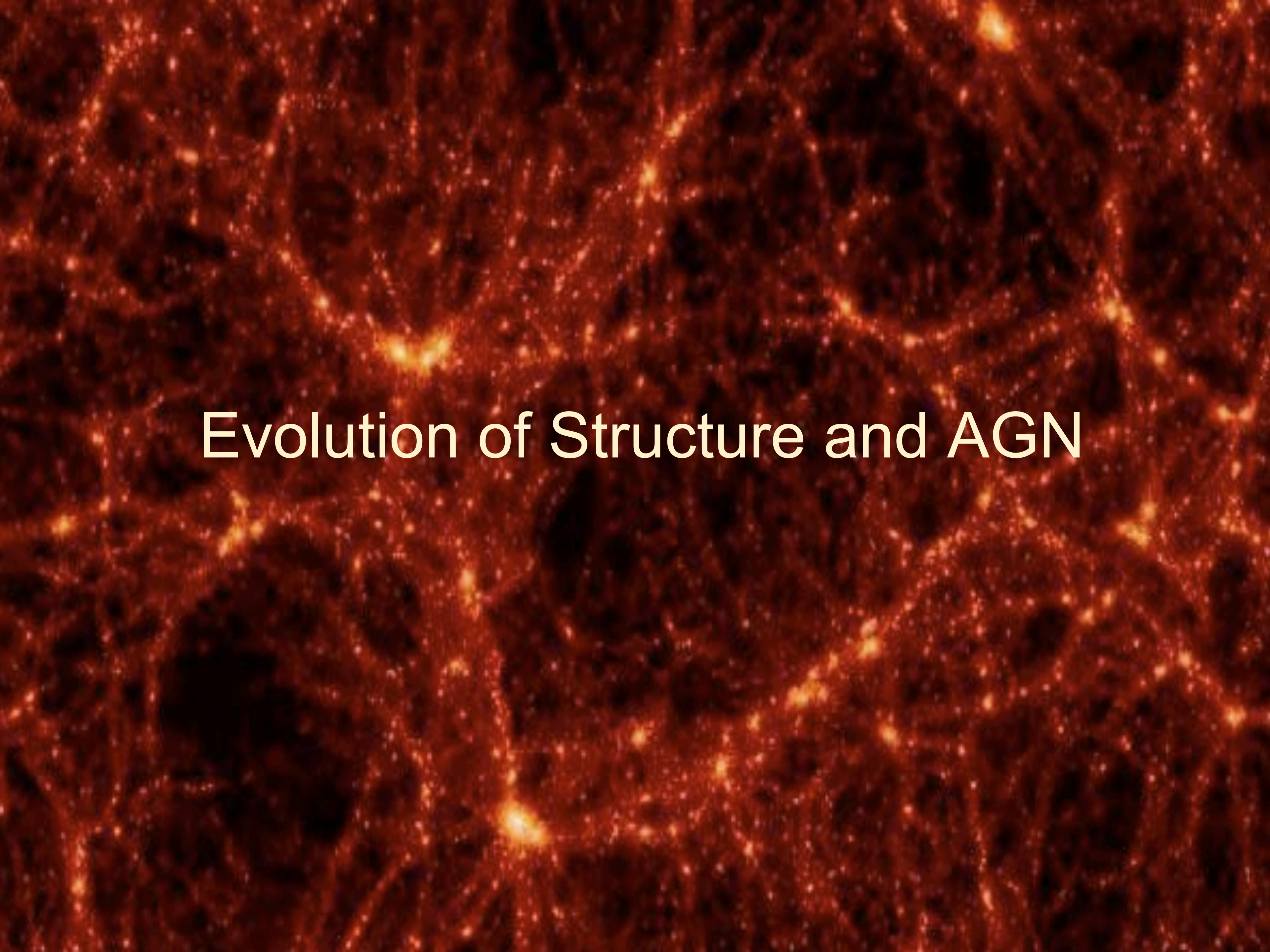


Evolution of Structure and AGN

Major Science Questions

Theme: Unveiling the high-z X-ray universe

- Black hole growth: how does the population of AGN evolve in the field?
- Black holes and LSS: how does the population of AGN evolve in group and cluster environments? (Physics of AGN triggering and quenching, links to SF)
- The first virialized LSS: when did the first galaxy groups appear?
- The fingerprints of feedback: how do the thermodynamic properties of galaxy groups and clusters evolve?
- The history of star formation: what is the enrichment history of the ICM?

Close connections with other WGs

- First Accretion Light (interface at highest *z*)
- Cycles of Baryons: evol. normal gals, brightest WHIM (cluster outskirts).
- Physics of Feedback: jet-ICM interactions/cavity inflation.

Summary of Key Findings

- These are important, far-reaching questions that can help motivate a flagship satellite mission. The science will be **uniquely enabled** by X-ray Surveyor.

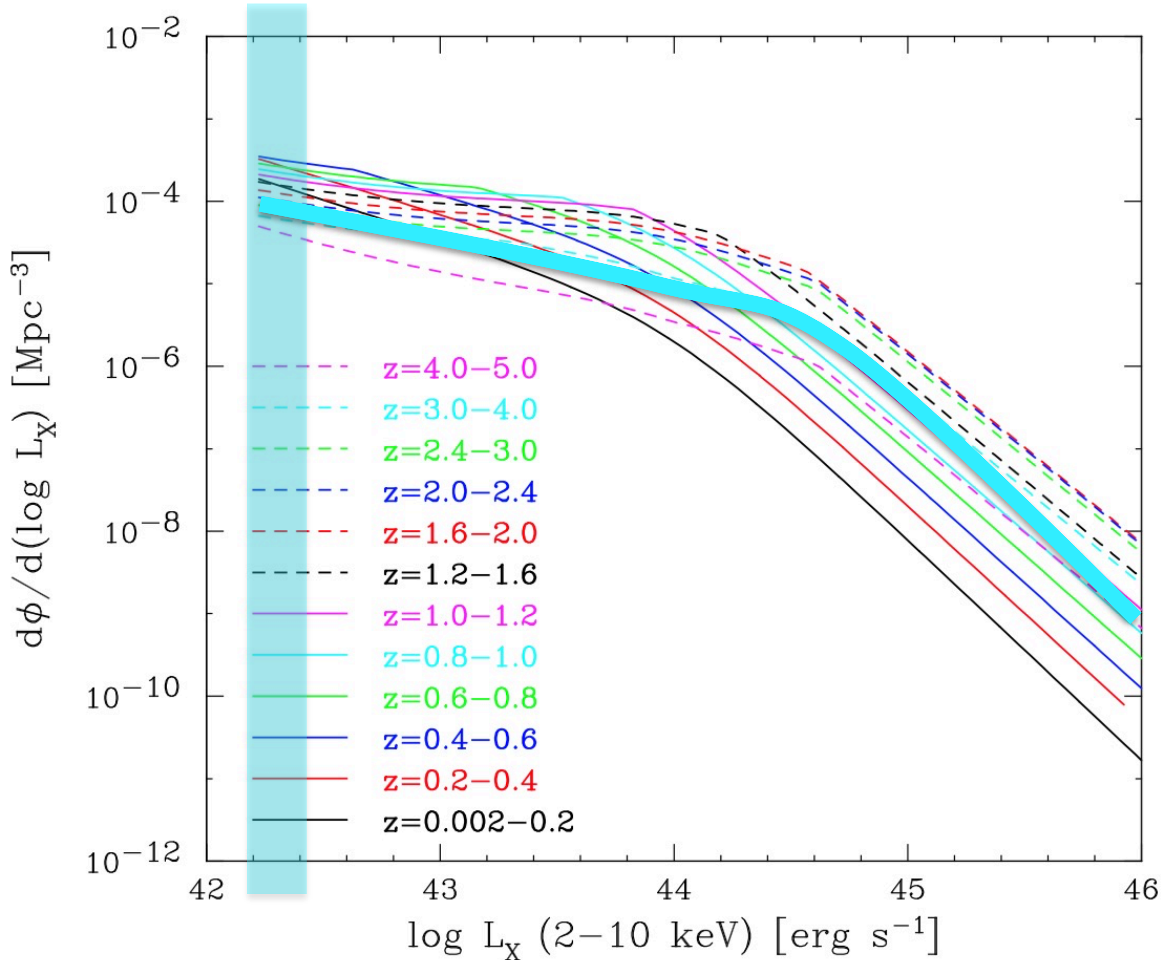
- There will be outstanding synergies on these topics with other major facilities in the 2020s and 30s (LSST, WFIRST, SKA, TMTs, ALMA, CMB-S4 ...)

