Observing the First Accretion Light with X-ray Surveyor

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X-ray Surveyor

Chandra

XMM-Newton

Athena
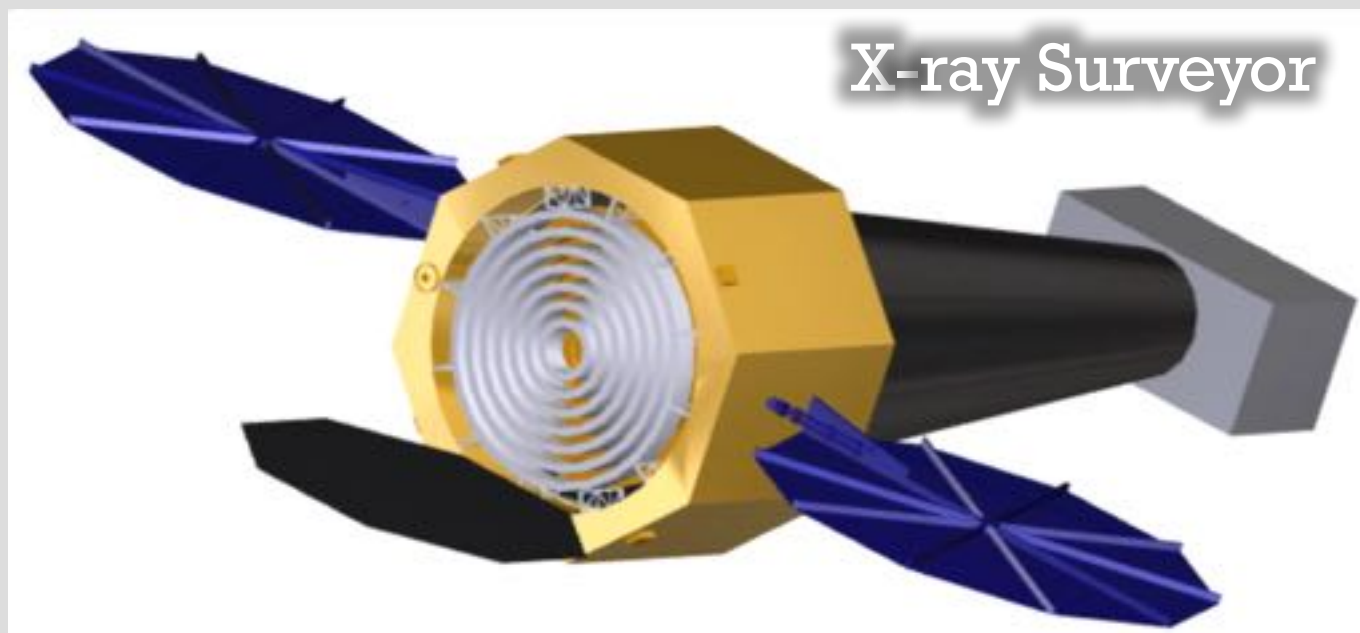
# Some Current X-ray Findings

General Observational Status

Over the past ~ 17 yr, the capabilities of Chandra and XMM-Newton have allowed a large expansion in the number of X-ray detected AGNs at $z = 4$-7.

X-ray follow-up of high-redshift AGNs first found in other multiwavelength surveys; e.g., SDSS, PSS, FIRST.

X-ray selected high-redshift AGNs in X-ray surveys. Critical since X-rays penetrating and not diluted.

Now have about 155 X-ray detections at $z = 4$-7, allowing reliable basic X-ray population studies out to the reionization era.

Space Density Declines for High-Luminosity X-ray AGNs

Vito et al. (2014)
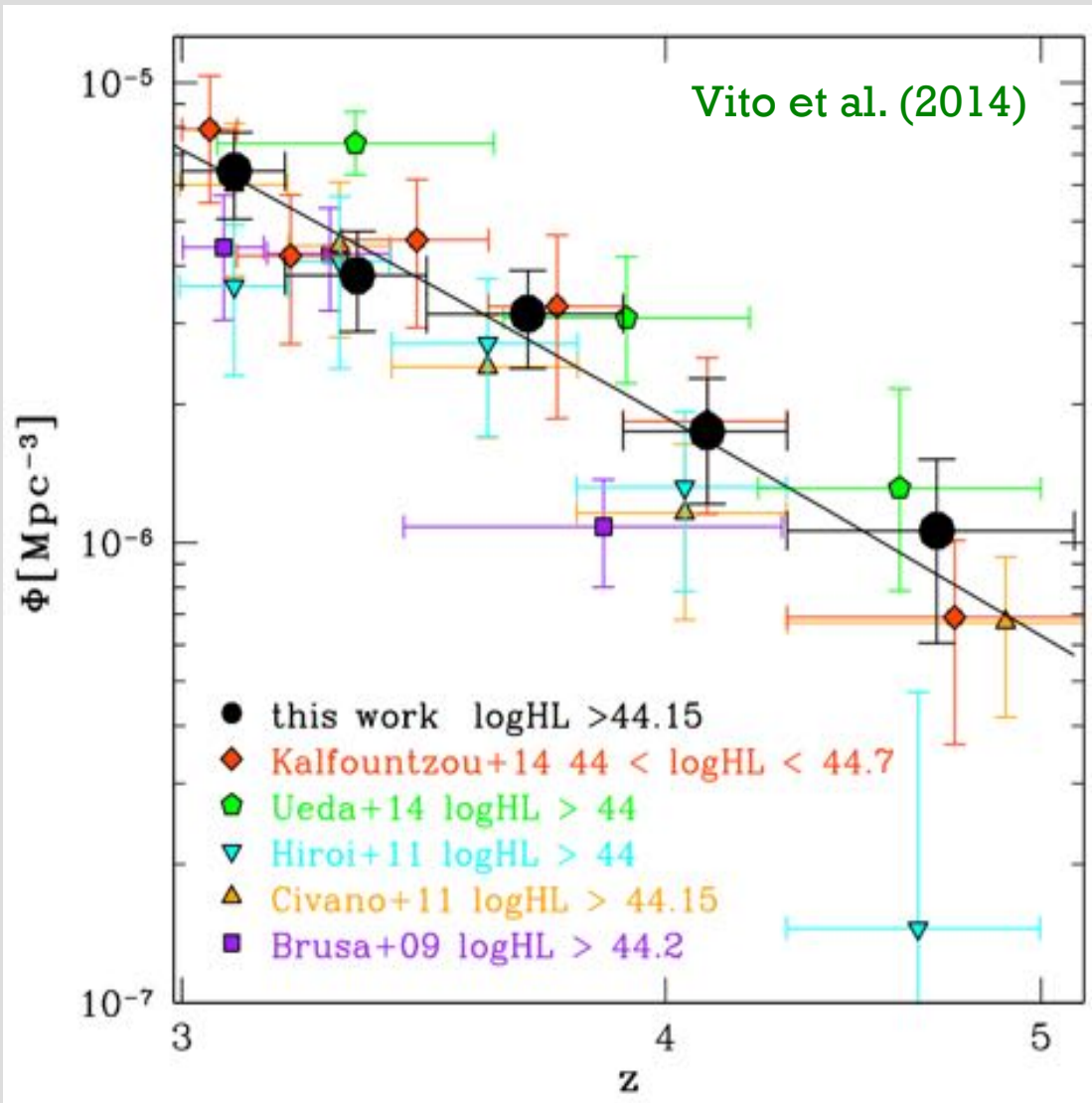
In contrast to early suggestions from ROSAT, clearly see ~ exponential decline for luminous X-ray selected AGNs at $z > 3$.
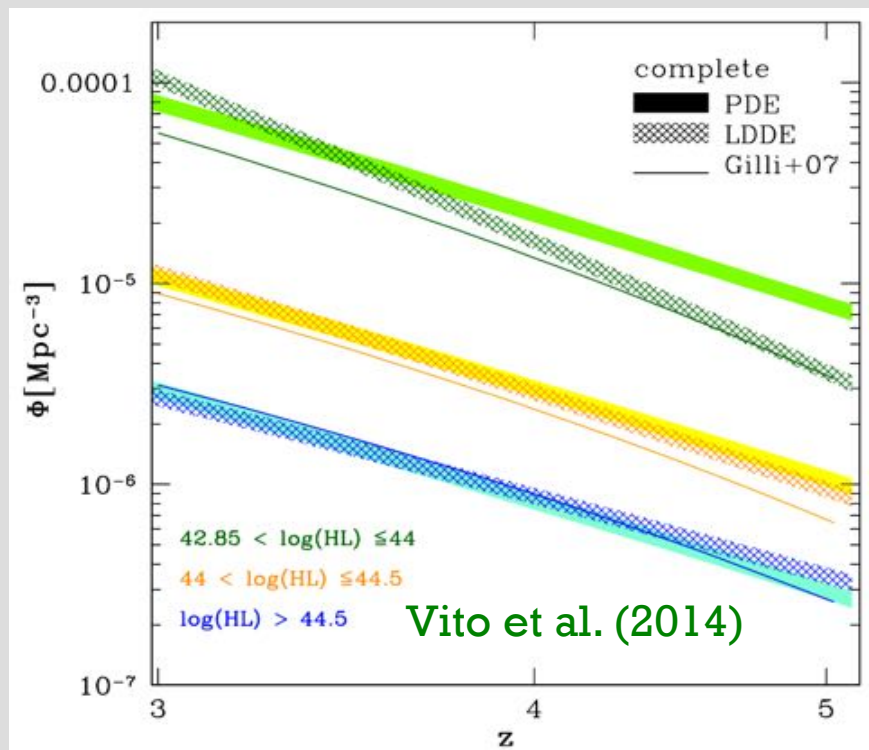
$\Phi \propto (1 + z)^p$ with $p = -6.0 +/- 0.8$

