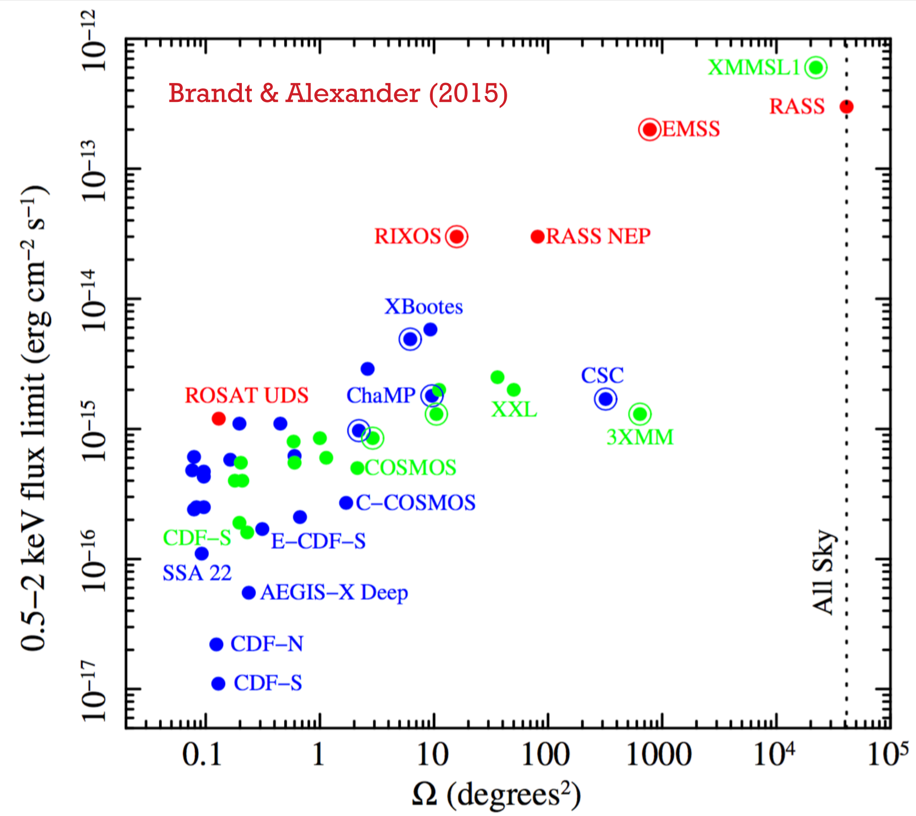
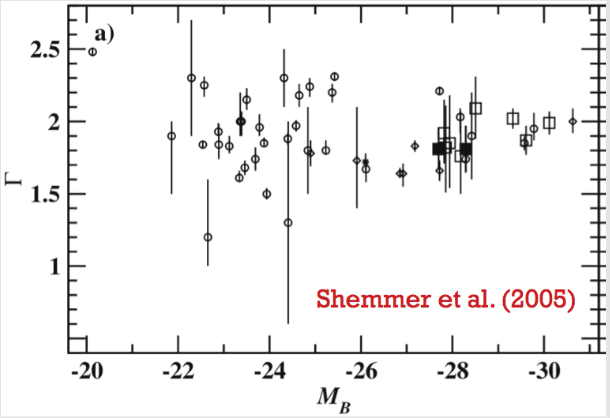
High-Redshift AGNs and the Next Decade of XMM-Newton

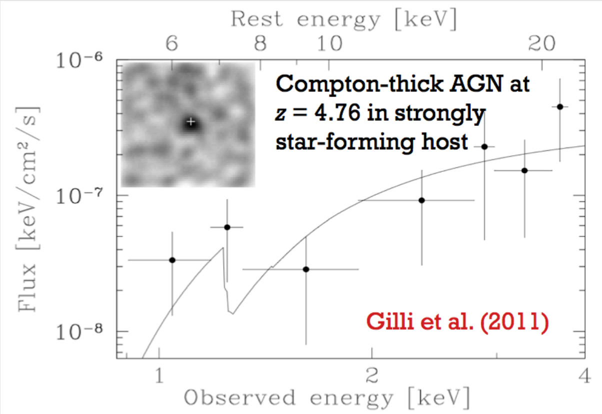
Niel Brandt (Penn State)

Demographics and Surveys



X-ray Spectroscopy





Current Observational Status

Over the past ~ 16 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.

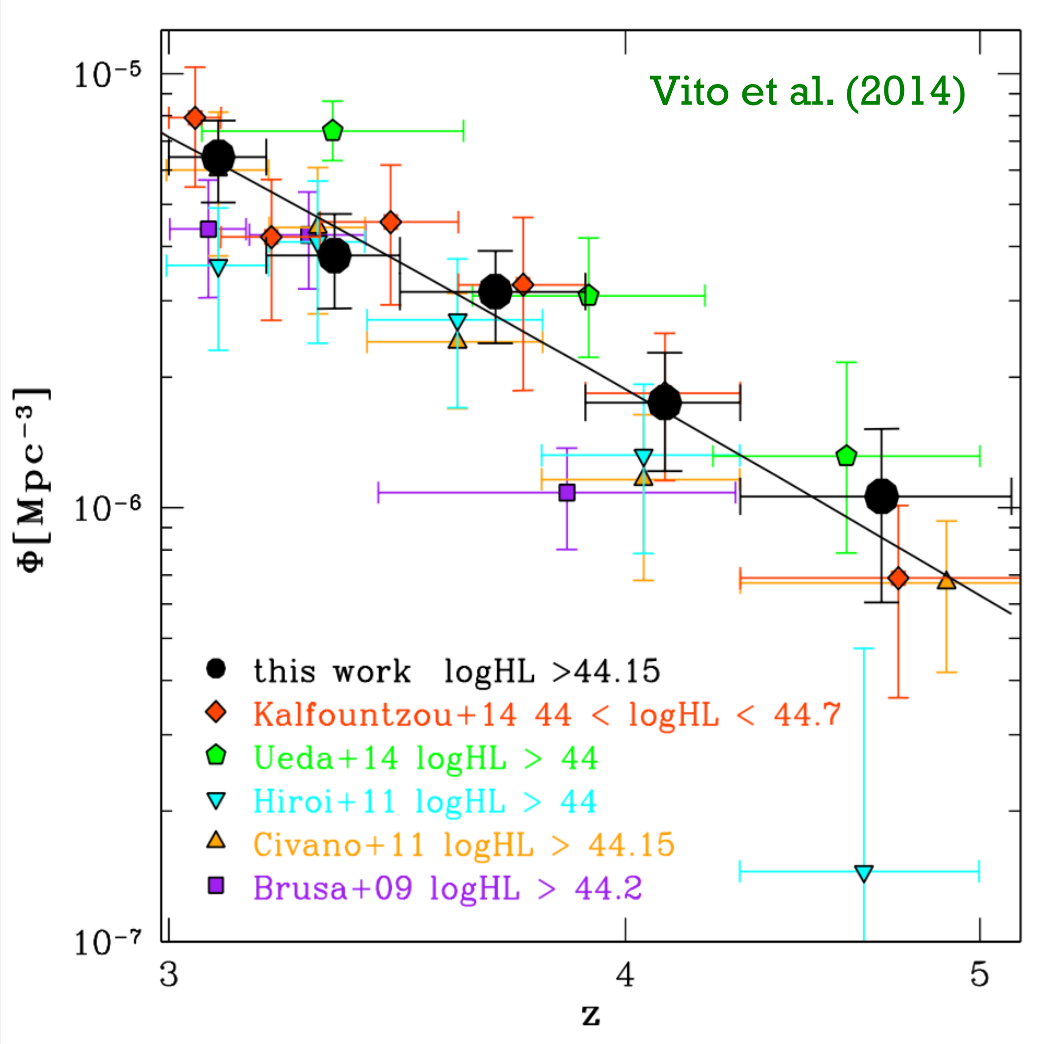
X-ray follow-up of high-redshift AGNs first found in other multiwavelength surveys; e.g., SDSS, PSS, FIRST.

X-ray selected high-redshift AGNs in X-ray surveys.

Now have 153 X-ray detections at z = 4-7 (according to Brandt & Vignali 2016 public list), allowing reliable basic X-ray population studies out to the reionization era.

Demographics and Surveys

Space Density Declines for High-Luminosity X-ray AGNs



In contrast to early suggestions from ROSAT, clearly see ~ exponential decline for luminous X-ray selected AGNs at $z > 3$.