- The key X-ray Surveyor characteristics that enable this science are the high spatial resolution across wide FOV and large effective area at soft energies.

  Primarily HDXI science, but calorimeter also important.
  Require megaseconds programs to address major questions, although observations will simultaneously address multiple science thrusts.

Black Hole Growth in the High Redshift Universe

Key question: How does the *full* population of growing black holes evolve at the peak epoch of activity and beyond?
Key requirements: Detect obscured AGN and *identify counterparts* to *z*~4 to ~2 orders of magnitude below the "knee" in the XLF.



Ueda et al. (2014)

Black Hole Growth in the High Redshift Universe

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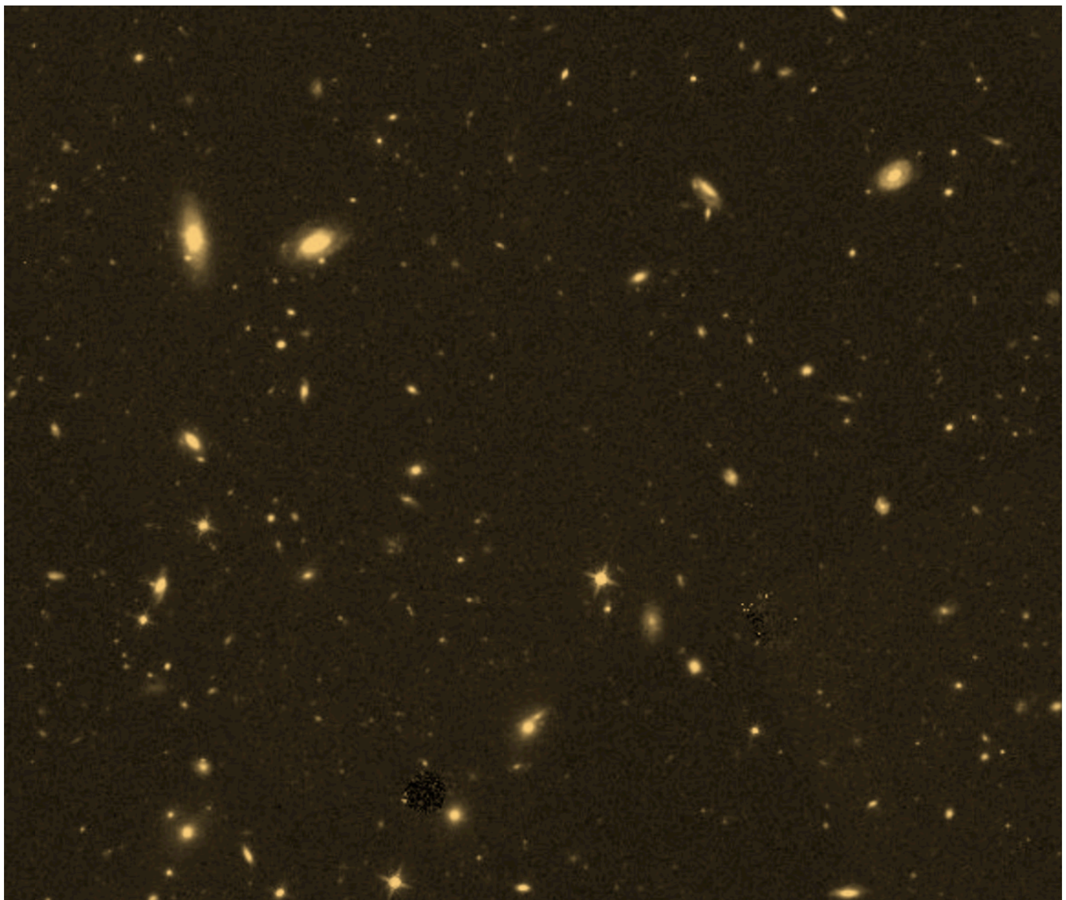