Space-density comparisons with optically selected quasars indicate agreement to within factors ~ 2-3.

Space Density at *z* ~ 3-5 for Moderate-Luminosity X-ray AGNs

Remaining debate here – small samples, tough follow-up, results can depend on analysis details.

Drop by a Factor of ~ 5 from *z* = 3-4 to *z* = 4-5, but with Perhaps a Milder Drop at High Luminosities?

Similar Decline at Moderate Luminosities as at High Luminosities?

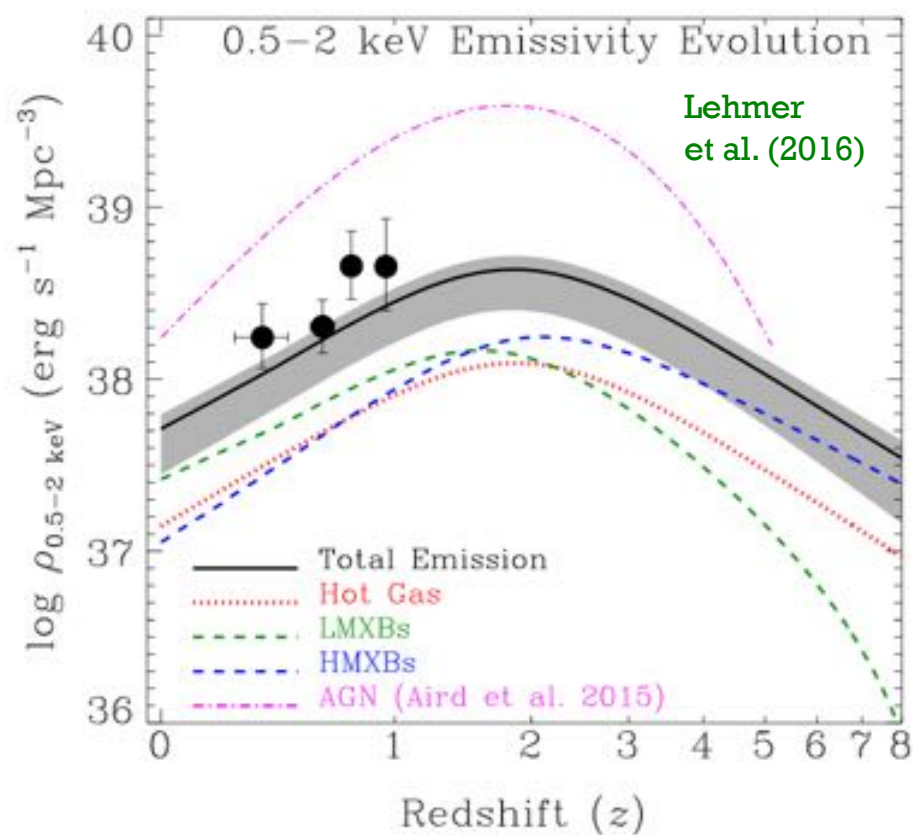Vito et al. (2014)

Georgakakis et al. (2015)
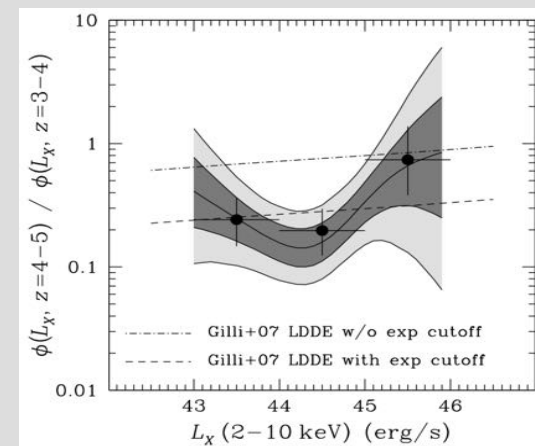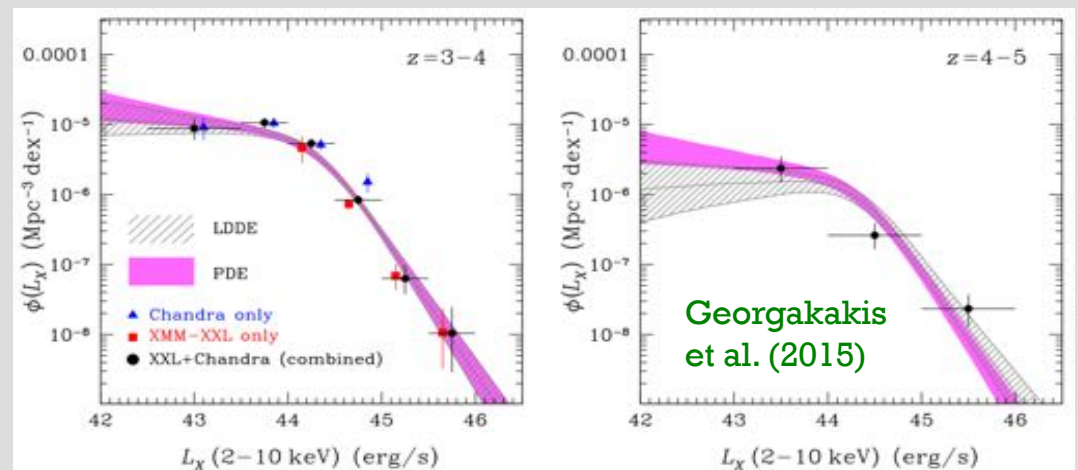
AGNs Probably Cannot Drive Reionization at $z \sim 6$

But AGNs and HMXBs likely have secondary IGM heating effects.

Hydrogen Ionizing Photon Rate Density
from AGNs as Function of Redshift
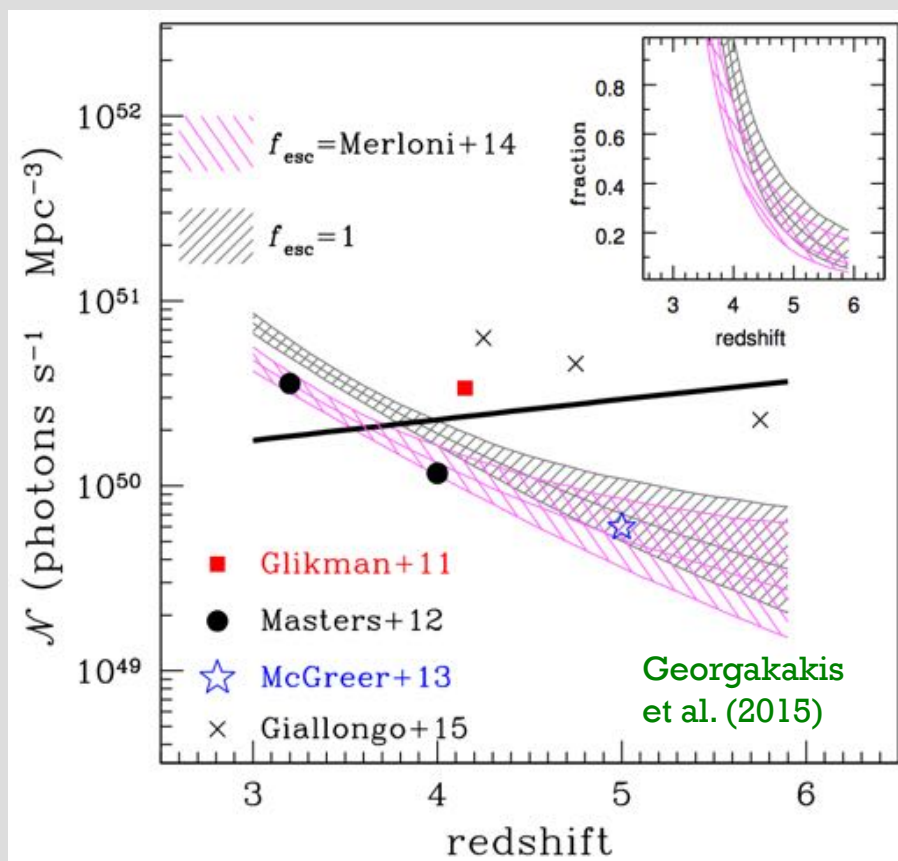
The Revenge of the X-ray Binaries at $z \sim 6$-8?
(ρ_{Gal} May Drop Off More Slowly Than ρ_{AGN})