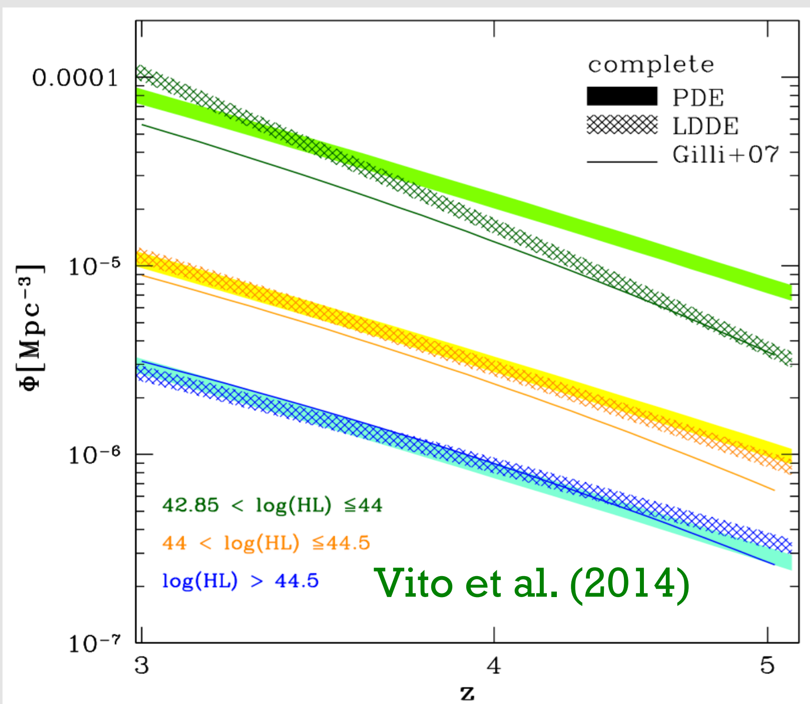
$\Phi \propto (1 + z)^p$ with p = -6.0 +/- 0.8

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

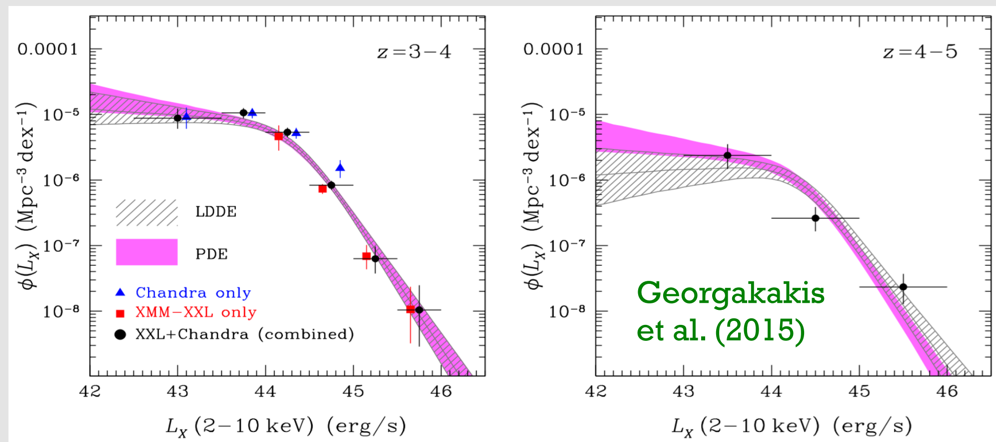
Space Density at z ~ 3-5 for Moderate-Luminosity X-ray AGNs

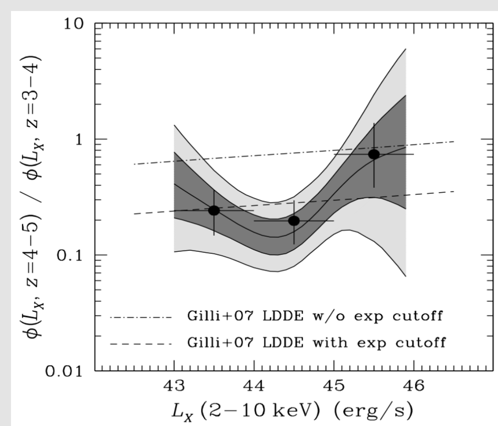
Remaining debate here – small samples, follow-up and completeness tough, results can depend on analysis details.

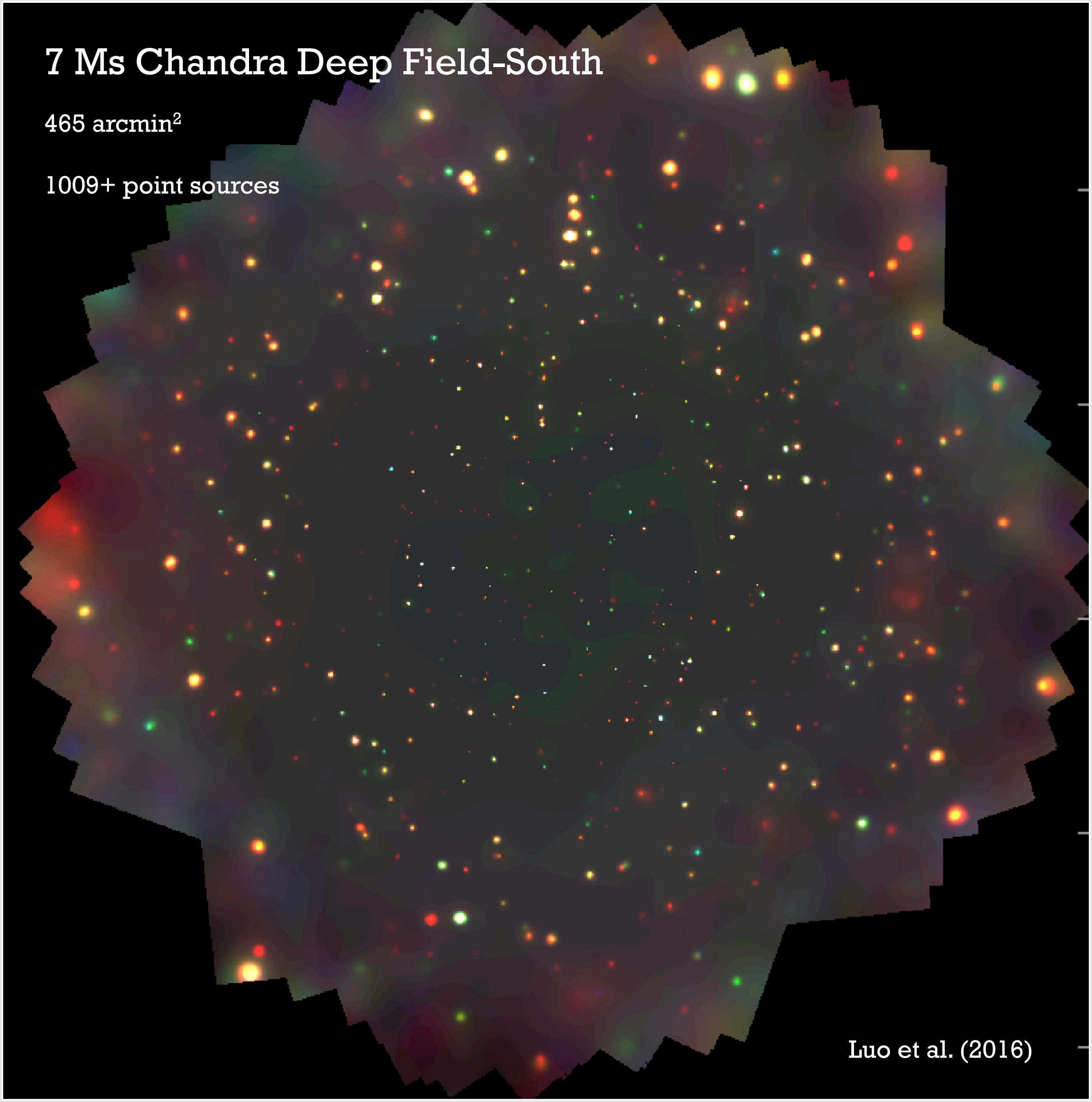
Similar Decline at Moderate Luminosities as at High Luminosities?



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






7 Ms Chandra Deep Field-South
465 arcmin^2
1009+ point sources
Luo et al. (2016)

Chandra Deep Field-South Stacking

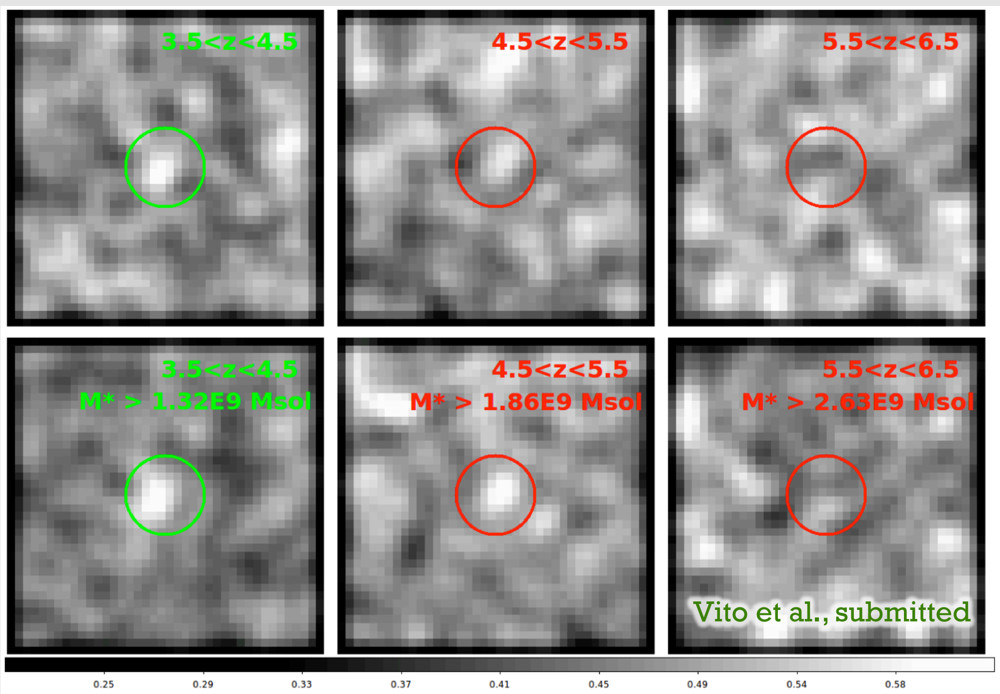
X-ray stacking of individually undetected galaxies (100-1300) can provide average X-ray detections to $z \sim 4.5+$, and useful upper limits at higher redshifts.