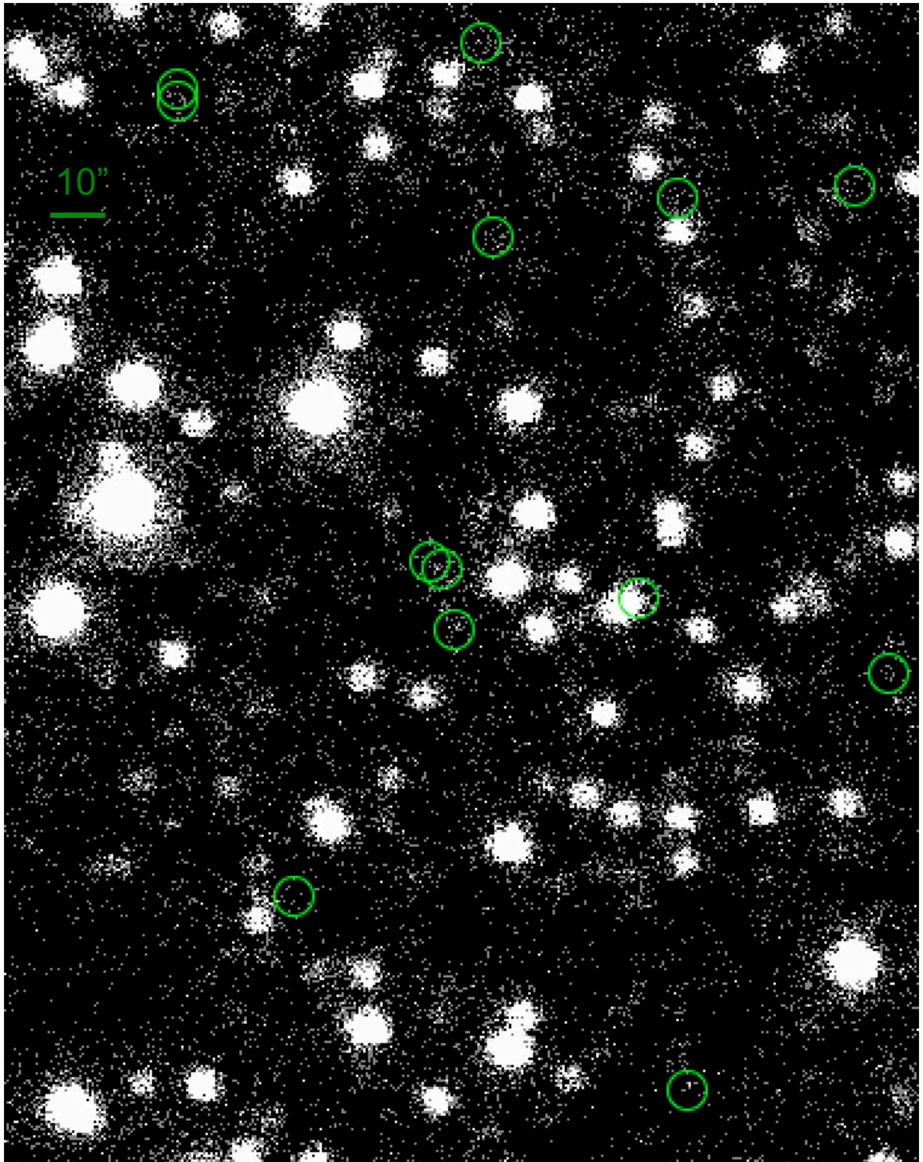
Simulations: Use the positions of HST/CANDELS galaxies in GOODS-S and populate them with X-ray sources consistent with an extrapolation of the known logN-logS

(following Hickox & Markevitch 2007)

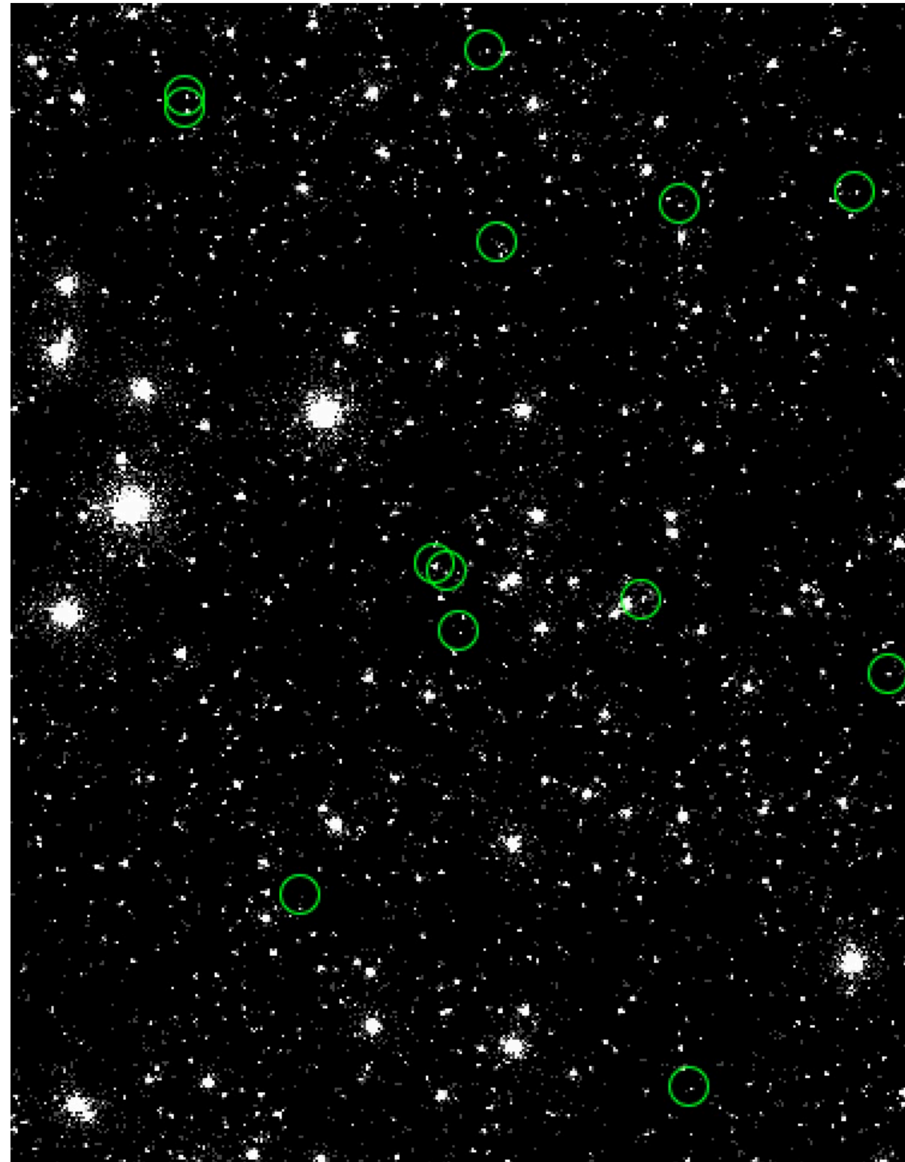
Black Hole Growth in the High Redshift Universe