7 Ms Chandra Deep Field-South Stacking

X-ray stacking of individually undetected galaxies can provide average X-ray detections to $z = 4.5$-5.5, and useful upper limits at higher redshifts.

Signal is mostly from massive galaxies, as assessed via sample splitting with 4-fold cross-validation testing.
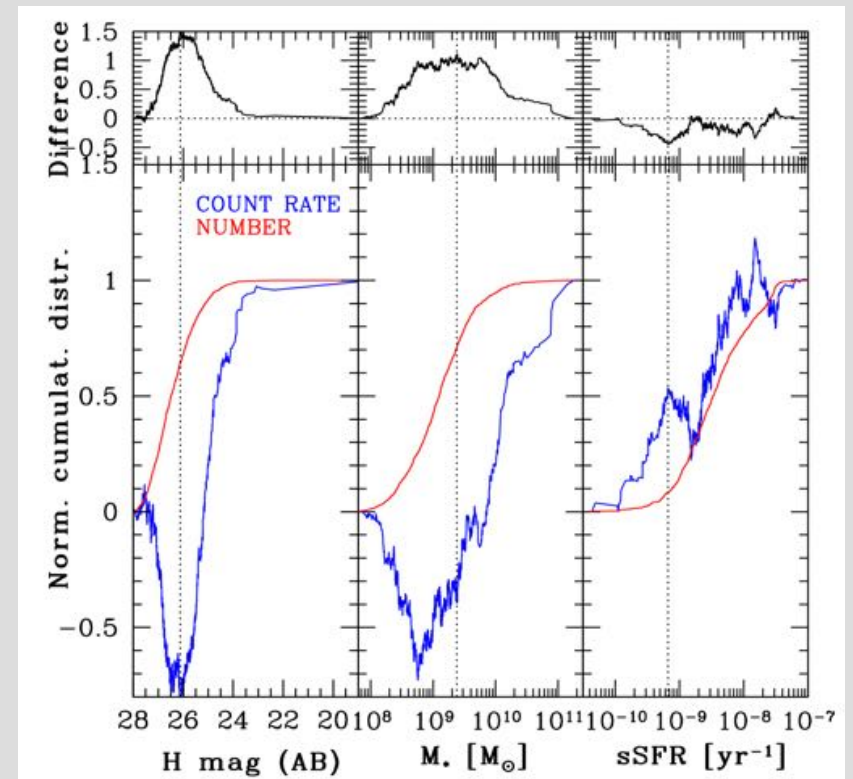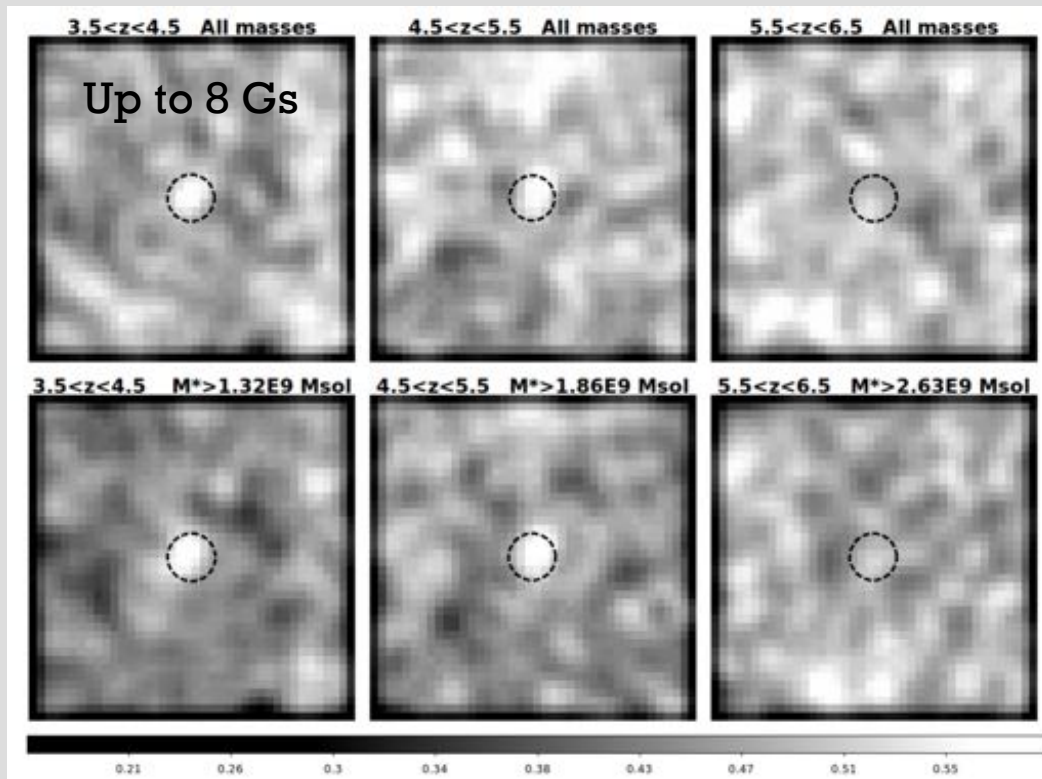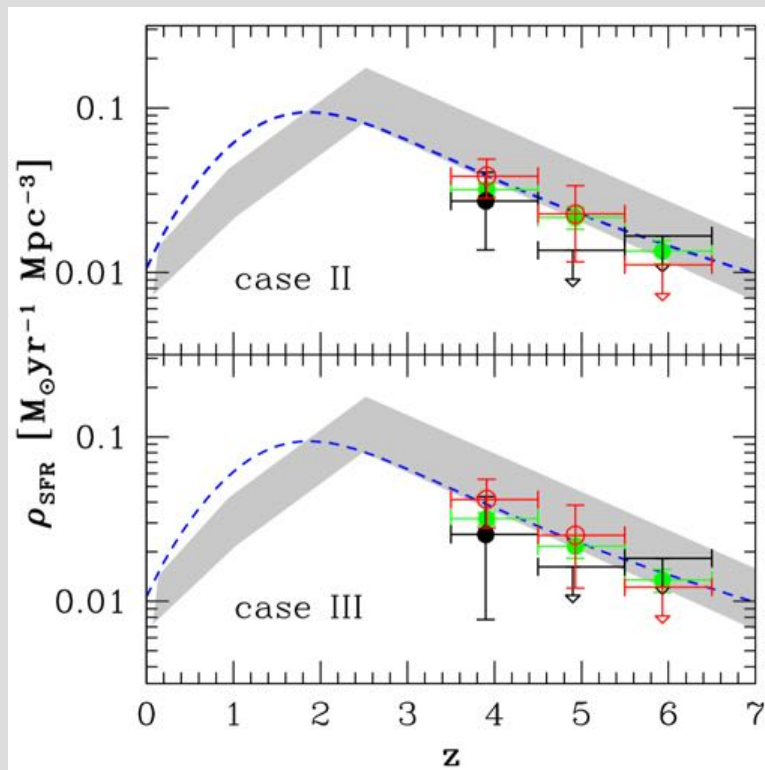

