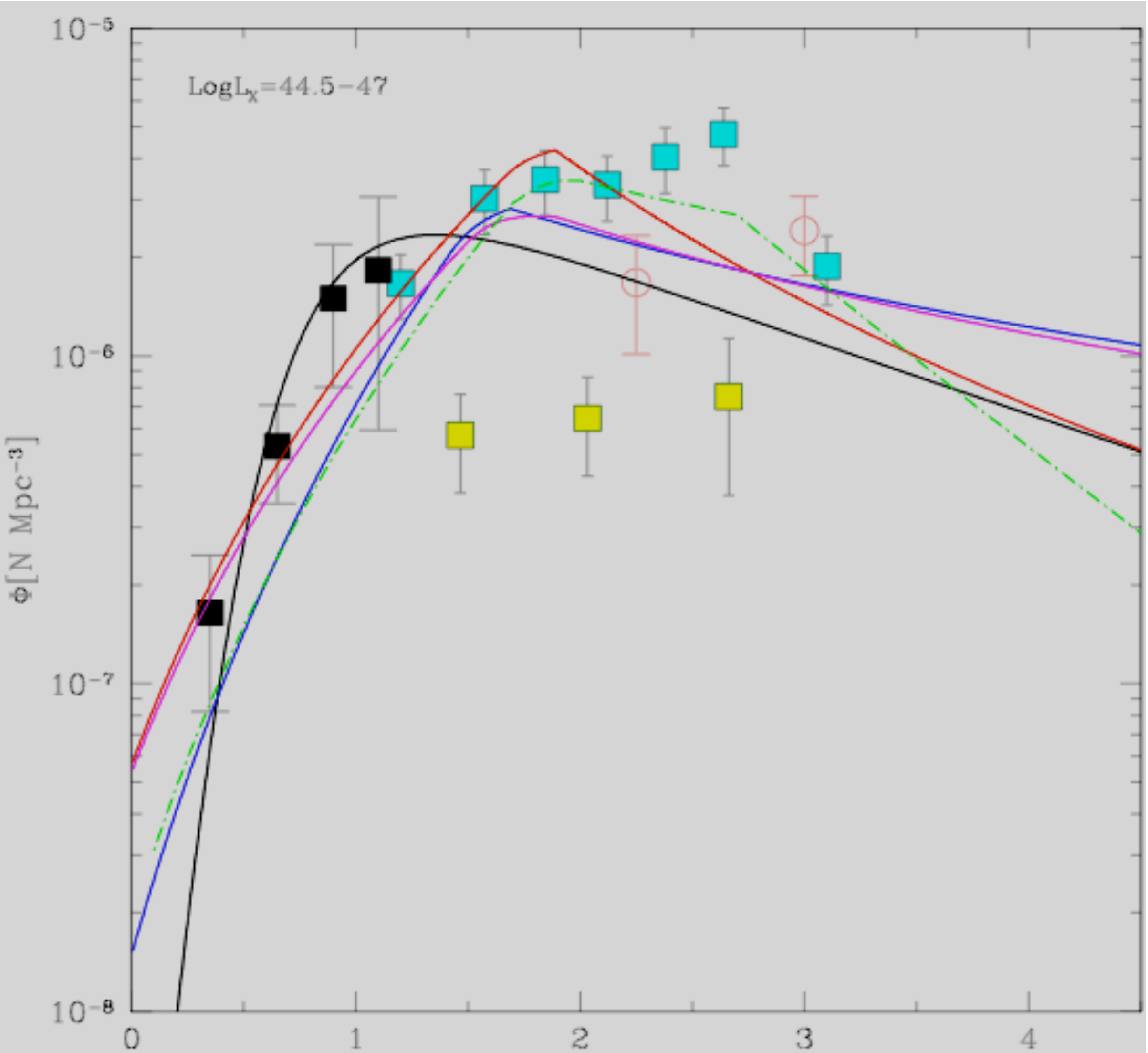
EXTRAPOLATION !!!