~4” PSF

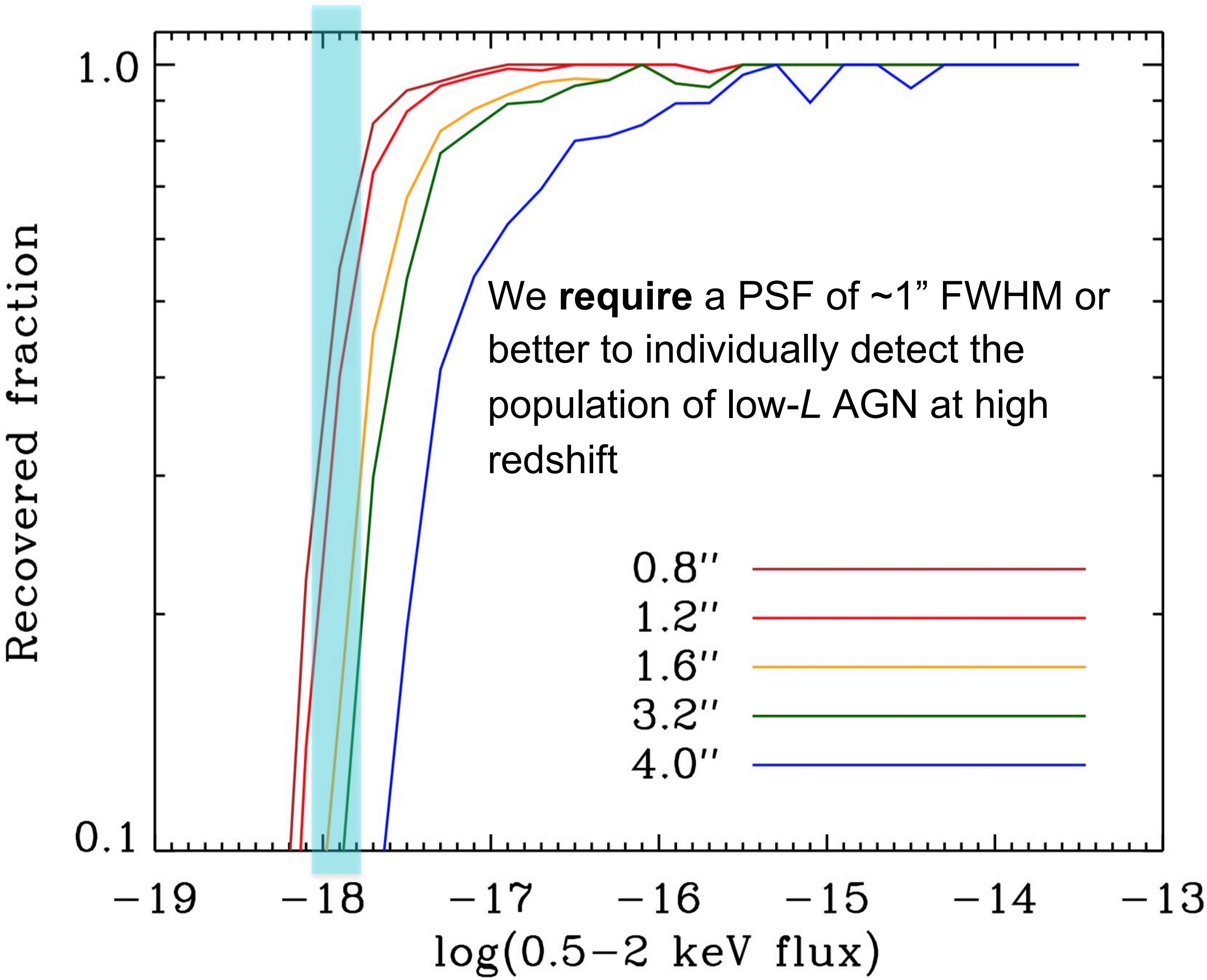
0.35 < z < 4.5 AGN



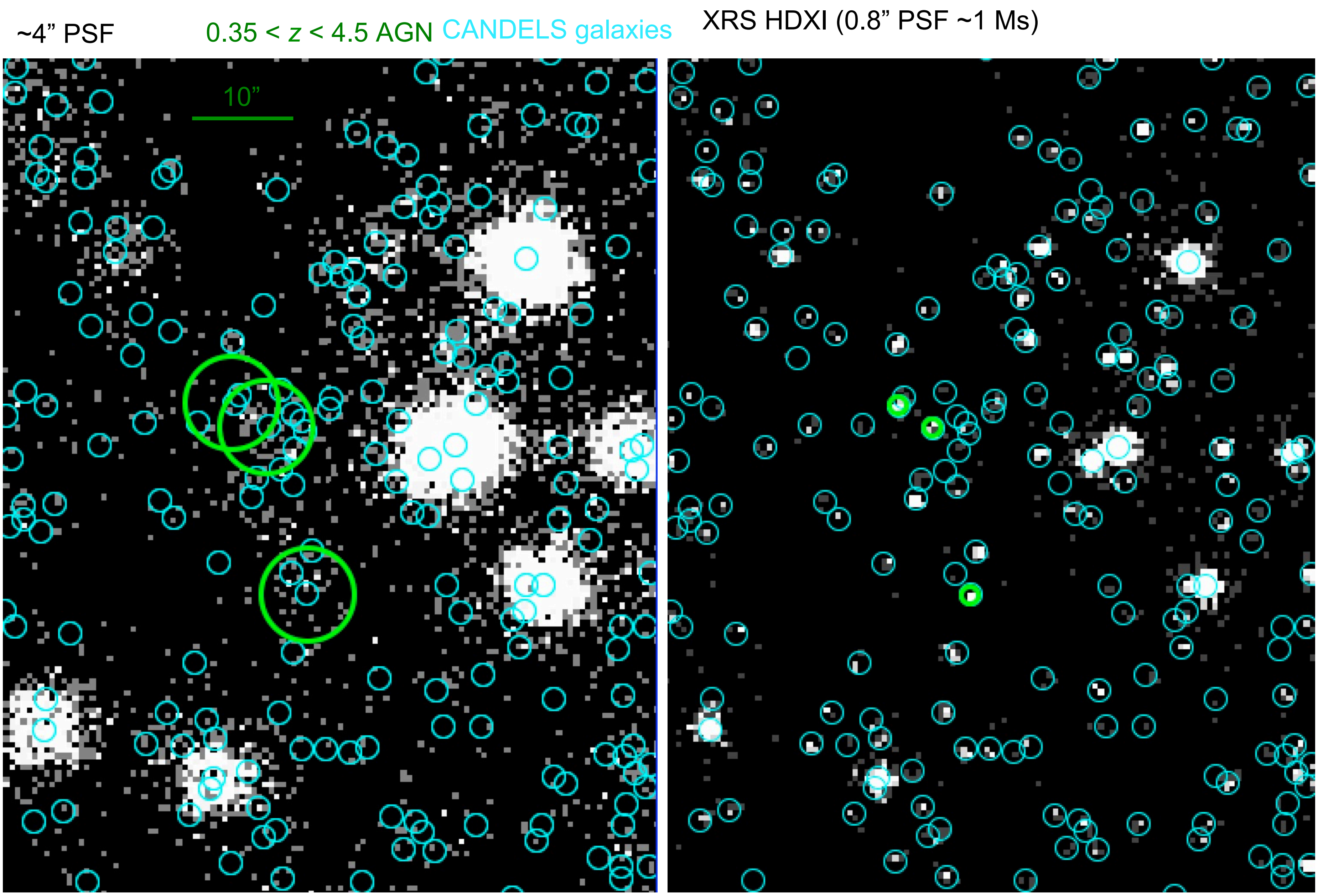
XRS HDXI (0.8” PSF ~1 Ms)