Vito et al. (2016)
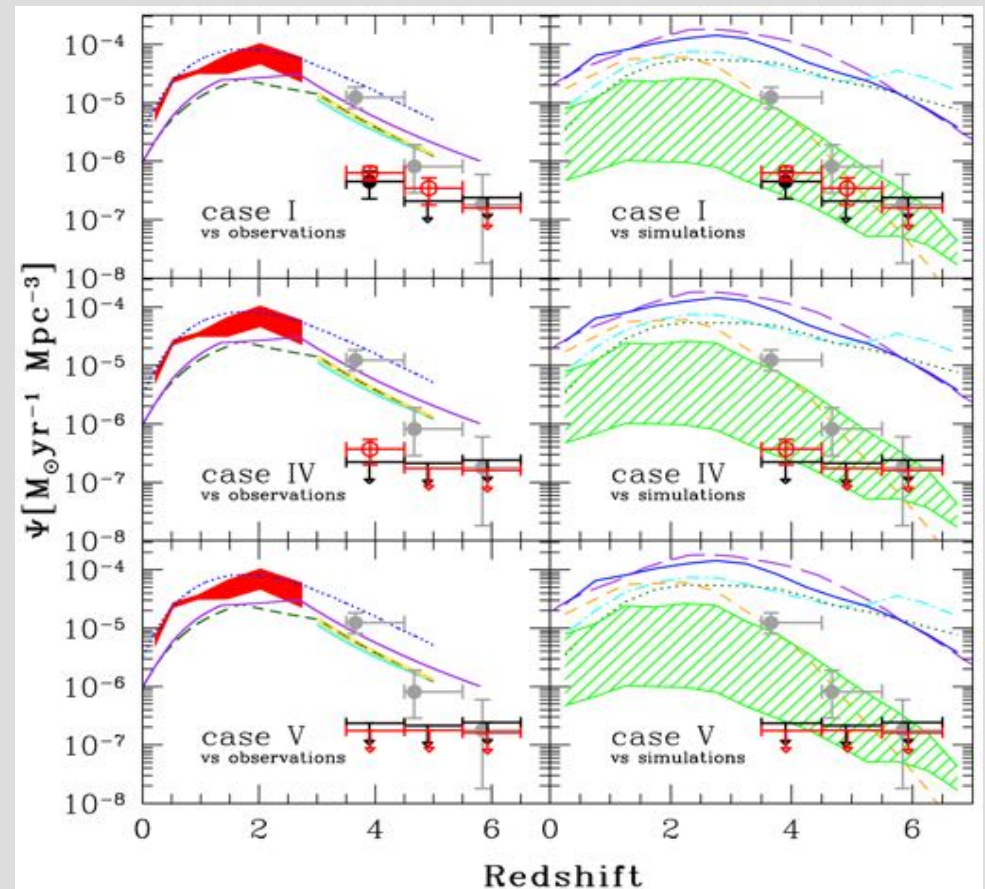
7 Ms Chandra Deep Field-South Stacking

Much, and perhaps all, of the observed flux can be attributed to X-ray binaries.

Most high-redshift SMBH accretion occurs in short AGN phase – continuous low-rate accretion contribution appears small.
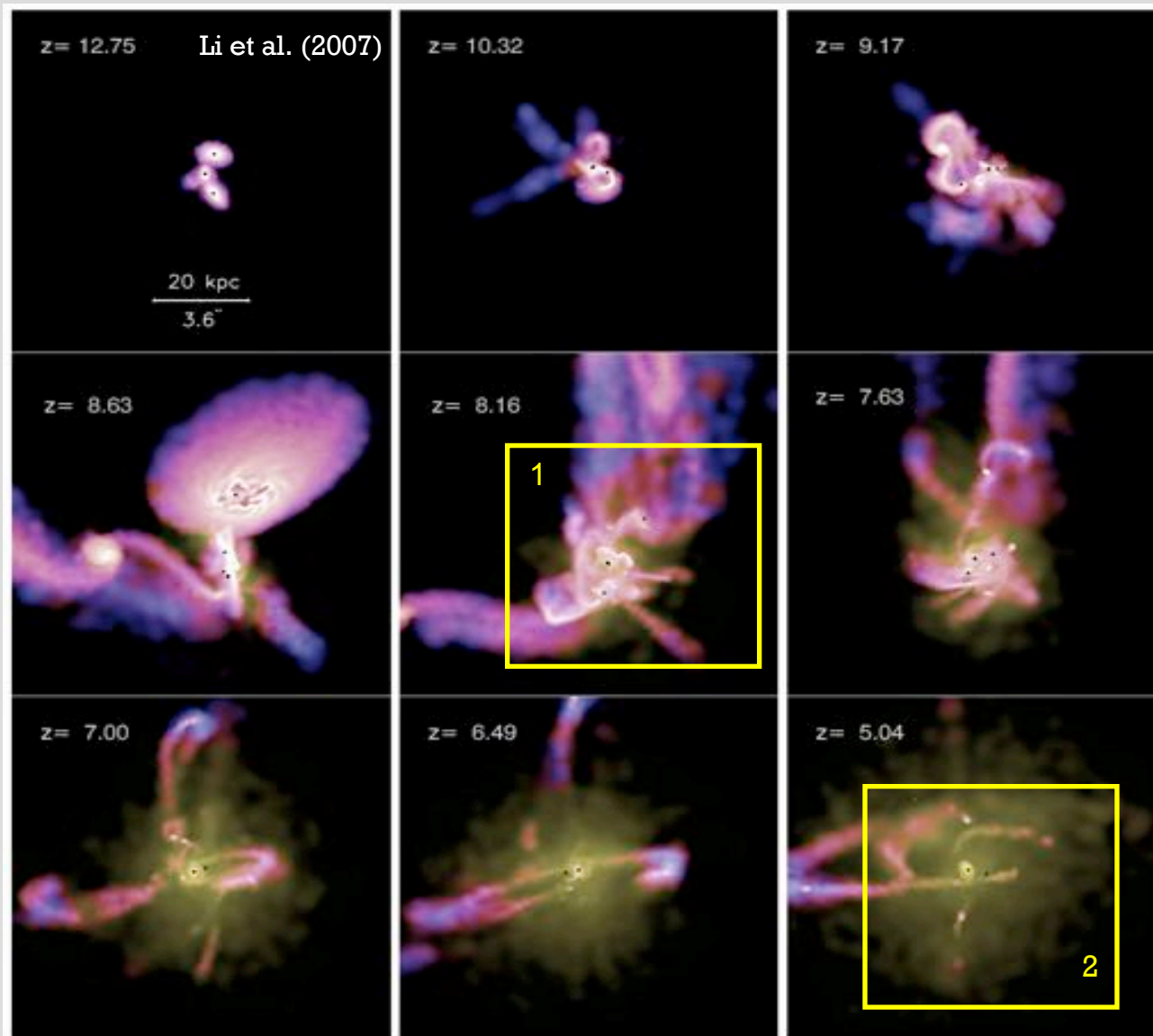
Aim to push this analysis to $z \sim 10+$ using Chandra stacking of JWST galaxy samples in CDF-S and other fields.

Vito et al. (2016)