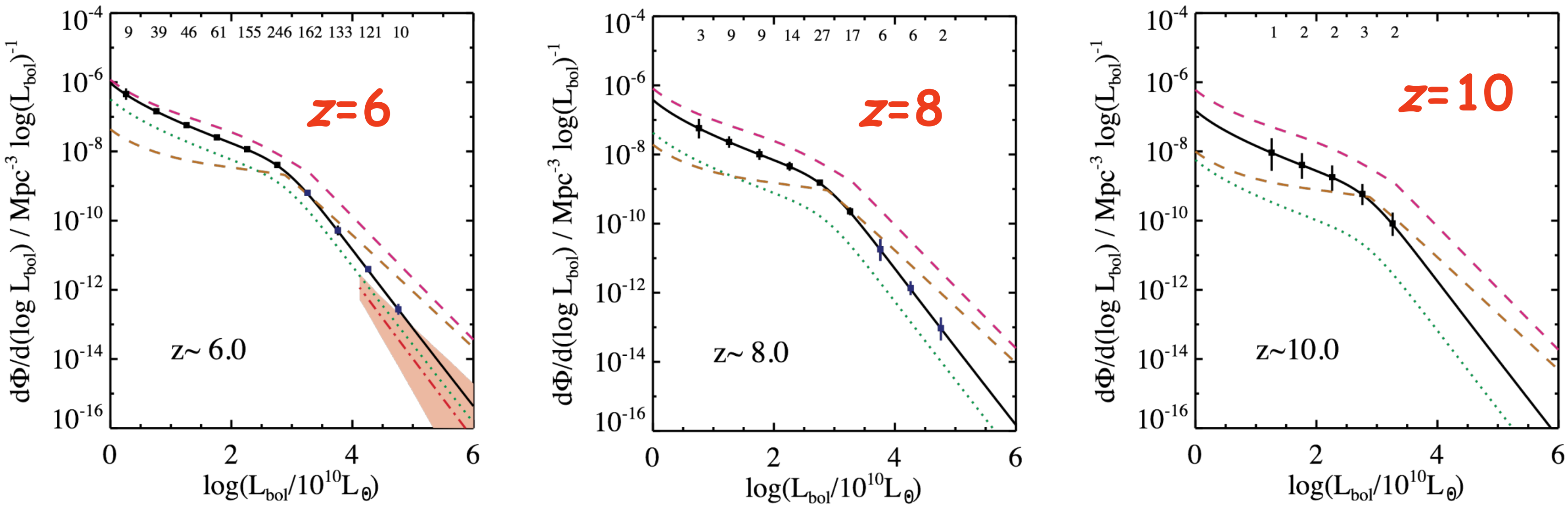


XLF @ z > 6
would constrain the physics of early BH formation

BH seeds mass function, accretion mechanisms

EXTRAPOLATION !!!