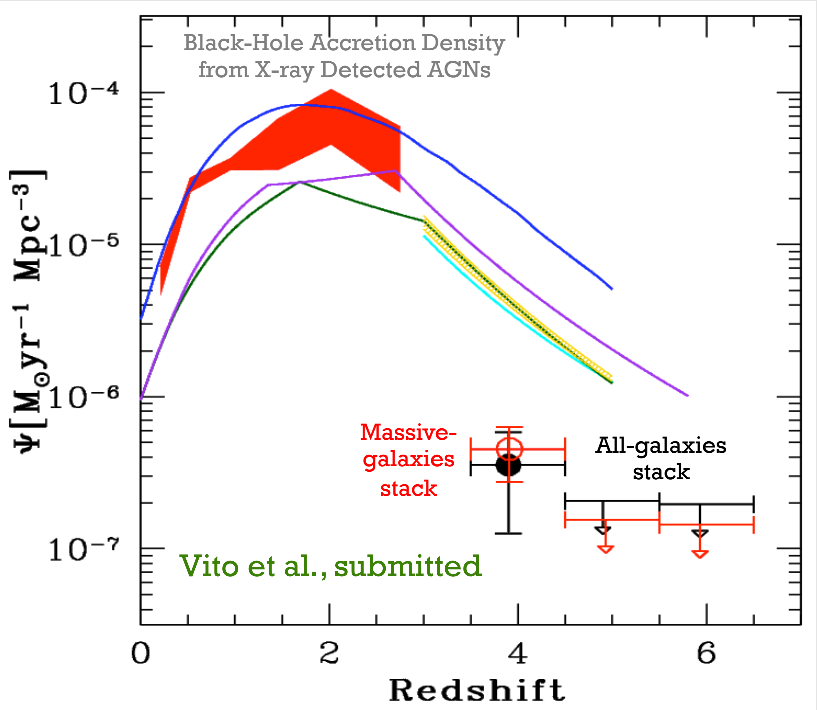
Much, and perhaps all, of the observed flux can be plausibly attributed to X-ray binaries.

Most high-redshift SMBH accretion occurs in short AGN phase – continuous low-rate accretion contribution appears small.

Collectively, surveys indicate that AGNs unlikely to drive reionization at $z \sim 6$.

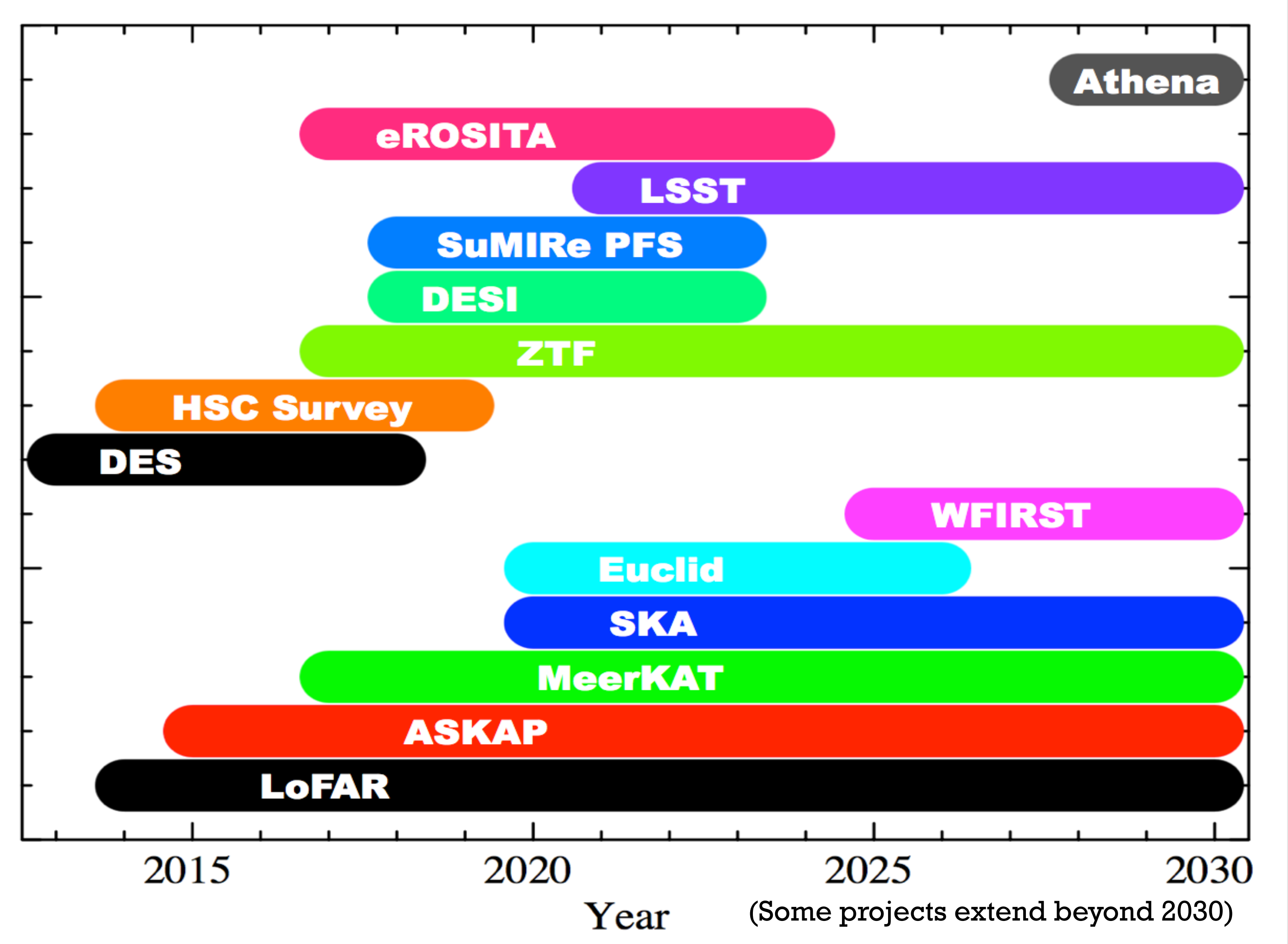
0.5-6 Gs Observations of *Average* High-Redshift Galaxies





Some Future Large Survey Projects

Next Decade of XMM-Newton



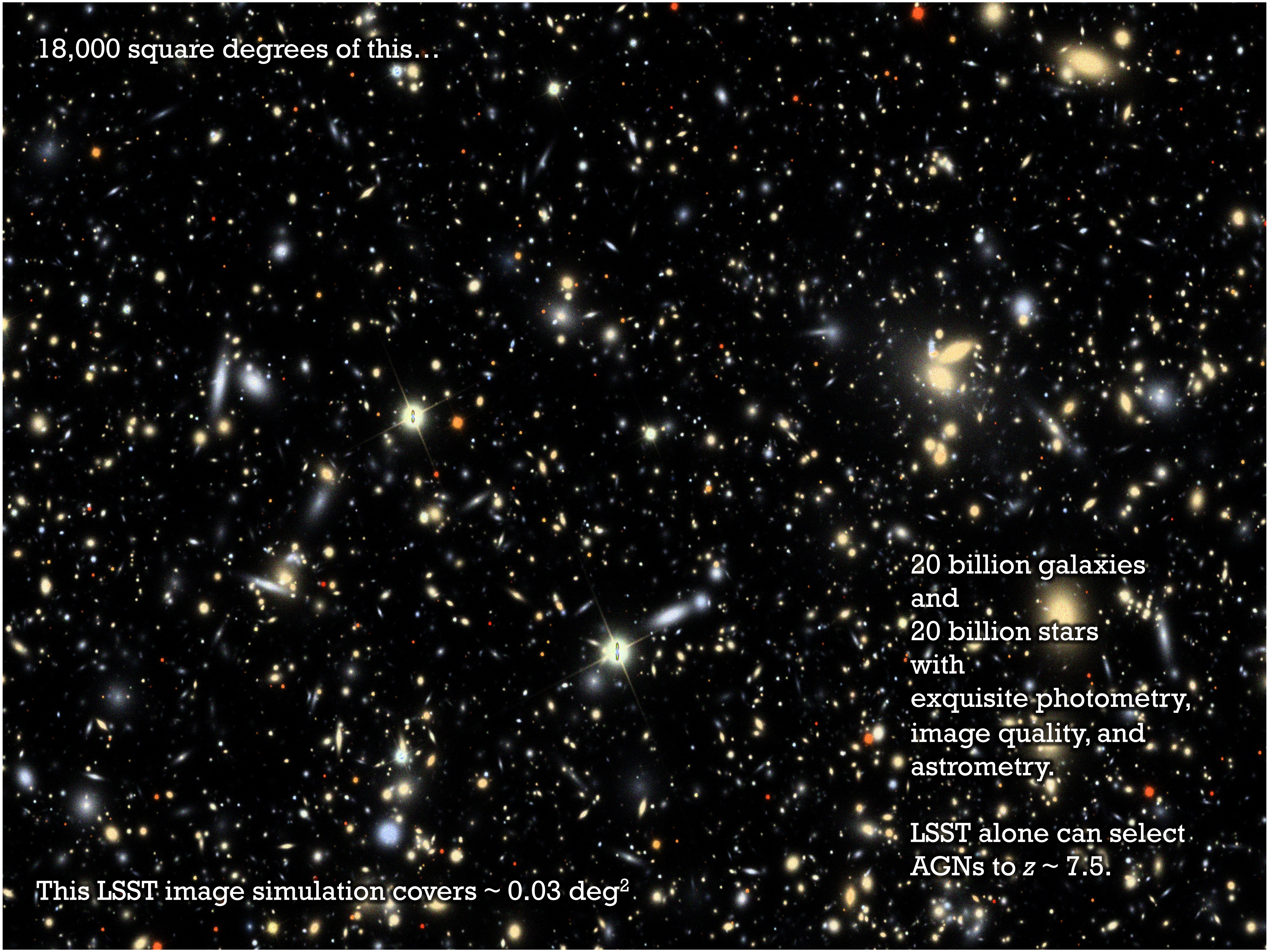
Note relation to LSST, HSC, DES, Euclid, WFIRST.