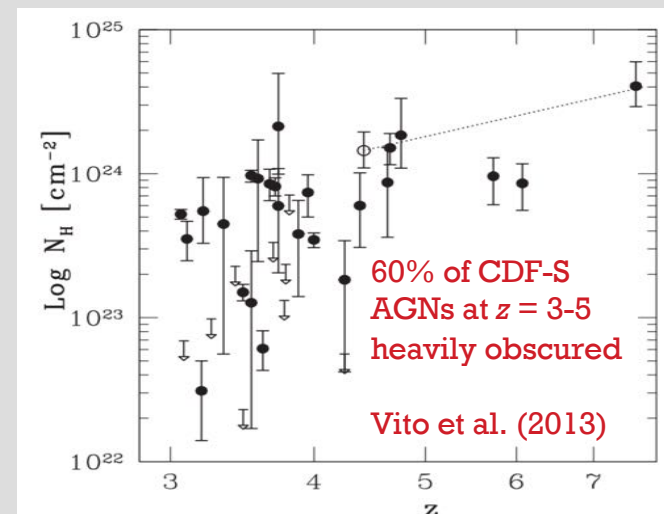# Simulation of the Formation of a *z* ~ 6 Quasar from Hierarchical Galaxy Mergers
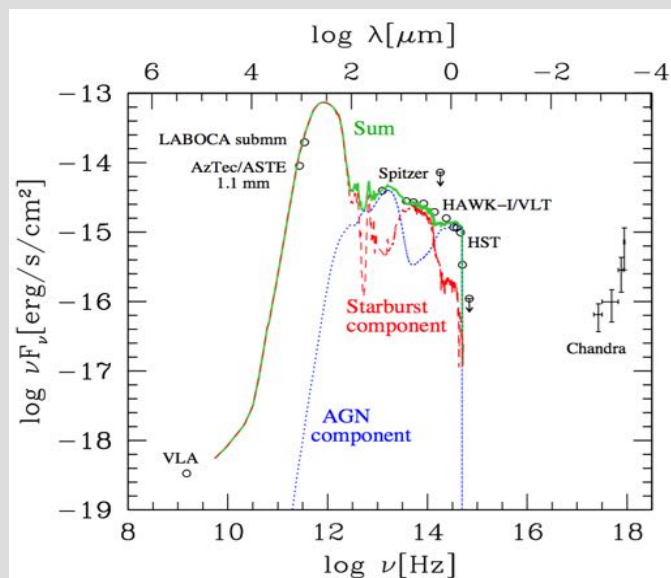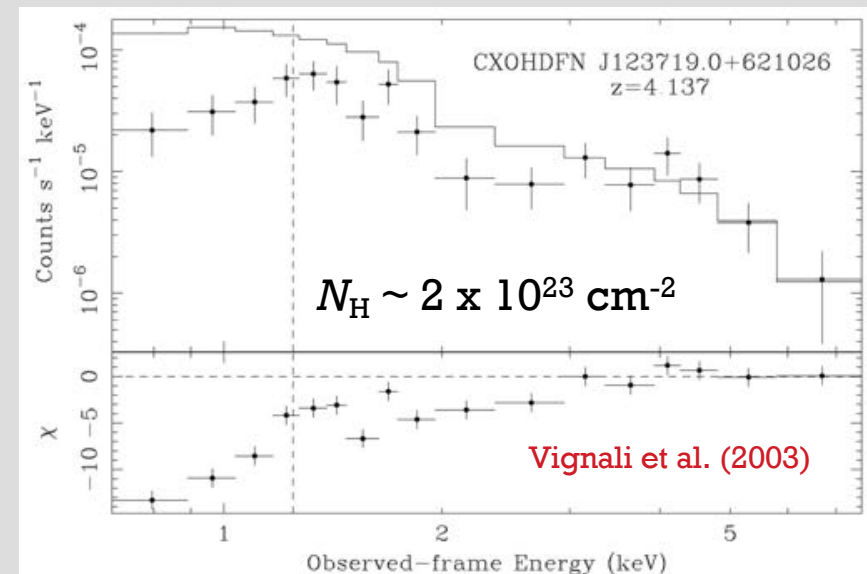

Gas density and temperature for high-redshift quasar host

Albeit at somewhat lower redshifts, we observe similar phenomena at *z* ~ 4-5:

(1) X-ray obscured protoquasars of moderate luminosity

(2) powerful winds from luminous quasars, likely capable of host feedback

X-ray Obscured Protoquasars of Moderate Luminosity at *z* ~ 4-5

Compton-thick AGN at *z* = 4.76 in strongly star-forming host

Gilli et al. (2011)

N_H ~ 2 x 10^{23} cm^{-2}

Vignali et al. (2003)

60% of CDF-S AGNs at *z* = 3-5 heavily obscured

Vito et al. (2013)
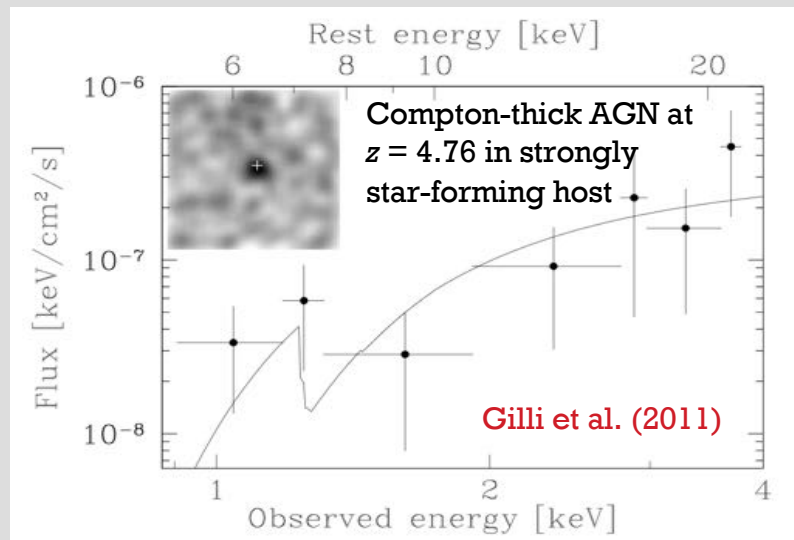
Powerful Winds from Luminous High-Redshift Quasars

z= 5.04

Li et al. (2007)

Fe XXV rest-energy

Epoch 1

$z = 3.91$

APM 08279+5255
ACIS *Chandra*
2002 Feb 24

Fe XXV rest-energy

Epoch 5

Chartas et al. (2009)

APM 08279+5255
ACIS *Chandra*
2008 Jan 14
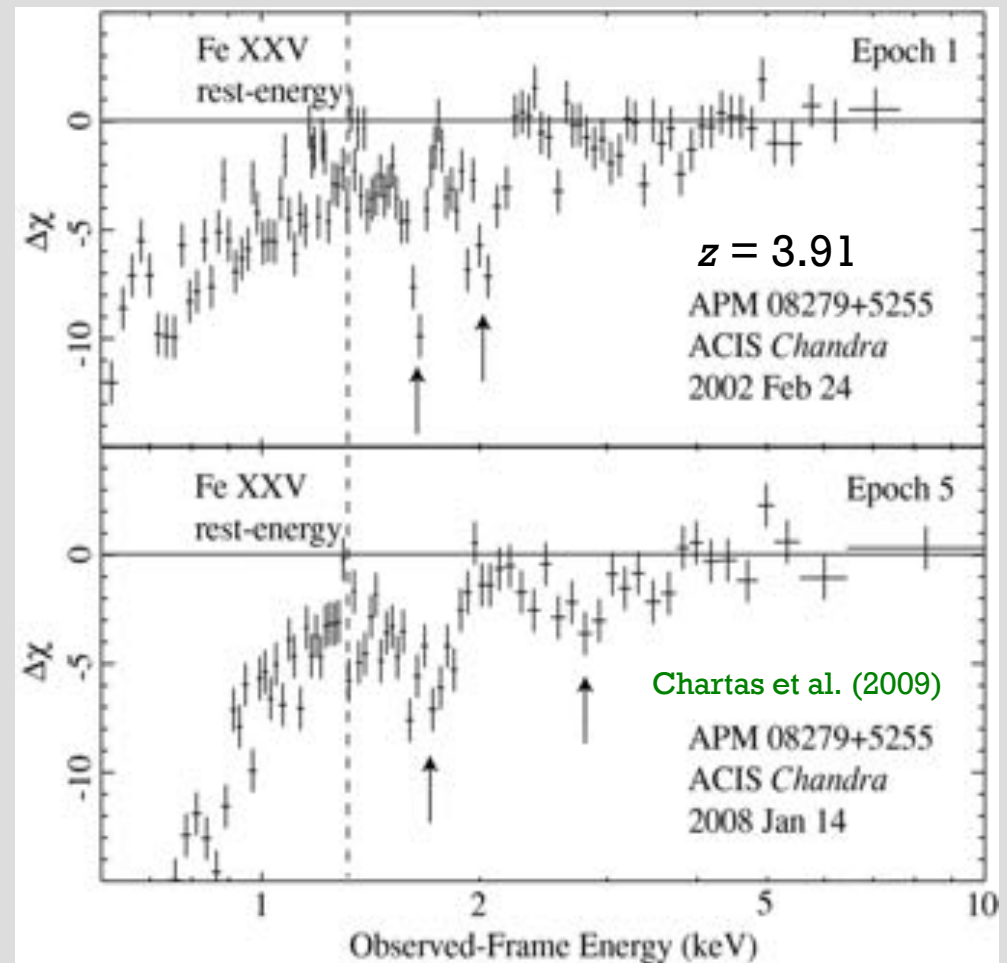
Observed-Frame Energy (keV)
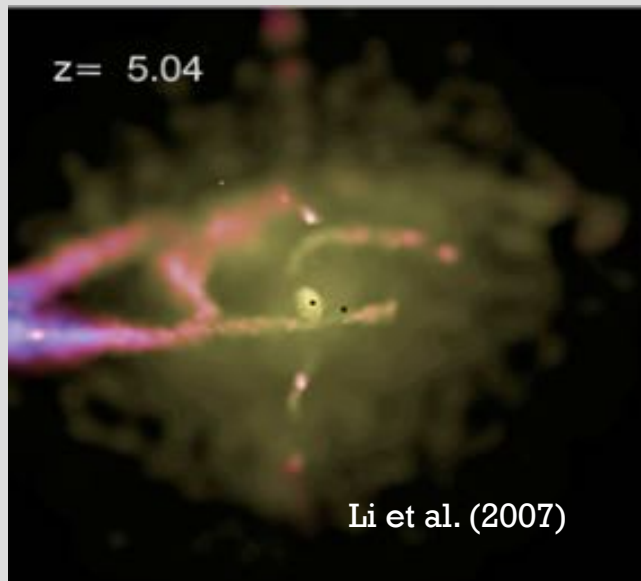
Implied X-ray velocity is $v \sim 0.2\text{-}0.4c$.