IXO: PREDICTED XLF

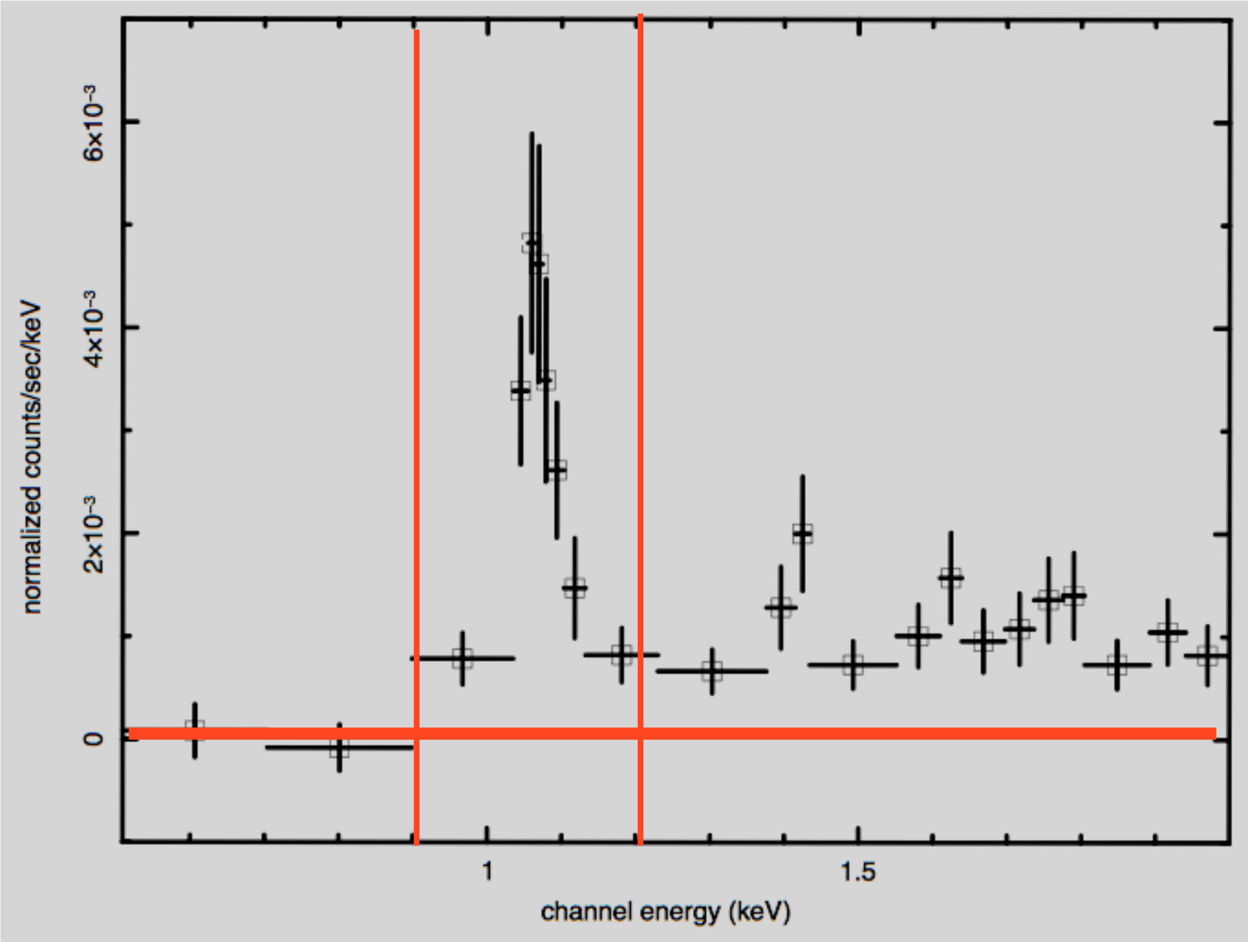


Observing Strategy
24 x 100 ks +
12 x 300 +
2 x 1000 = 8 Msec

170 z ~ 6 log L_X > 42.5