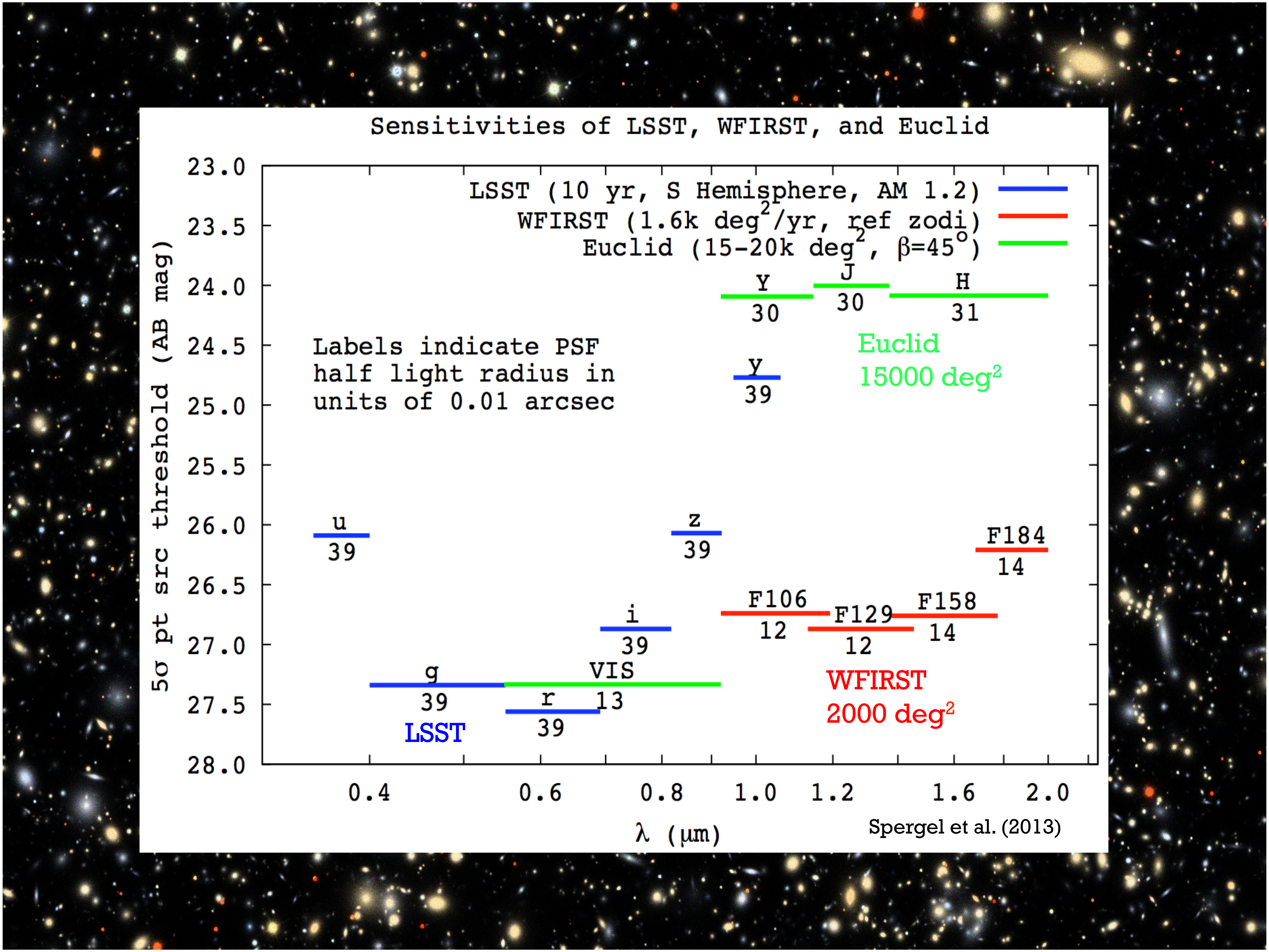
LSST Becoming Real!

M1M3 after polishing - in storage in Tucson, and soon will be joined to mirror cell.

Members of the CD-3 Review Committee gathered with the members of the LSST Camera Team at the CD-3 Review held at Brookhaven National Laboratory on August 4-6, 2015. Image credit: LSST Project Office

LSST support building - 3rd floor under construction

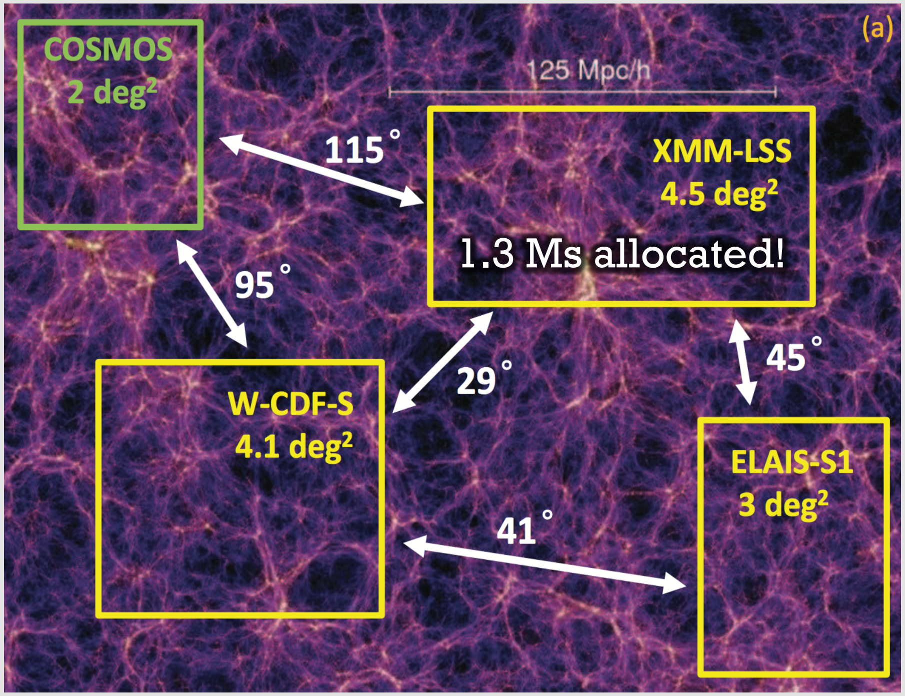

18,000 square degrees of this…
20 billion galaxies
and
20 billion stars
with
exquisite photometry,
image quality, and
astrometry.
LSST alone can select
AGNs to $z \sim 7.5$.
This LSST image simulation covers ~ 0.03 deg^2



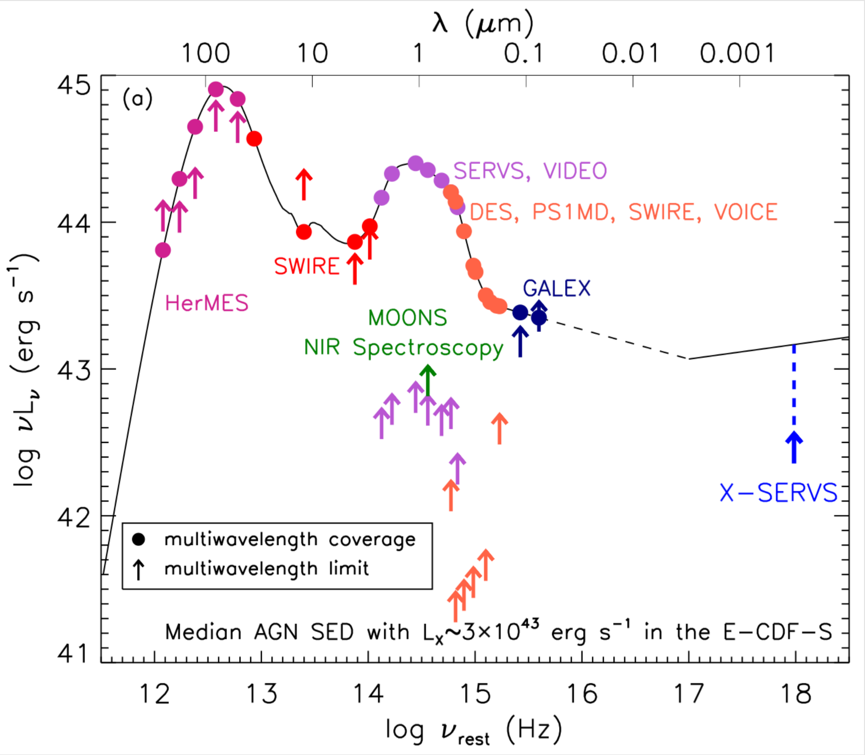
Sensitivities of LSST, WFIRST, and Euclid
LSST (10 yr, S Hemisphere, AM 1.2)
WFIRST (1.6k deg²/yr, ref zodi)
Euclid (15-20k deg², β=45°)
Labels indicate PSF half light radius in units of 0.01 arcsec
5σ pt src threshold (AB mag)
λ (μm)
23.0
23.5
24.0
24.5
25.0
25.5
26.0
26.5
27.0
27.5
28.0
0.4
0.6
0.8
1.0
1.2
1.6
2.0
u
39
g
39
r
39
i
39
z
39
y
39
Y
30
J
30
H
31
VIS
13
F106
12
F129
12
F158
14
F184
14
LSST
Euclid
15000 deg²
WFIRST
2000 deg²
Spergel et al. (2013)