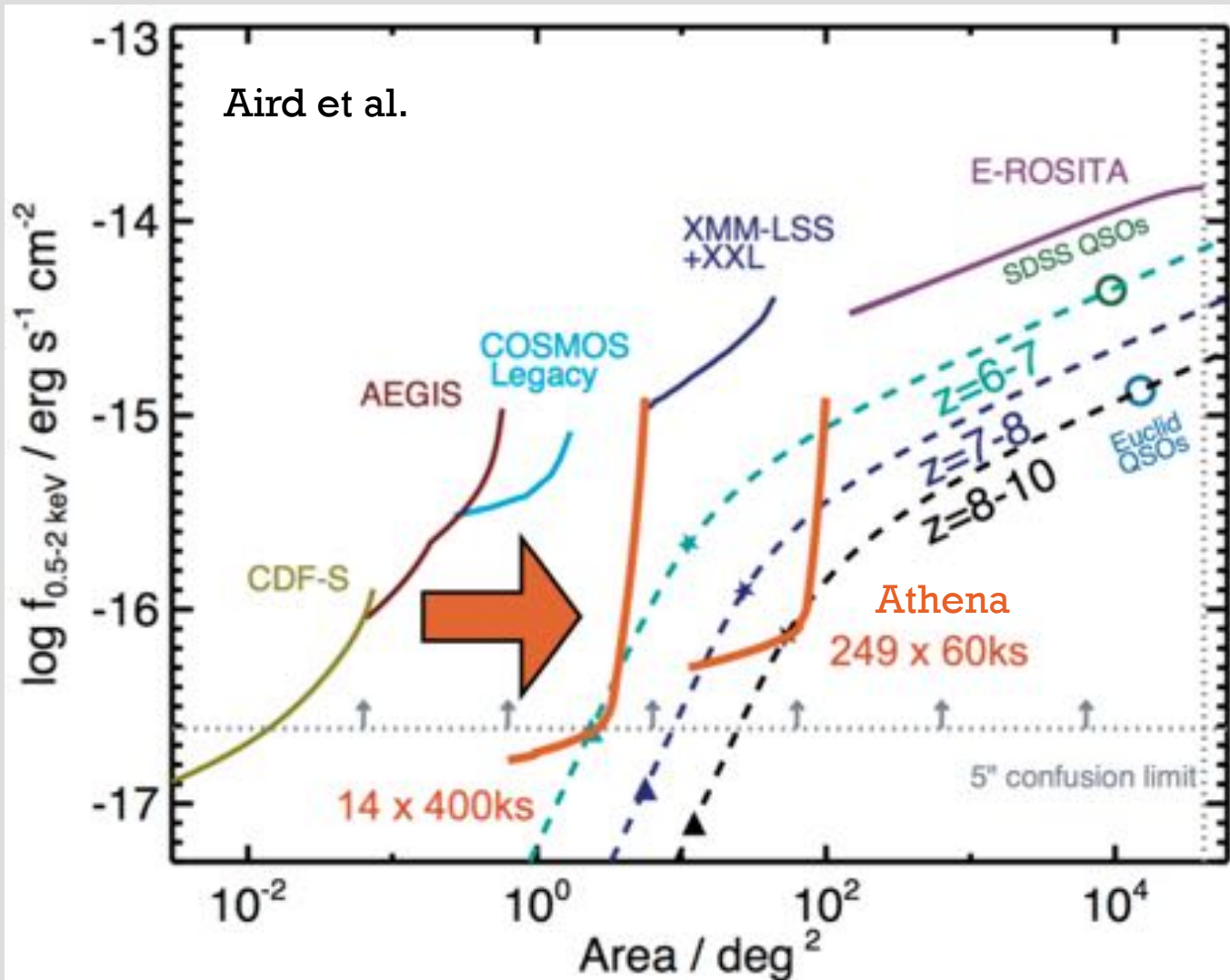Implied mass-outflow rate is $\sim 10\text{-}30 \ M_\odot \ yr^{-1}$ and kinetic luminosity is $\sim 10^{46\text{-}47} \ erg \ s^{-1}$.

Could be present but undetected in many other high-redshift quasars (had boost from gravitational lensing).

X-ray Surveyor and Athena

# Athena Can Generate a Lot More of What We Currently Have Only in Small Amounts

Aird et al.

A *very good thing* for getting reliable AGN source statistics at $z \sim 5$-10.

Will provide a lot more photons for source spectral and variability diagnostics.

Source confusion with a 5'' PSF will prevent it from going deeper than the deepest Chandra observations.

High-Redshift Quasars from Euclid, WFIRST, and LSST

Sensitivities of LSST, WFIRST, and Euclid

Spergel et al. (2013)
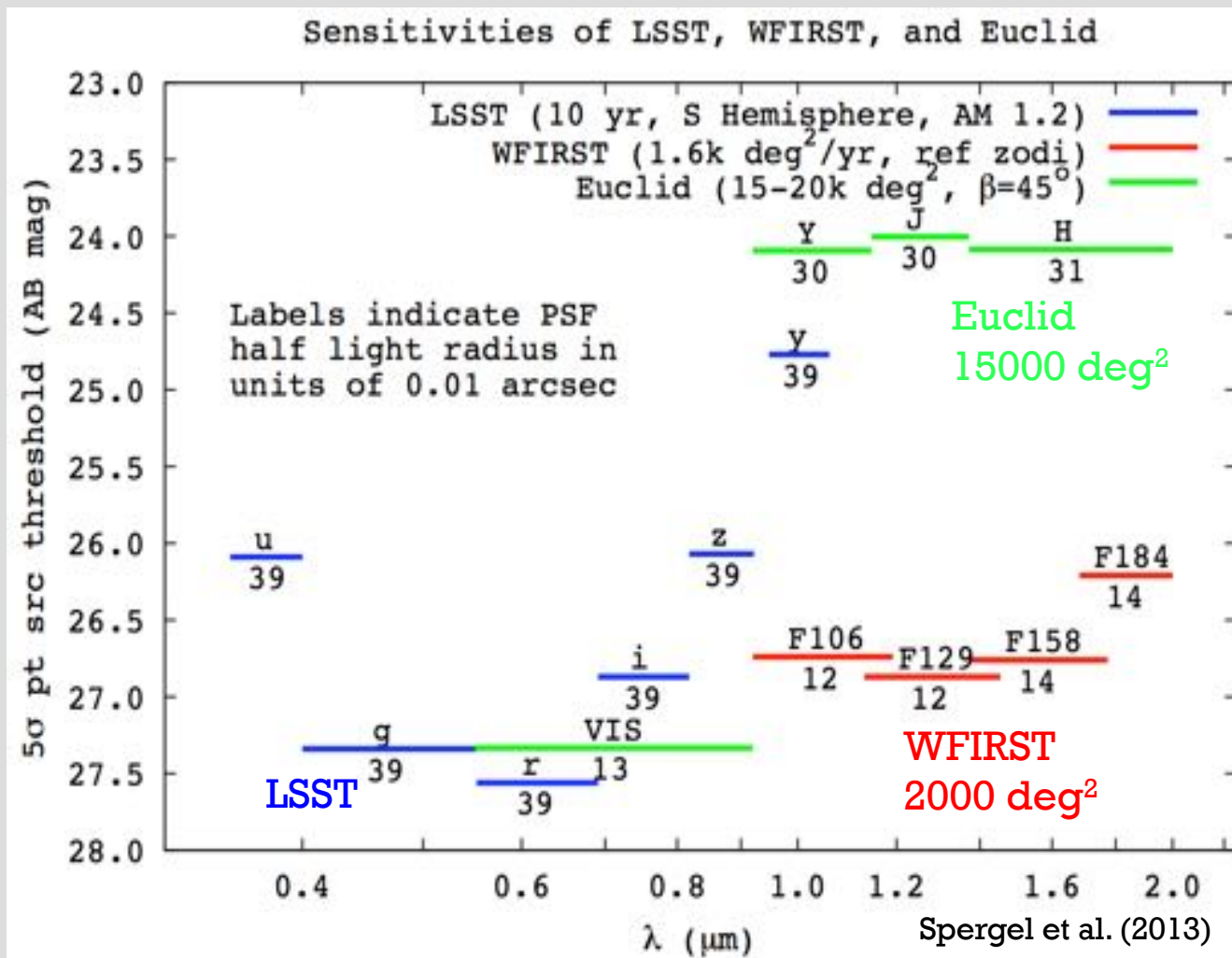
Combination of Euclid, WFIRST, and LSST will be very powerful for finding the first quasars.