Black Hole Growth in the High Redshift Universe



Black Hole Growth in the High Redshift Universe

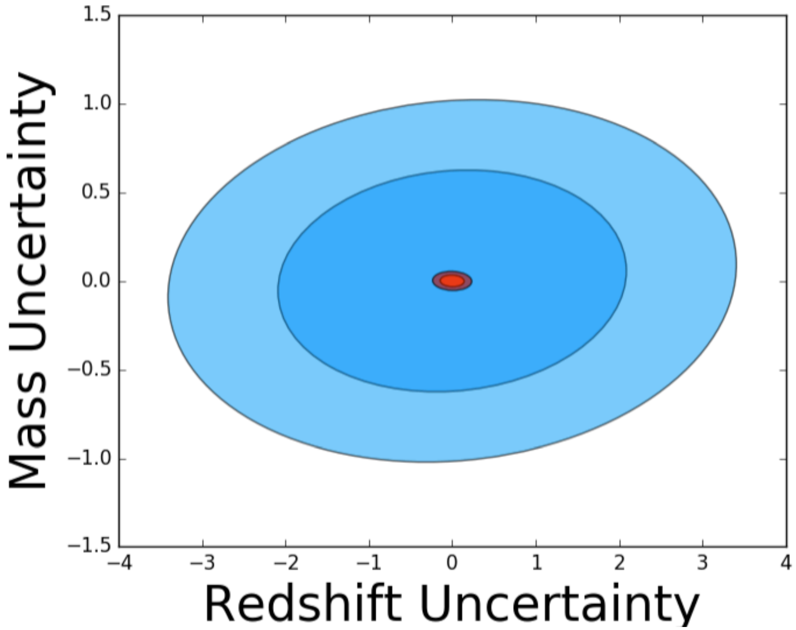


Black Holes and LSS

Key Questions: what quenches/triggers AGN? How does this relate to star formation quenching/triggering in clusters and the field?

Key measurements: density of AGN in clusters vs. field, as fn of flux and cluster redshift, radius and mass. Current constraints on AGN and star formation evolution in clusters $(1+z)^{5.3\pm2}$ and $(1+z)^{5.7\pm2}$ resp. (e.g. Martini+ ‘09; Haines+ ‘09, Ehlert+ ‘15).

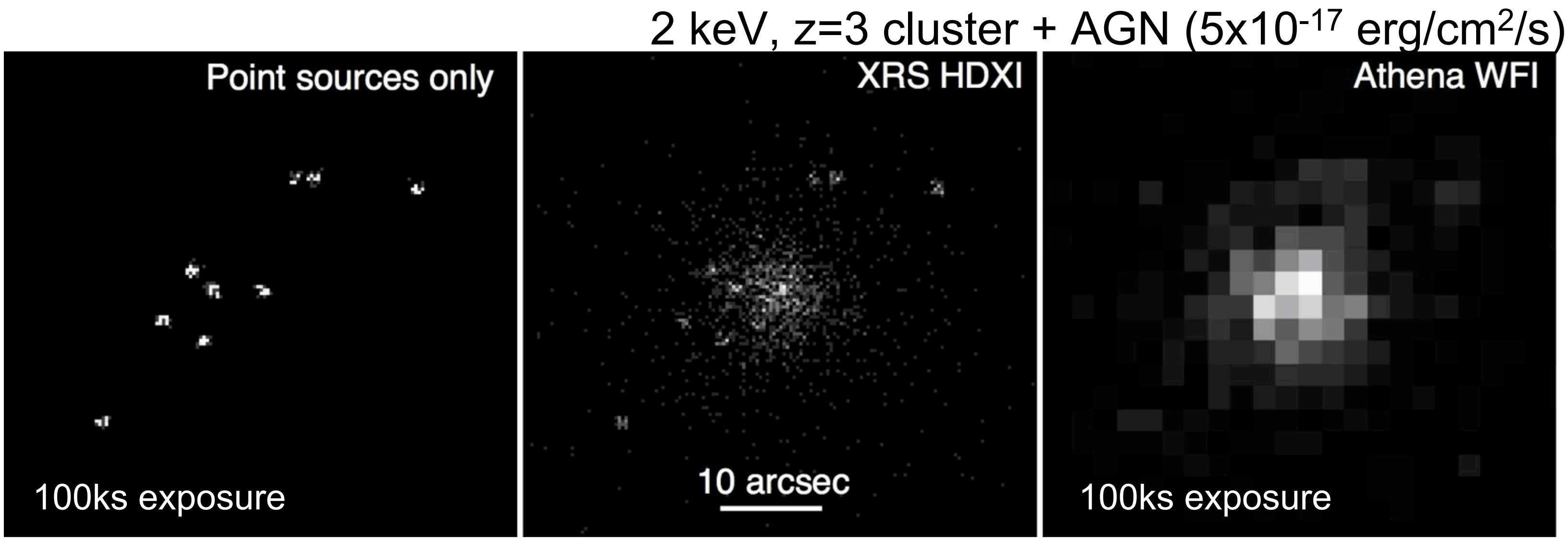
Blue: Ehlert et al. 2015 (Chandra)
Red: Predicted 1000 XRS clusters to z=3

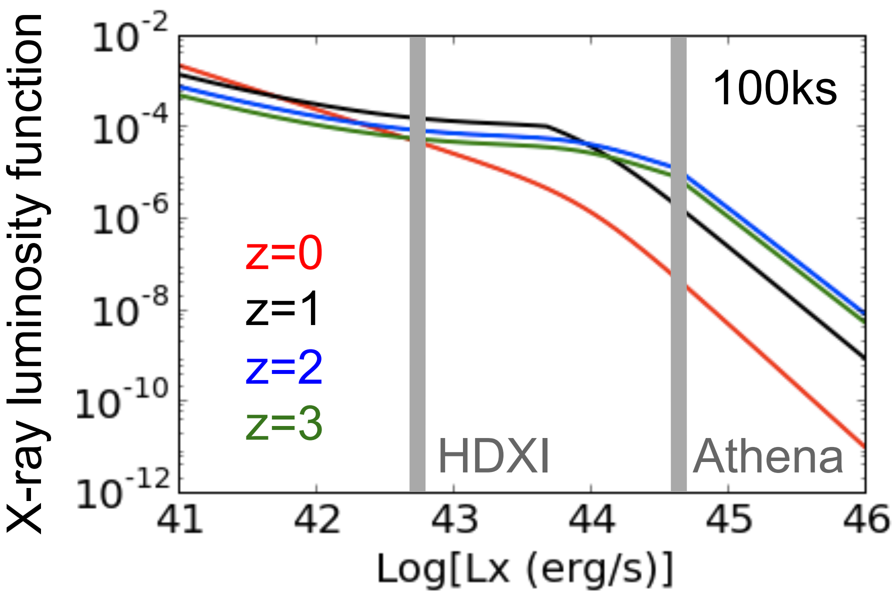


XRS will probe orders of magnitude deeper than Chandra or Athena and be more complete than OIR studies. By providing robust centers, masses and radii for host clusters it will enable statistical modeling that avoids need for (challenging) spectroscopic OIR follow-up.