X-SERVS: Need Good X-ray Coverage of LSST Deep-Drilling Fields (40,000 Visits)

X-SERVS Fields



Superb Multiwavelength Data



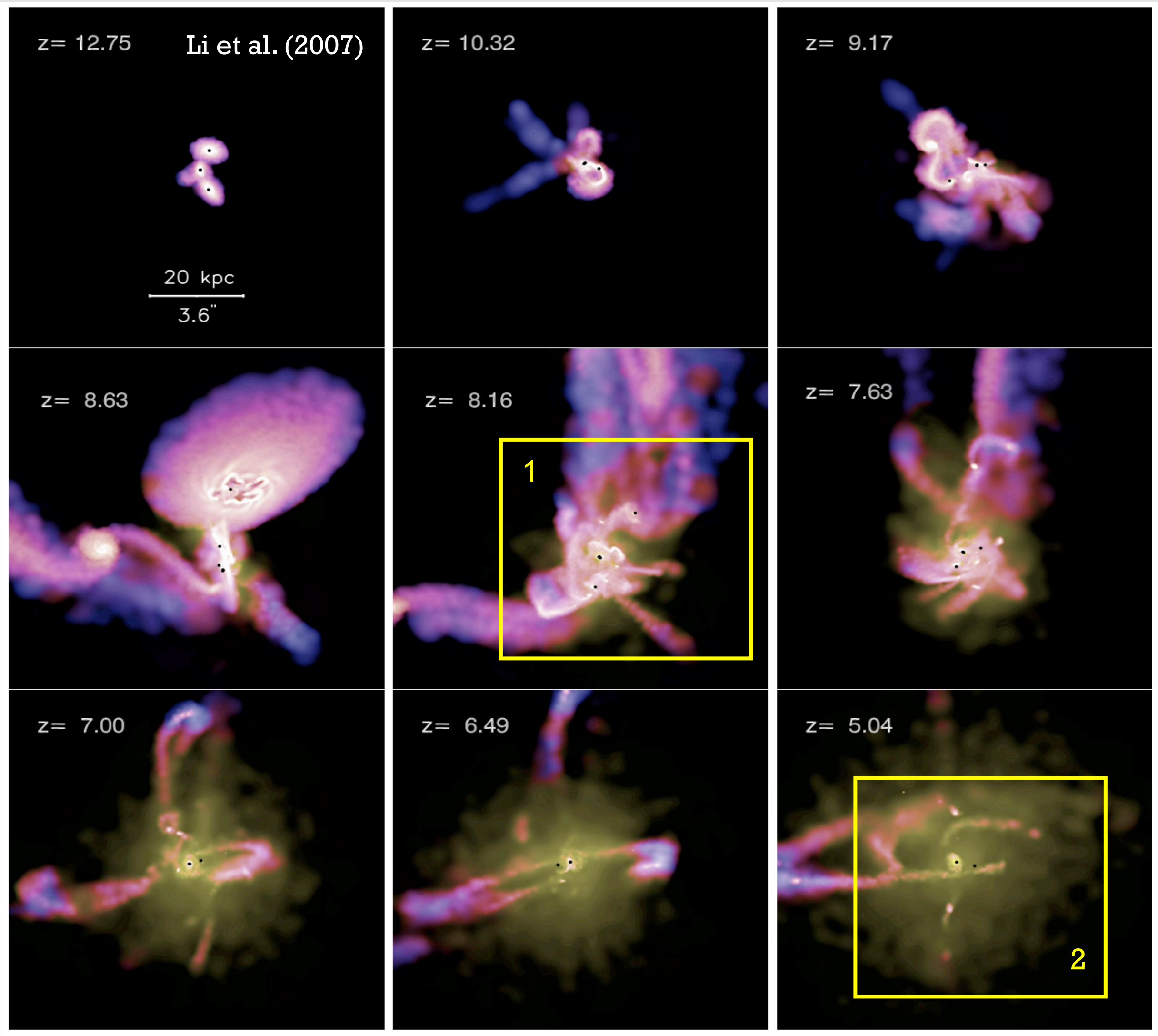
Study SMBH growth across the full range of cosmic environments – voids to massive clusters.

Expect 11,000 AGNs and 760 X-ray groups/clusters.

Incredible legacy value as LSST/DES Deep-Drilling Fields and best multiwavelength fields.

X-ray Spectroscopy

Simulation of the Formation of a $z \sim 6$ Quasar from Hierarchical Galaxy Mergers



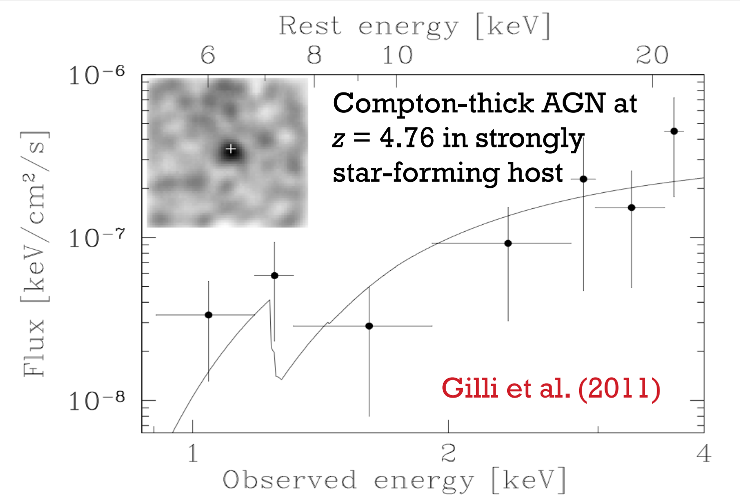
Gas density and temperature for high-redshift quasar host

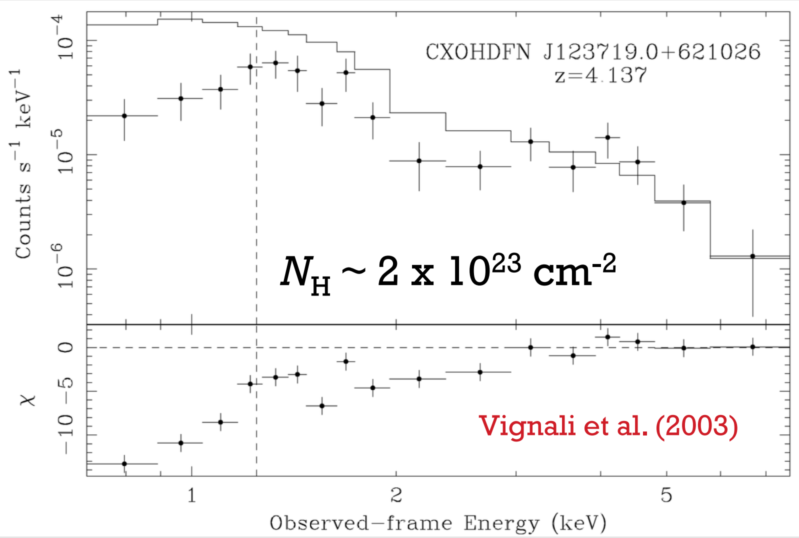
Albeit at somewhat lower redshifts, we observe similar phenomena at $z \sim$ 4-5:

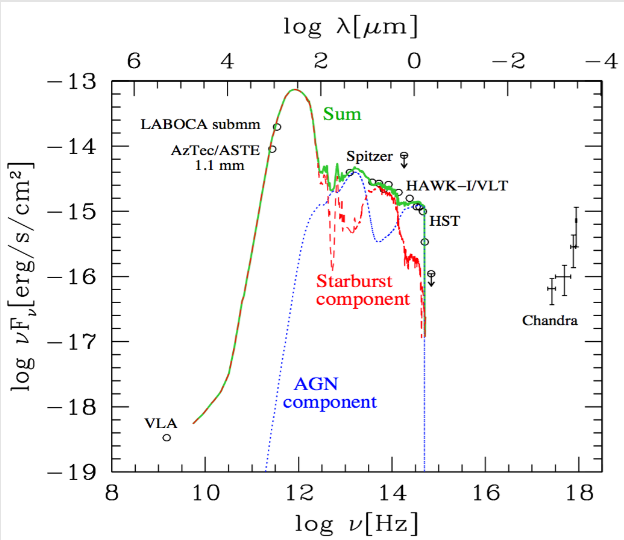
(1) X-ray obscured protoquasars of moderate luminosity.

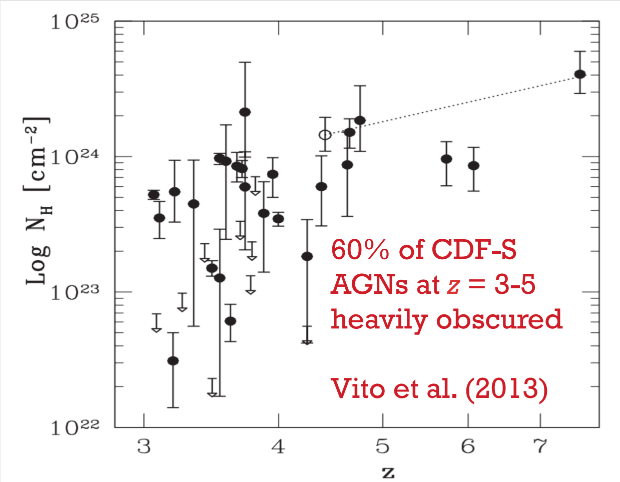
(2) powerful winds from luminous quasars, likely capable of host feedback.