Euclid should deliver ~ 1400 luminous quasars at $z > 7$.

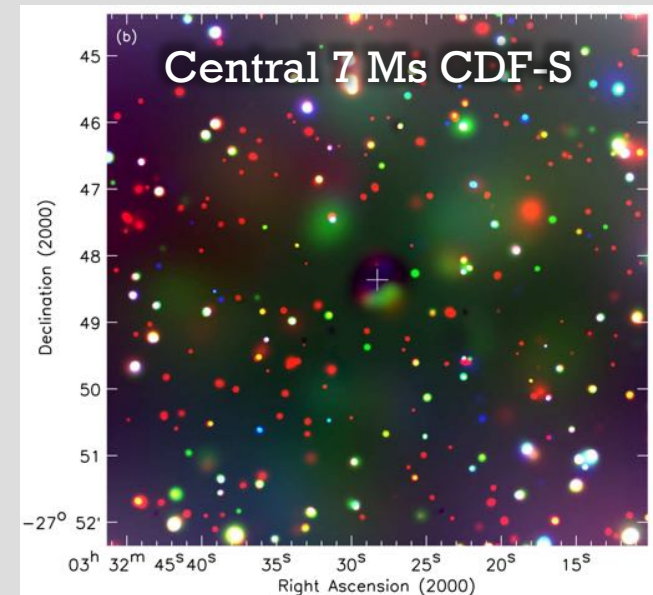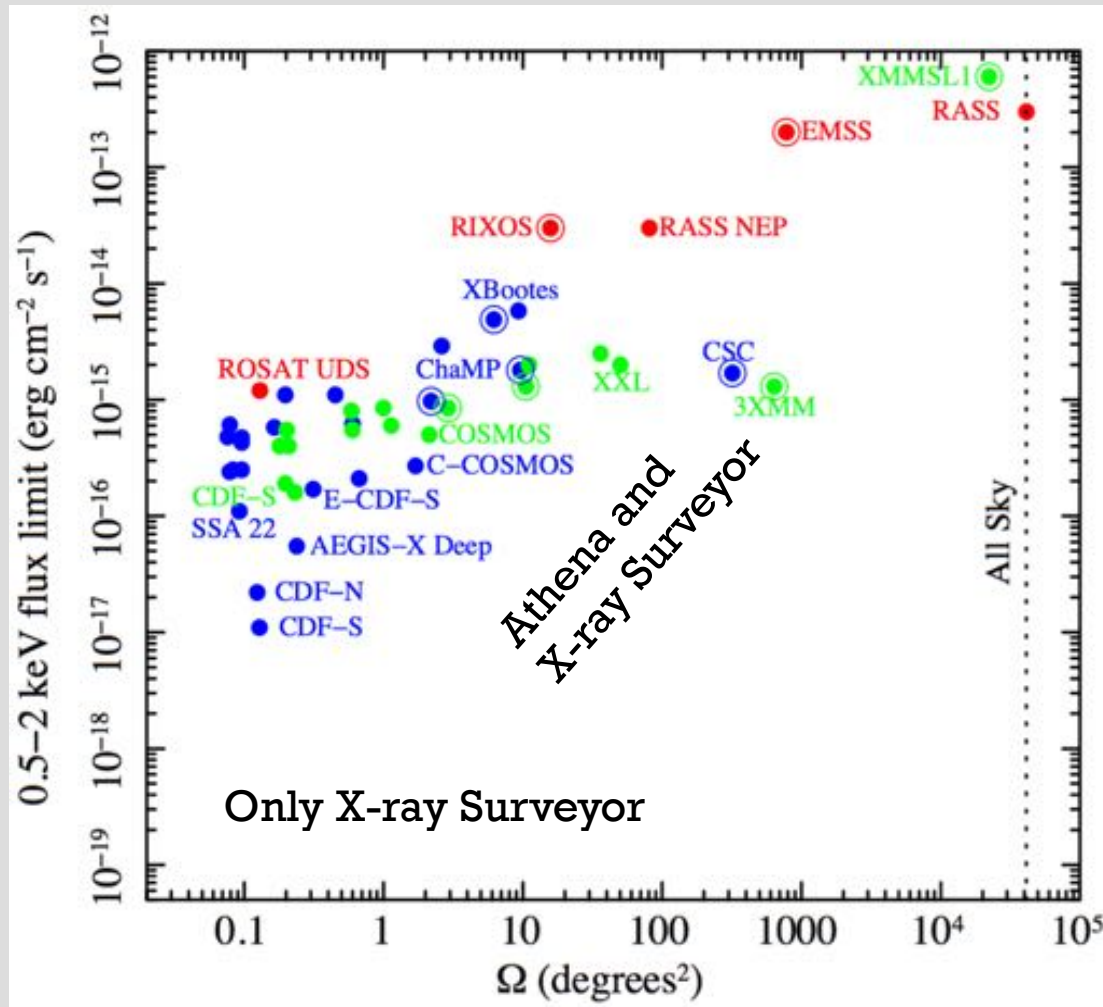WFIRST+LSST will push considerably deeper than Euclid over ~ 15% of the area.

Expect ~ 1500 quasars at $z > 7$ (~ 30 at $z > 10$).