47 z ~ 8 log L_X > 43
15 z~ 10 log L_X > 43.5

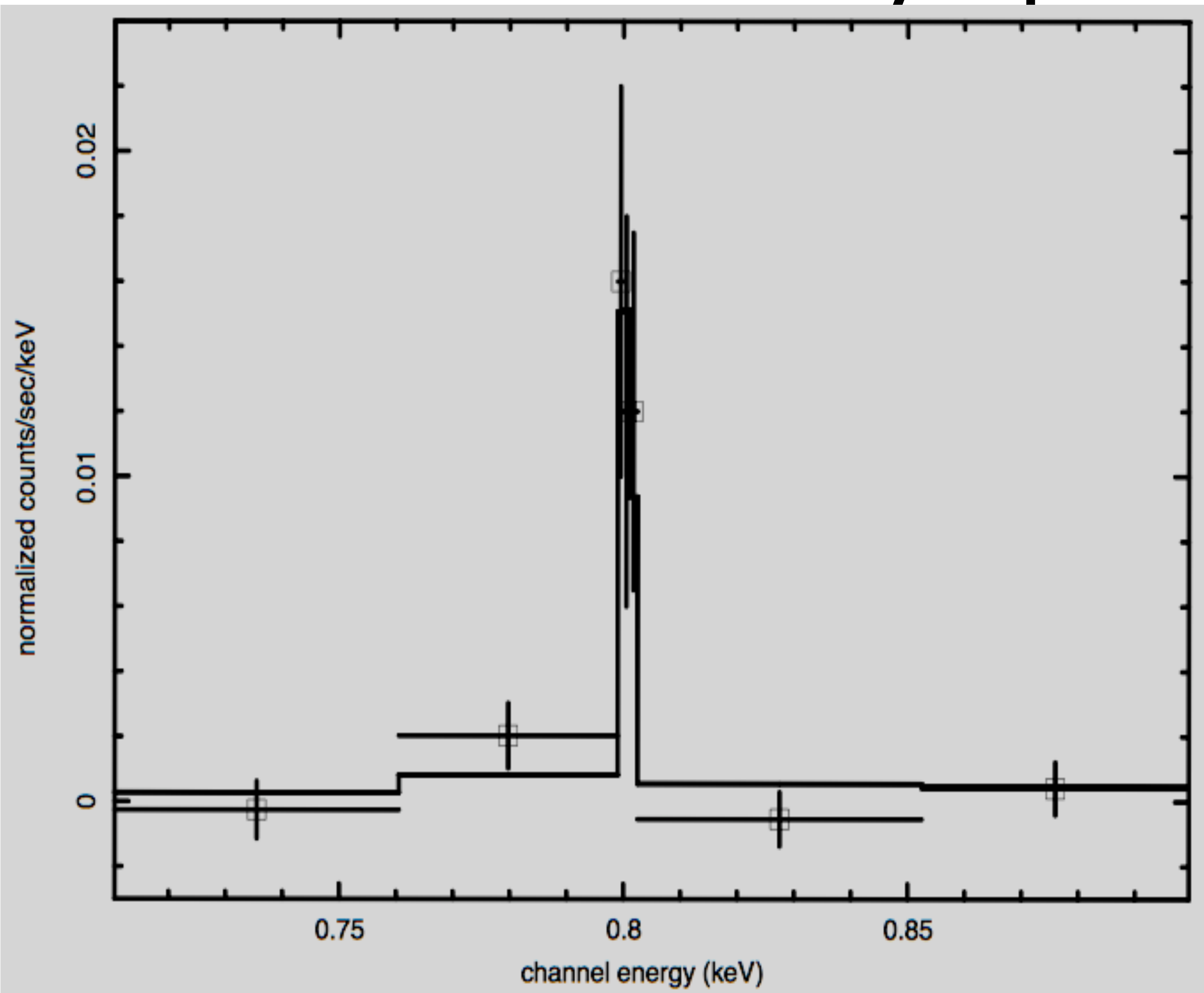
Detection of mini-QSO 10^6 M_{SUN} at L/L_E ~ 1