X-ray Obscured Protoquasars of Moderate Luminosity at $z \sim 4$-5

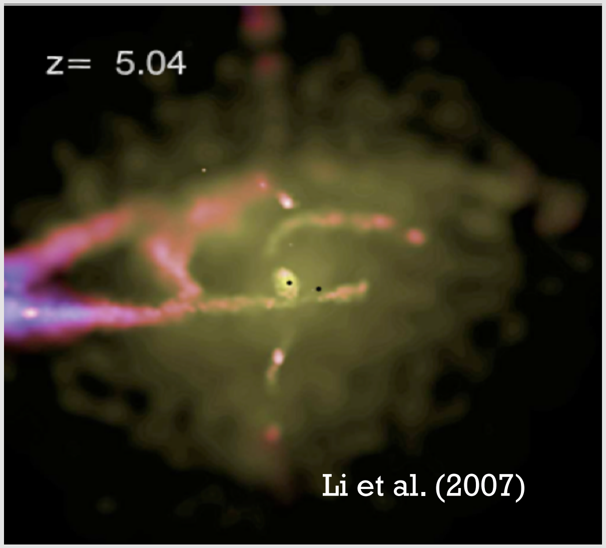




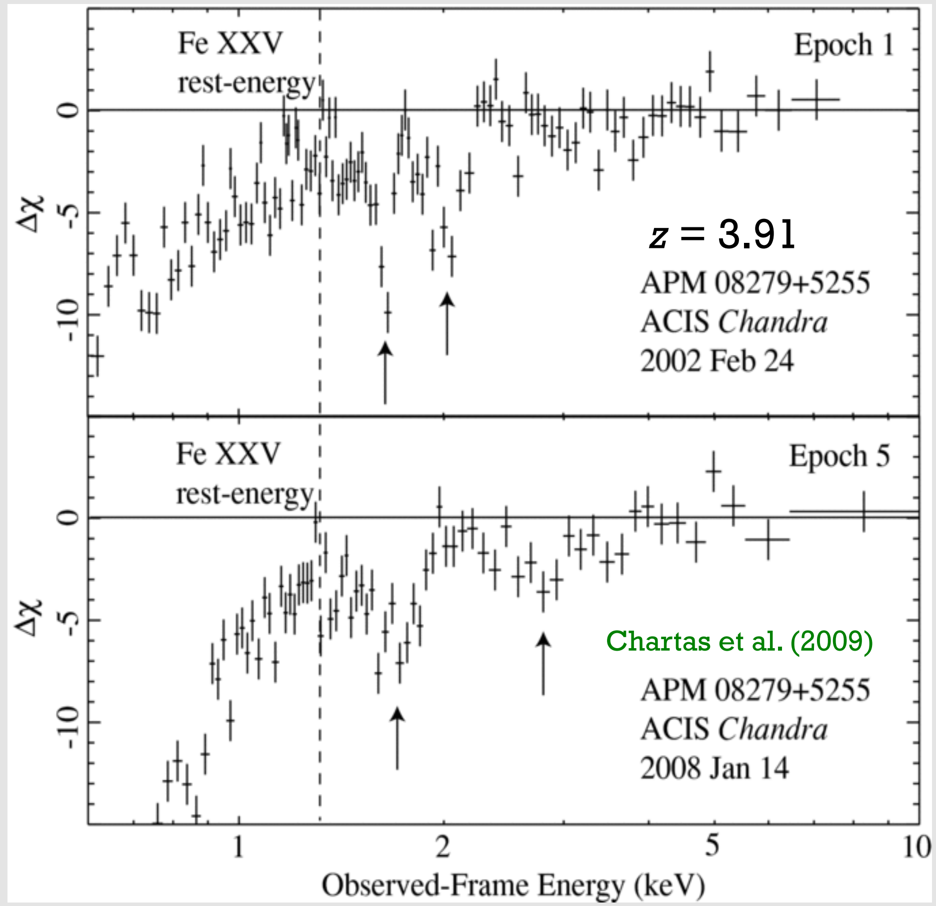




Powerful Winds from Luminous High-Redshift Quasars



X-ray Broad Absorption Lines from Iron K Indicating a Powerful Wind – High-Redshift Feedback in Action?



Implied X-ray velocity is $v \sim 0.2$-$0.4c$.

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

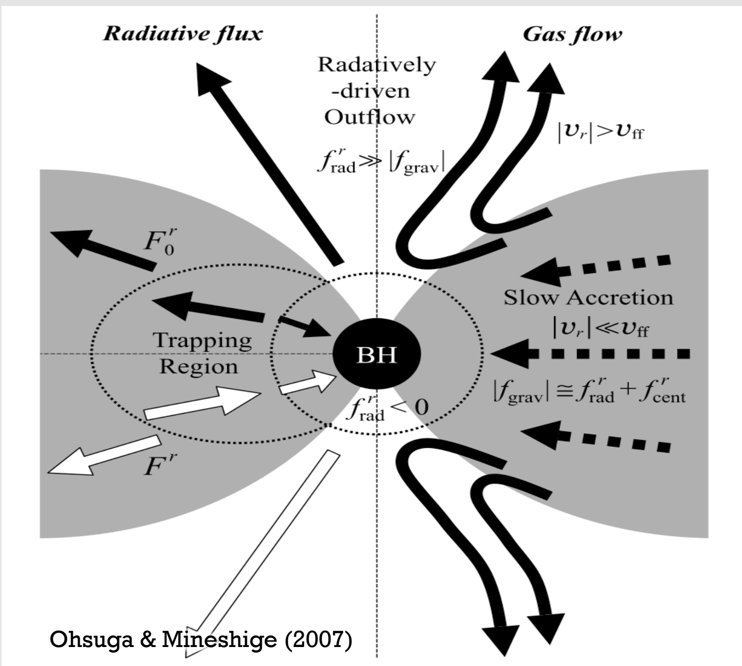
Could be present but undetected in many other high-redshift quasars (had boost from gravitational lensing).

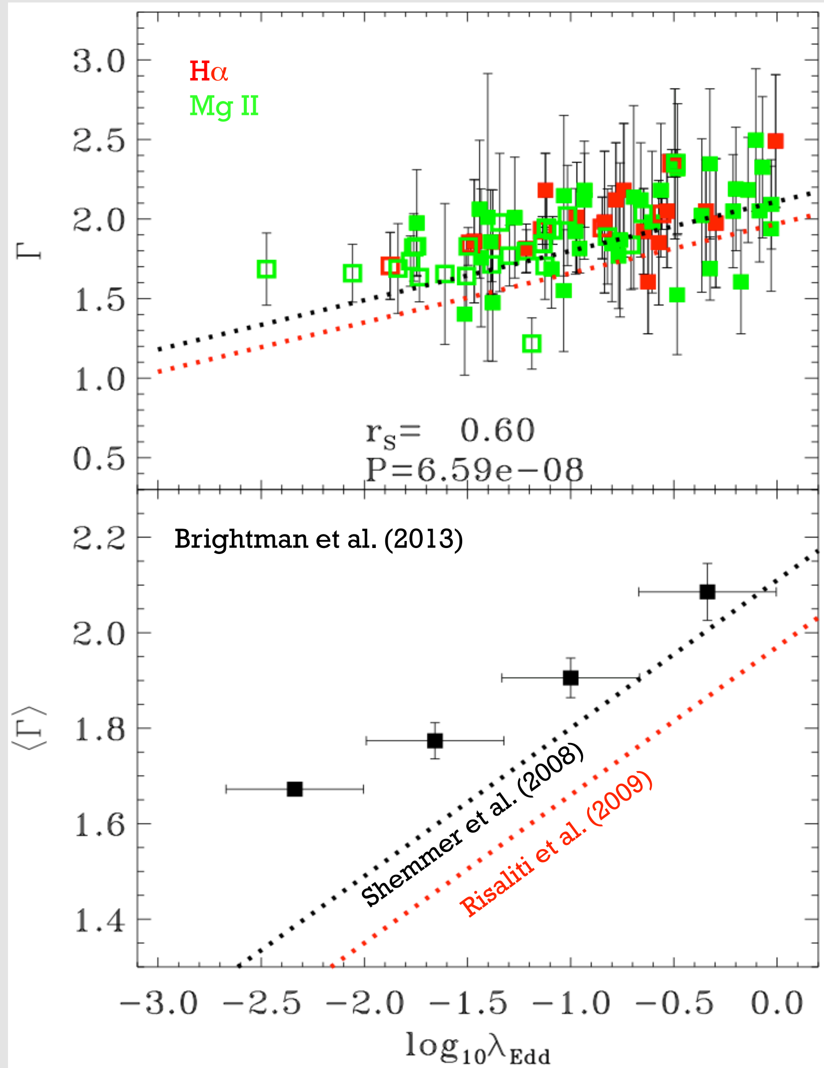
X-ray Continuum and L / L_{Edd}

Theoretically challenging to grow the ~ 10^9 $M_\odot$ SMBHs found at z = 4-7.