AGNs from 25 Ms Athena Survey versus Euclid and WFIRST+LSST

Seeds of SMBHs with X-ray Surveyor
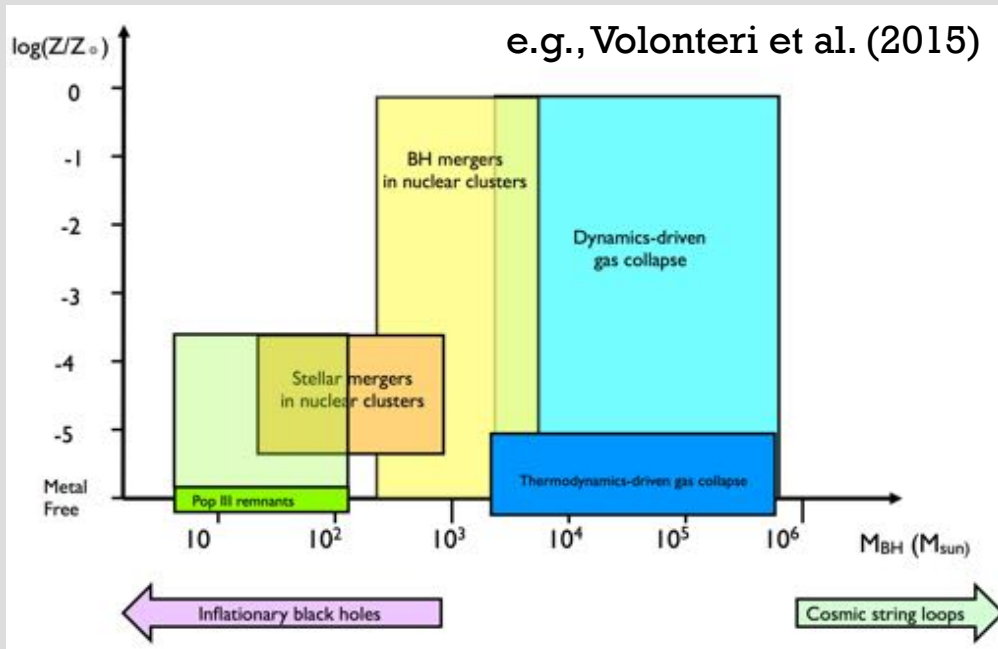

Only X-ray Surveyor

Central 7 Ms CDF-S
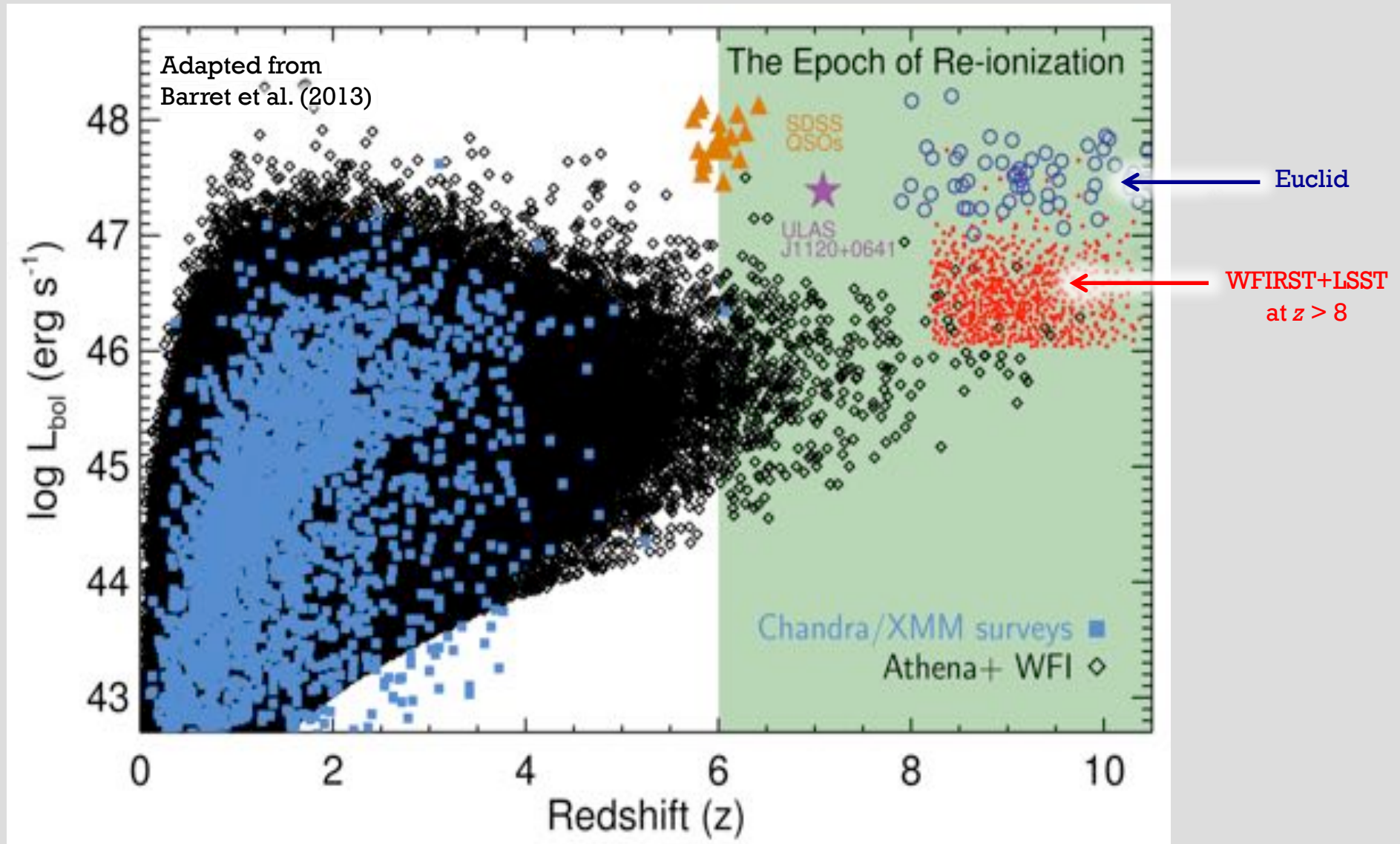
Need the excellent imaging of X-ray surveyor to push to X-ray fluxes far below Chandra (and get reliable counterparts).

At $z = 8$, can detect BH to ~ 3×10^4 M$_\odot$, including obscured systems.

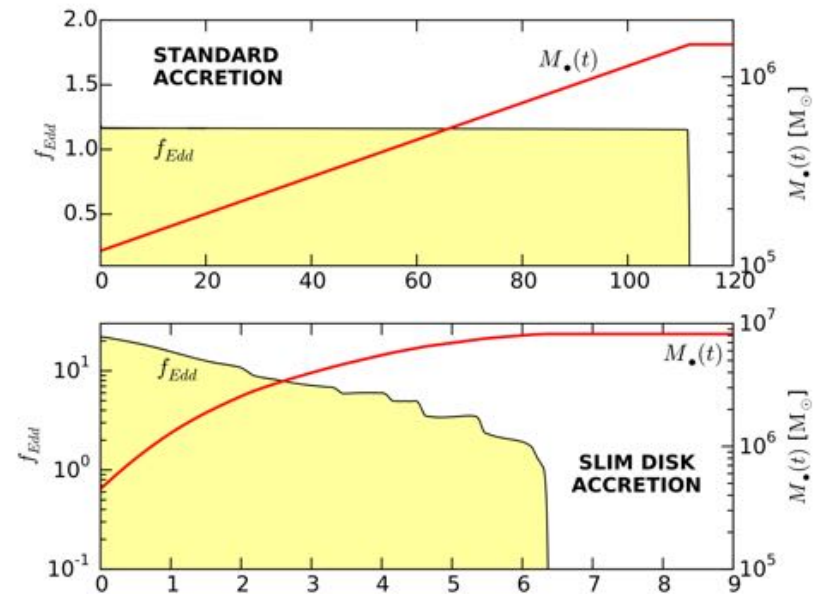Can expect to constrain observationally the population of first SMBH seeds, so that can pin down growth models.

Seeds of SMBHs with X-ray Surveyor

e.g., Volonteri et al. (2015)

Low-mass seeds with ~ uninterrupted rapid accretion?

Massive seeds from direct-collapse black holes?

Is super-Eddington growth of seeds possible?

Figure 2. Time evolution of the Eddington ratio f_{Edd} and of the black hole mass $M_\bullet$, in the standard case, where $L = f_{Edd} L_{Edd}$ (top) and the slim disc case, where $L \sim \ln(f_{Edd}) L_{Edd}$ (bottom), so that luminosity remains sub-Eddington, while accretion is super-critical.

Seeds of SMBHs with X-ray Surveyor

The behavior of the high-redshift X-ray luminosity function (XLF) at the faint end will be key for insights into seed-growth models.

Growth from light seeds should lead to a large number of faint high-redshift AGN fueled by accretion onto low-mass BH.

For heavy seeds, AGNs can more easily reach luminosities close to L_*, producing a flatter faint end of XLF.

Our stacking-analysis constraints suggest a fairly flat end of the XLF.

Improved quantitative predictions of XLF behavior for different seed models will be most helpful. As well as other observables that can distinguish light vs. heavy seeds.

Some Additional X-ray Surveyor High-Redshift Science

Protoclusters and protogroups around high-redshift AGNs.

High-redshift jet imaging.

GB 1428+4217, z=4.72
Jet
Cheung et al. (2012)
Chandra-VLA
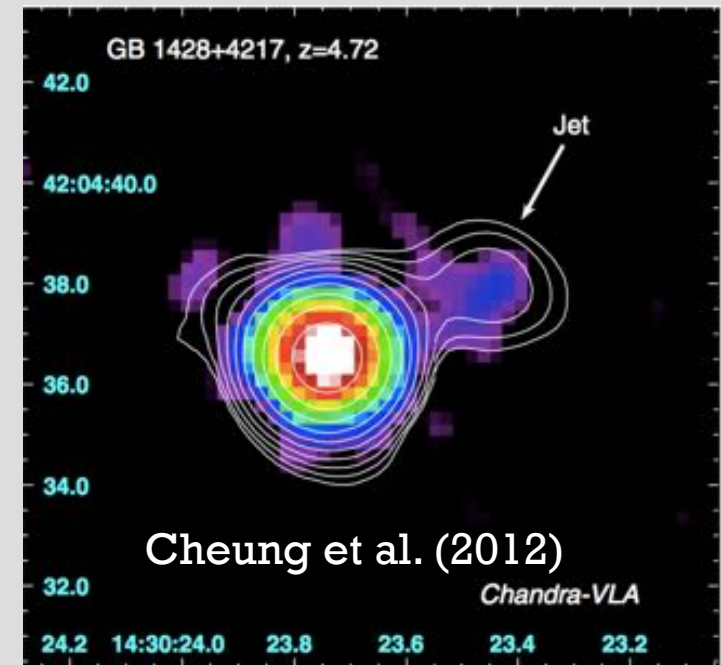
Wind spectroscopy for feedback assessment.