10 Ms+ (archival) project with HDXI. Outstanding multi-wavelength synergies.

Black Holes and LSS: enabling the science

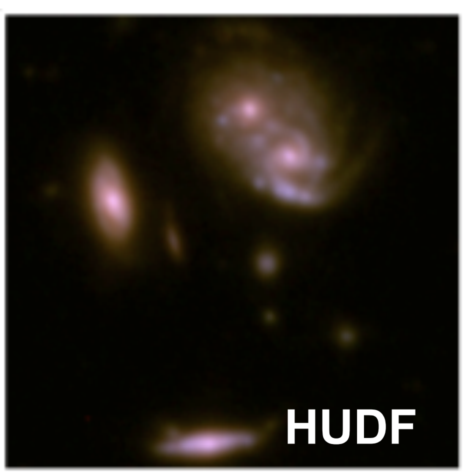




Identifying AGN in clusters: Good PSF critical to separate cluster and AGN emission at high-z → requires sub-arcsec resolution over wide FOV.

AGN in clusters can be studied far deeper with XRS vs. Athena → many more sources and new physical insights (going below knee in XLF).

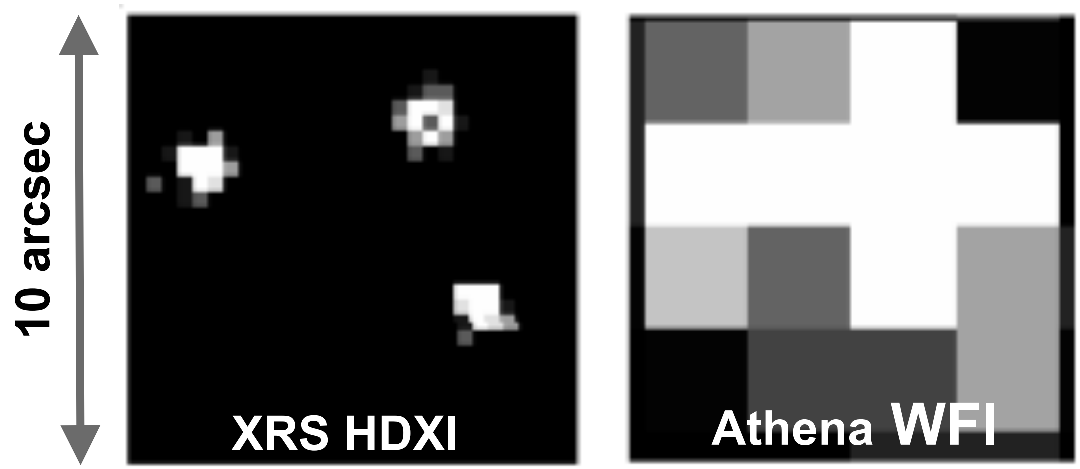
Black Holes and LSS: multi-wavelength synergies



Potential for multi-wavelength synergies are huge but will be limited by our ability to match AGN to host galaxies, especially in crowded cluster fields,

WFIRST deep fields will achieve ~ few 10^5 gal/sq degree (>3 per square 10 arcsec, similar to Hubble deep fields); JWST will go even deeper.

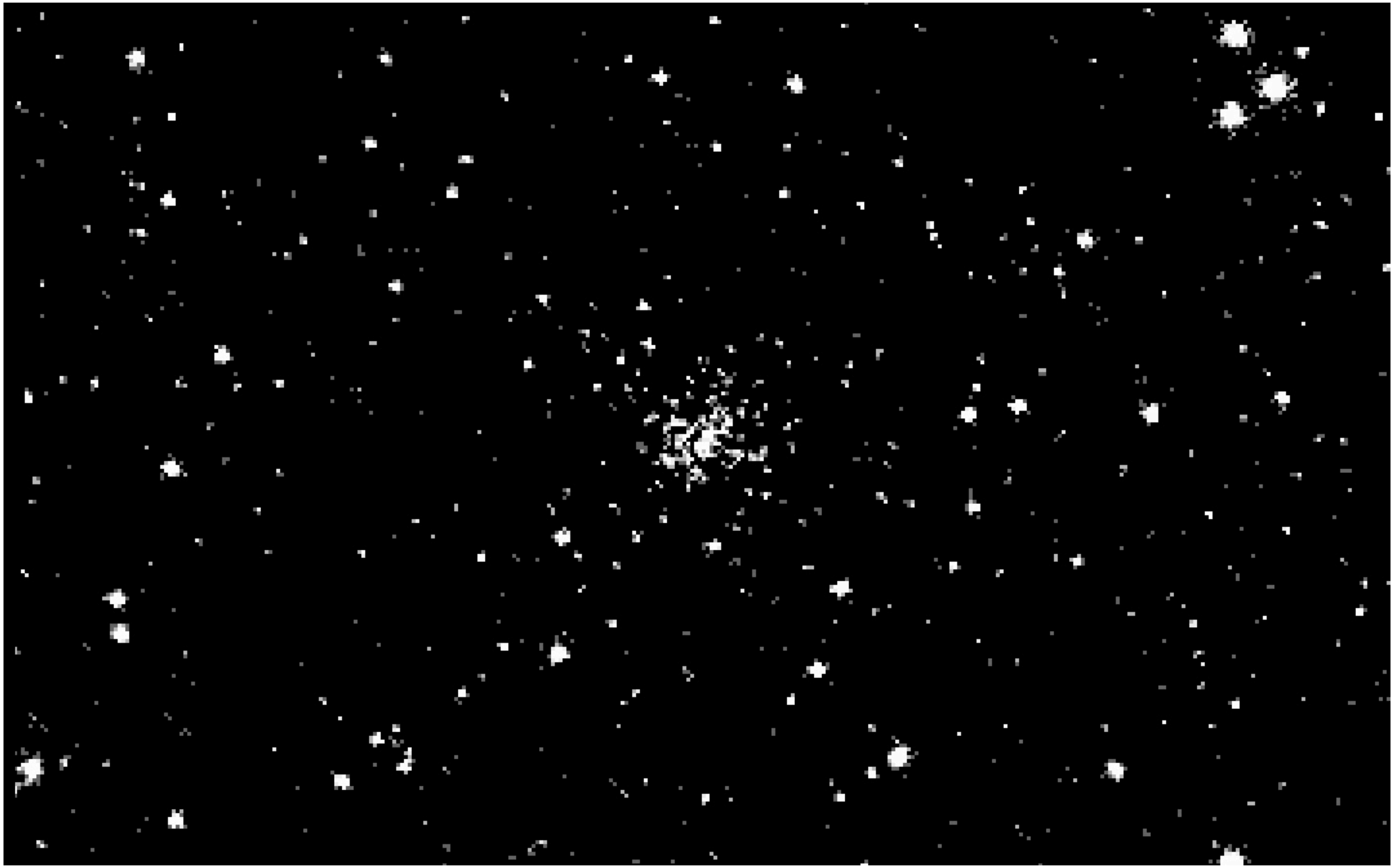
Spatial resolution and good astrometry will be paramount. Also true for studies of binary/offset AGN.