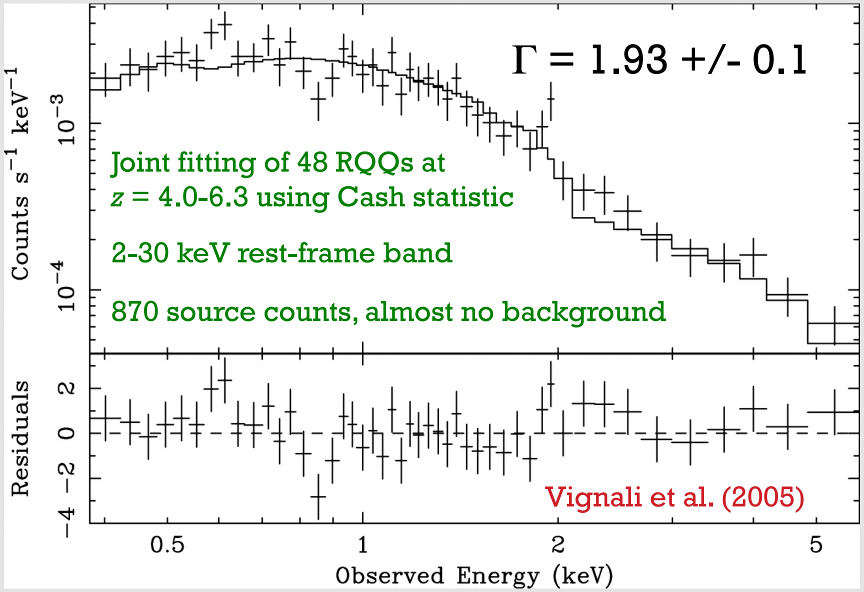
Would like to determine if they are growing via rapid or super-Eddington accretion.

For radio-quiet objects, can use the Γ-λ_{Edd} relation.





Basic Chandra and XMM-Newton Results on X-ray Continuum Shape

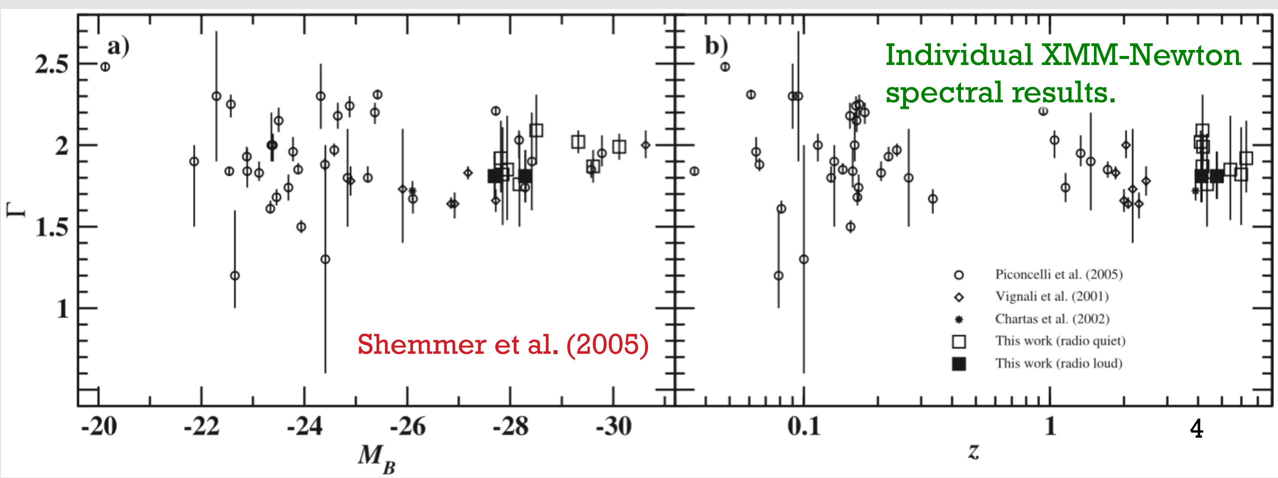


Current studies do not indicate widespread extraordinary L / L_{Edd} for radio-quiet quasars out to $z \sim$ 4-5.5.

Hints of steep X-ray spectra for two $z \sim$ 6-7 quasars – one debated (Farrah et al. 2004; Page et al. 2014; Moretti et al. 2014).

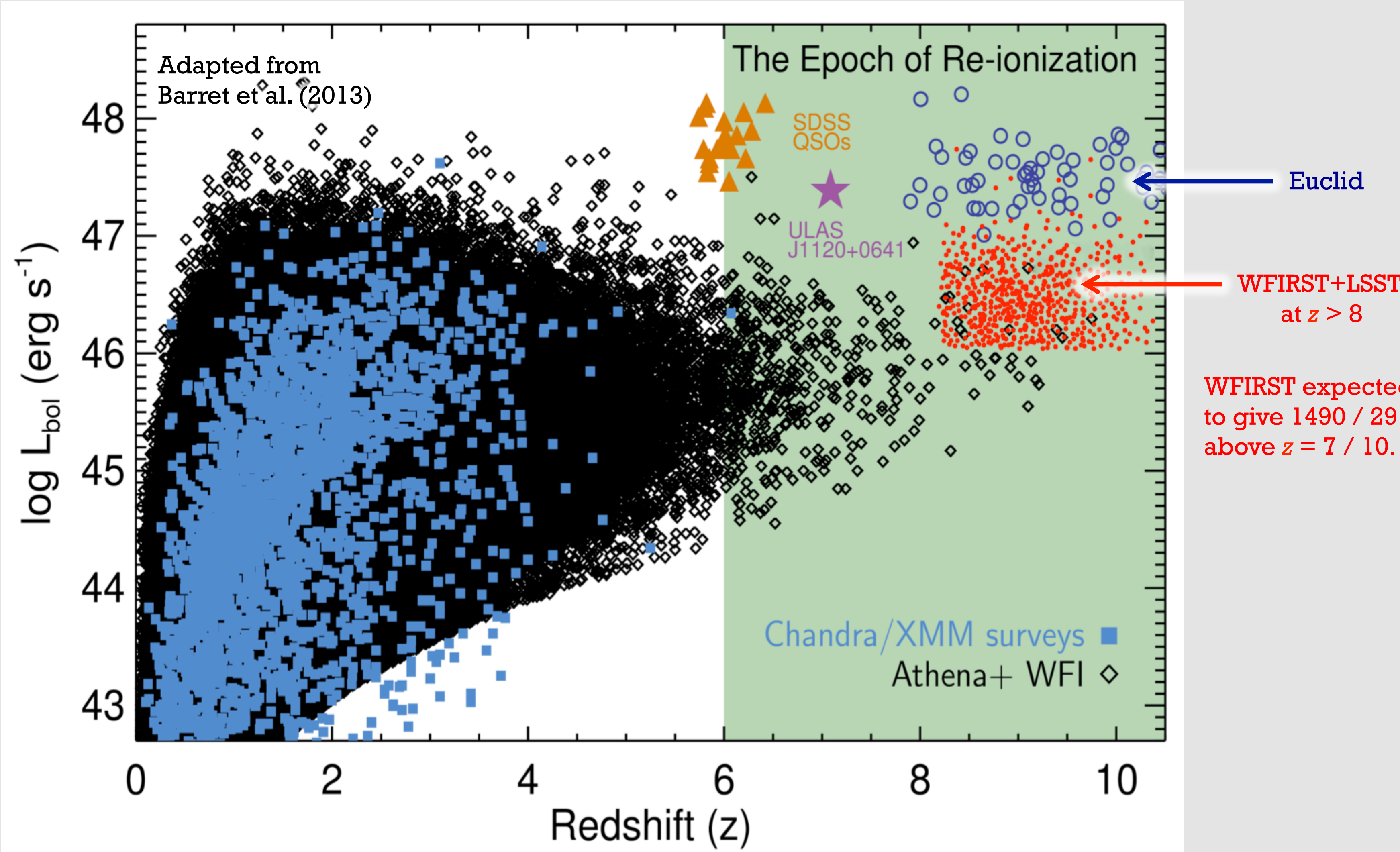
All current studies suffer from limited photon and source statistics.

XMM-Newton could improve the situation and push to higher redshifts.



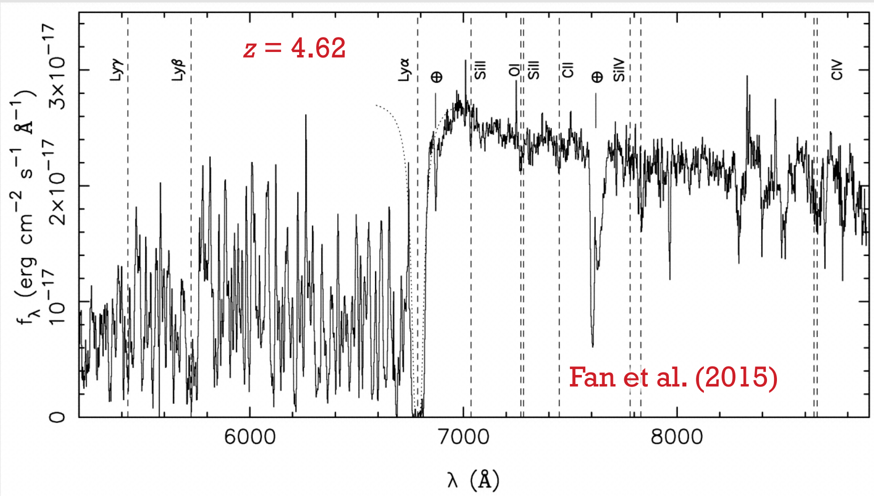
It would be very helpful if background flaring accommodations could be made for faint sources.