IXO X-ray Spectra



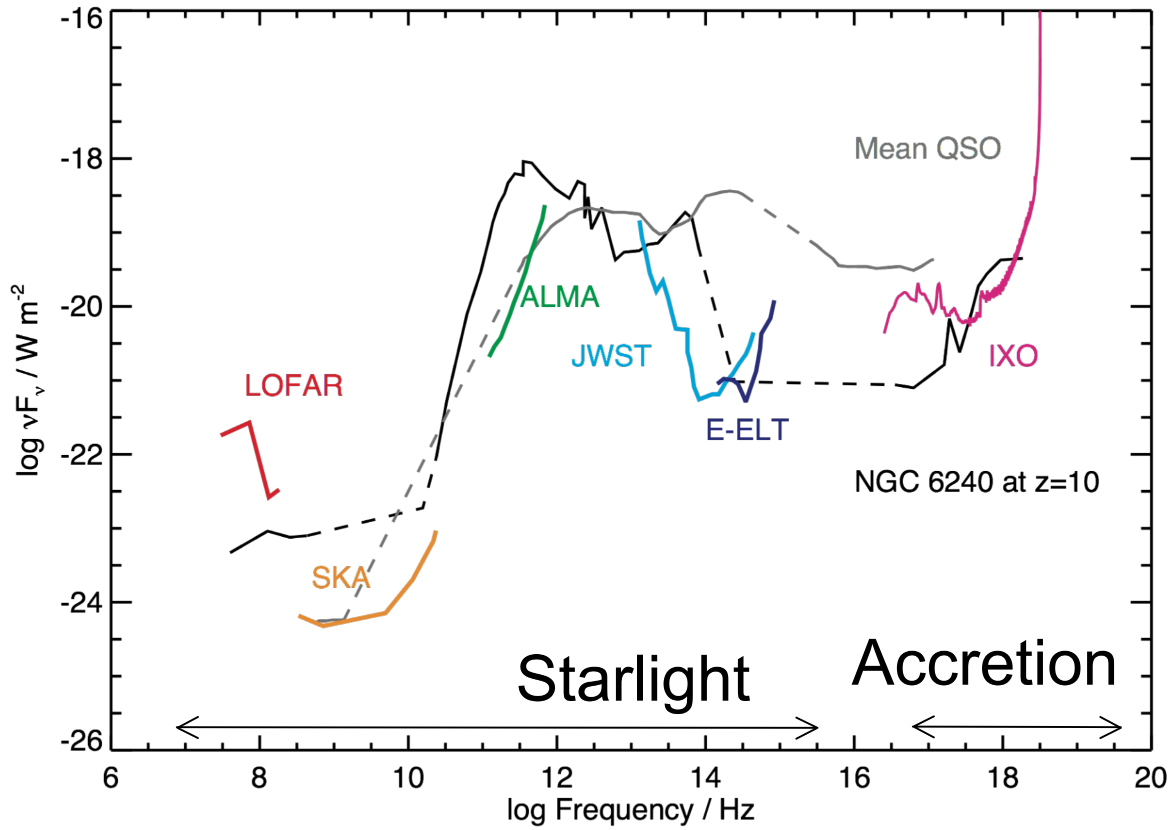
Compton Thick ($N_H \sim 10^{24}$ cm^{-2}) AGN at z = 5 ($L_X \sim 10^{43}$ cgs - $F_X \sim 10^{-16}$ cgs, line EW ~ 1 keV (rest-frame)

IXO X-ray Spectra



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

MULTIWAVELENGTH FOLLOWUP



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

Accretion & (co)-Evolution
X-rays

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

Issue(s)= Opt Id. (spurious), redshift (Ms with NIRSPEC)

Final remarks

- Trace SMBH growth at z>6 (to z=8-10)

  Enough z>6 objects to build up an XLF and constrain early SMBH growth and feedback in formation of first galaxies(assuming a "clever" strategy is adopted and "enough" time is invested in surveys). IXO would provide spectra for moderately bright high-z QSOs.

- Provide complete census at z<3

  AGN/Galaxy Co-evolution and SMBH regulation of star formation.Unique capability to identify through X-ray spectroscopy faint obscured AGN and Compton Thick objects at the peak of their activity

IXO is well matched to the sensitivity of other future facilities like JWST and ALMA to recognize high-z and heavily obscured SMBH. Dedicated follow up observations of high-z QSO identified by eROSITA - WFXT and/or Pan-STARRS , LSST ...