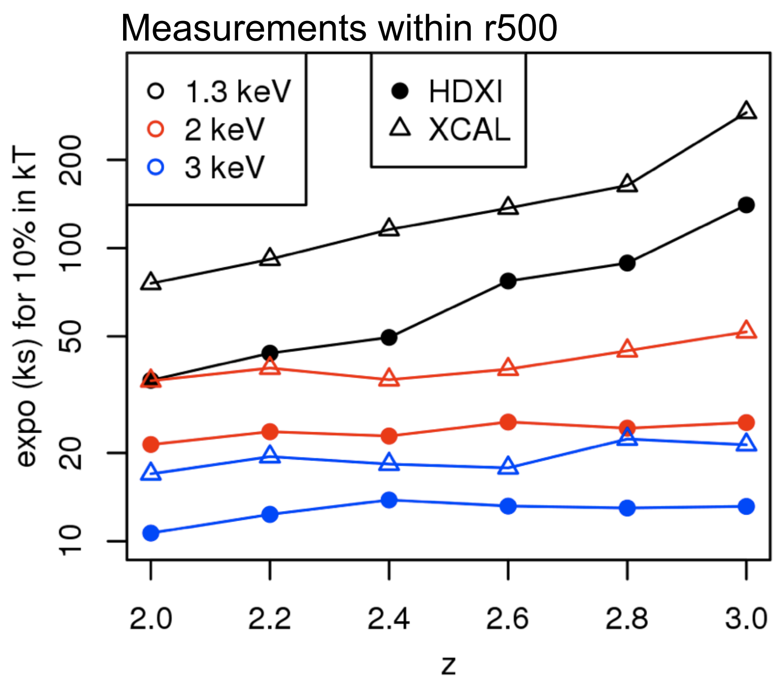
The first virialized LSS

Deep HDXI images will identify the first virialized structures at high redshift (here is a kT=2 keV group at z = 4)

XRS HDXI (0.8" PSF ~1 Ms)



The fingerprints of feedback



Feedback processes play a key role in shaping the evolution of galaxies and large scale structure.

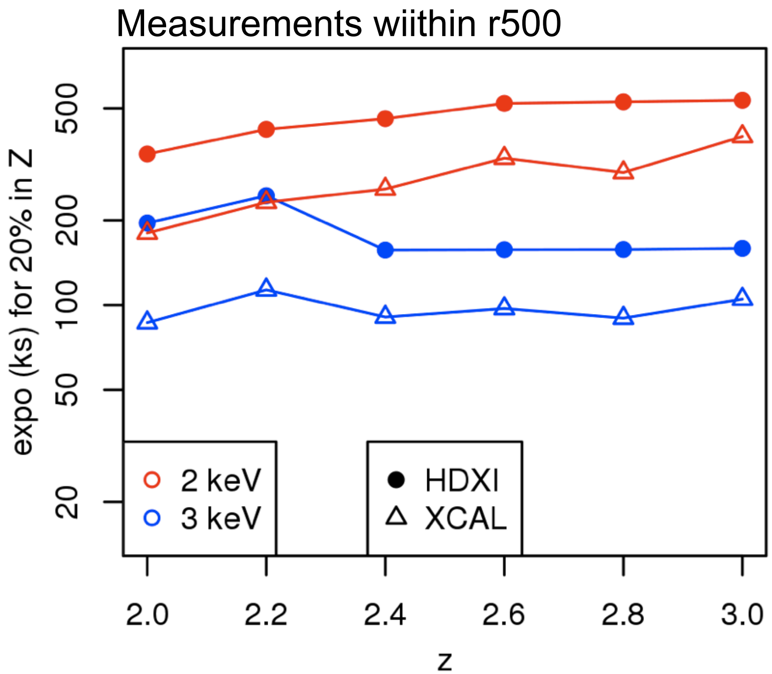
The clearest fingerprints of feedback are found in the thermodynamic properties of groups and clusters, and their evolution with redshift.

Synergies: SKA,CMB-S4,WFIRST +

Key measurements: gas temperature and density profiles out to epoch when star formation and AGN activity peaked and clusters first formed (z~3).

Require ~100ks per target to measure kT(r) to ~10% precision at z~3, and tens of clusters to probe evolution/scatter → multiple Ms project with HDXI.

The history of star formation



The ICM provides a reservoir for the metals produced over generations of star formation.