XMM-Newton Targets at $z \sim 6$-10 from LSST, Euclid, and WFIRST



WFIRST expected to give 1490 / 29 above z = 7 / 10.

Weak-Line Quasars at High Redshift

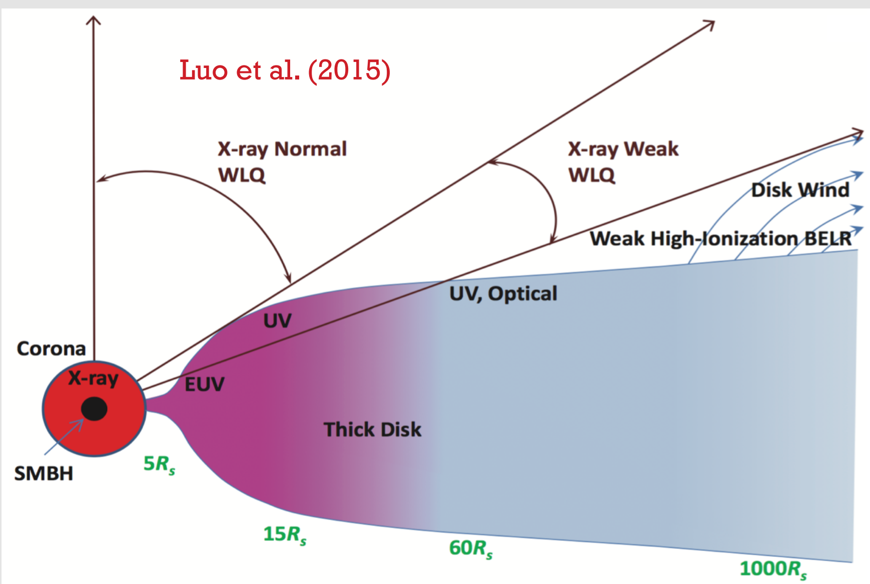


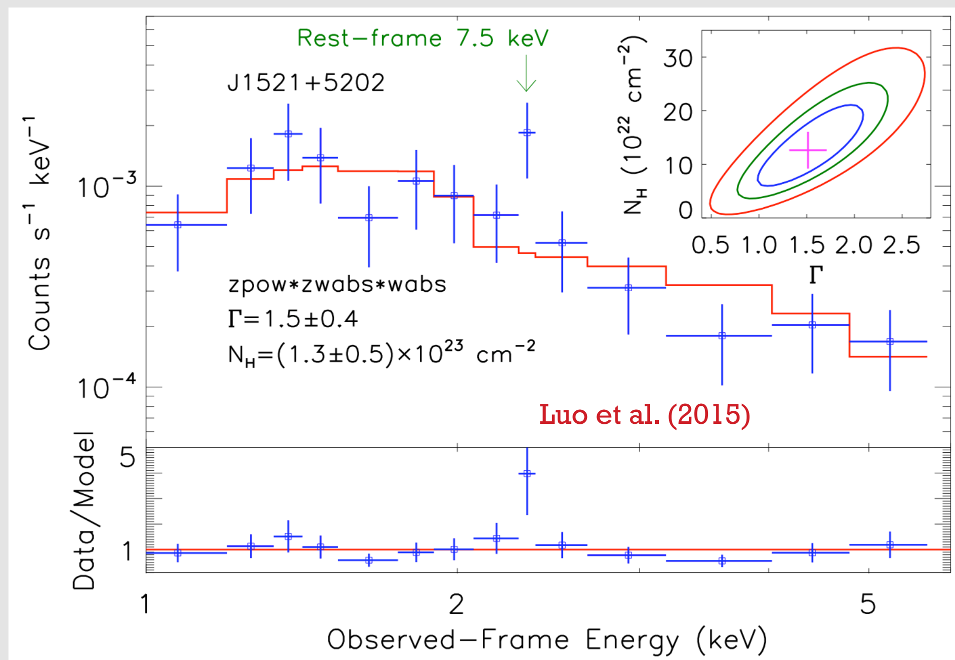
SDSS has now found ~ 400 WLQs at z ~ 1-6.

WLQ fraction may rise toward high redshift.

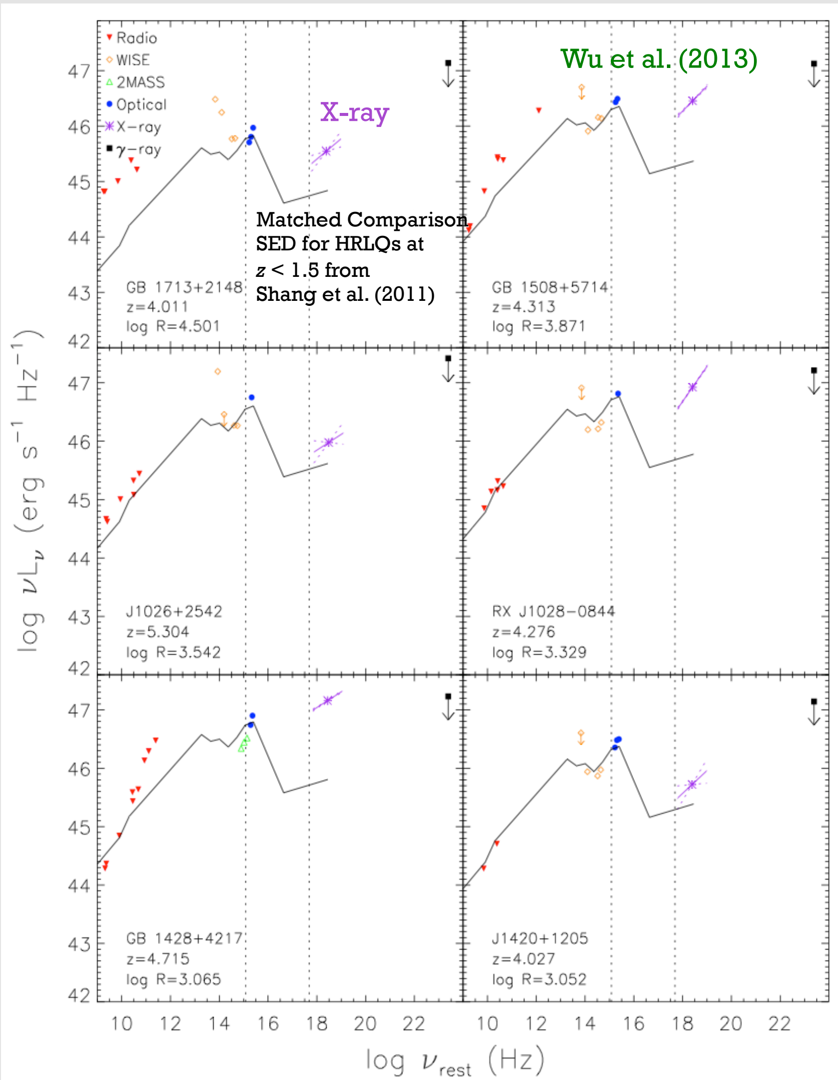
X-ray studies of 51 WLQs support a thick inner disk model due to high $L / L_{\rm Edd}$.

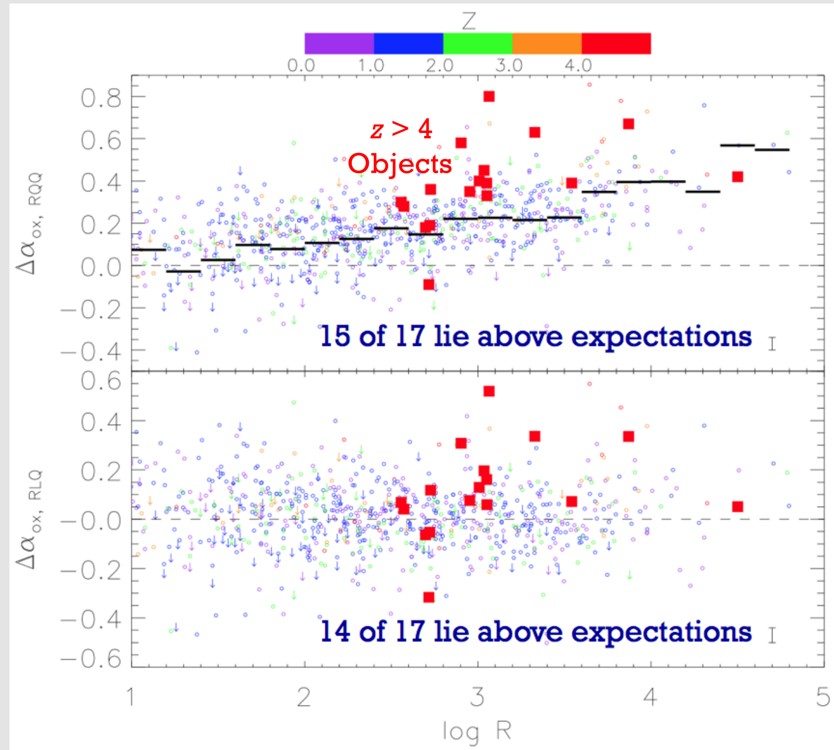
Further X-ray spectroscopy of exceptional WLQs can usefully test the model.





Highly Radio-Loud Quasars Show Evidence for Enhanced Jet-Linked X-ray Emission at z ~ 3-5





HRLQs at z = 3-5 appear 2-3 times X-ray brighter than matched HRLQs at lower redshifts.

Could be IC/CMB growing as $(1+z)^4$, in which case only makes significant contribution at $z > 2$.

Further XMM-Newton spectroscopy needed.

The End