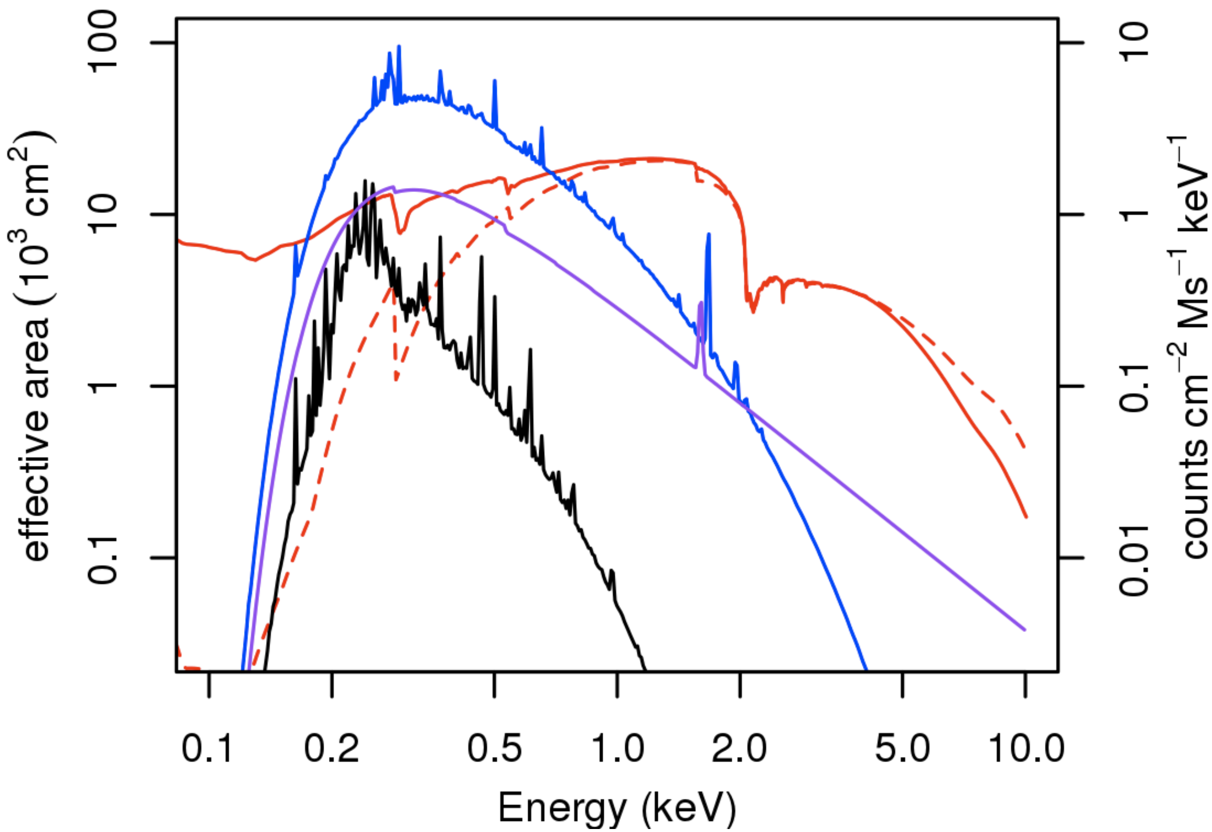
The abundances of elements and their spatial distribution powerfully constrains the integrated history of star formation and SN enrichment.

Synergies: WFIRST,CMB-S4,TMTs+

Key measurements: abundance measurements in ≥2 radial bins out to the epoch when star formation peaked and clusters first formed (z~3).

Require ≥200ks per target to measure metallicity to 20% precision in ≥2 radial bins at 2<z<3, and enough trgets to probe system-to-system scatter → multiple Ms project with XCAL (2x quicker + more info. than HDXI).

Importance of soft response



HDXI, XCAL ARFs

1 keV z=3 cluster

3 keV z=3 cluster

Γ=1.9 z=3 AGN

All behind N_H=3e20/cm^2

The primary discovery space for X-ray Surveyor (bringing maximal synergies with other major multi-wavelength projects) is the high redshift X-ray universe. The enabling characteristics are **high spatial resolution across large FOV** and **large effective area at soft (E<5 keV) energies**.

Summary

Major Science Questions

- Black hole growth: how does the population of AGN evolve in the field?
- Black holes and LSS: how does the population of AGN evolve in group and cluster environments? (Physics of triggering and quenching, links to SF)
- The first virialized LSS: when did the first galaxy groups appear?
- The fingerprints of feedback: how do the thermodynamic properties of galaxy groups and clusters evolve?
- The history of star formation: what is the enrichment history of the ICM?

Key Findings

- These are important questions that can help motivate a flagship mission.
- The science will be uniquely enabled by X-ray Surveyor.
- Outstanding synergies with other major facilities in the 2020s and 30s.
- Critical mission characteristics are **high spatial resolution (< 1”)** across **wide FOV** and **large effective area at soft energies**.

Spreadsheet

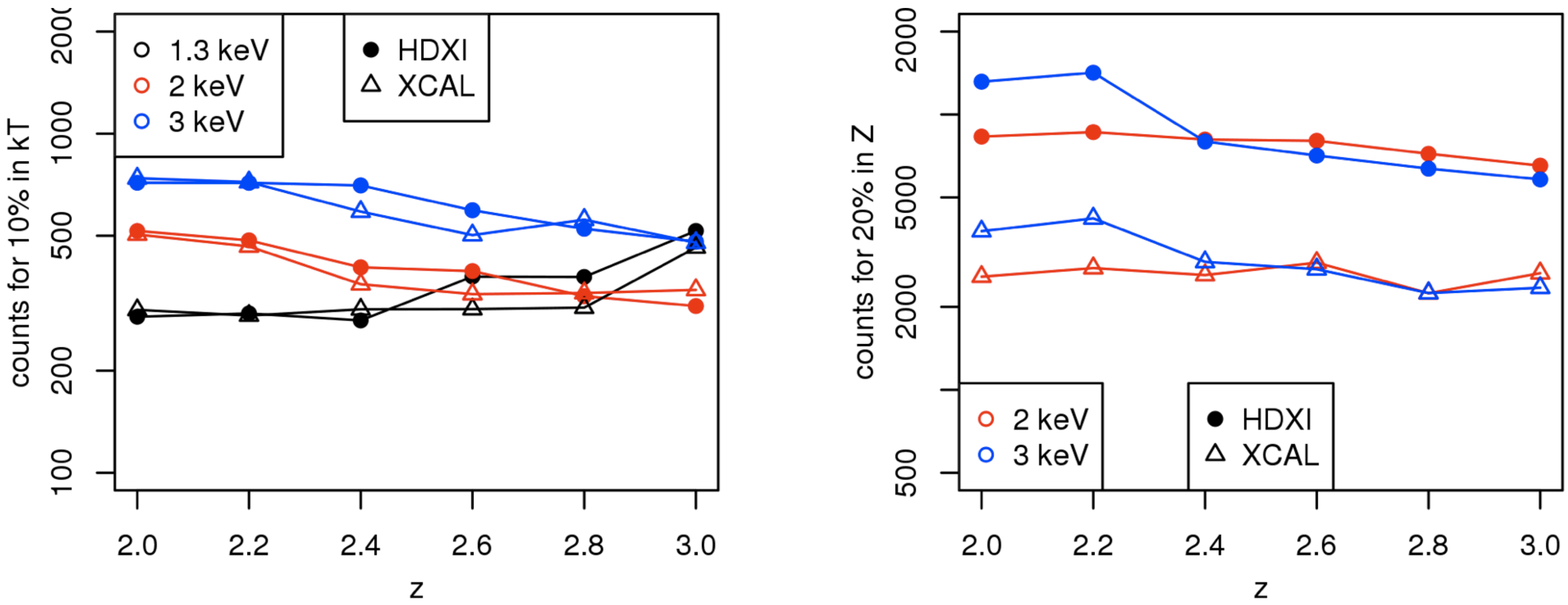
Should we paste a .png of our spreadsheet here?

Backup Slides

Simulation details for cluster thermodynamics/metal studies

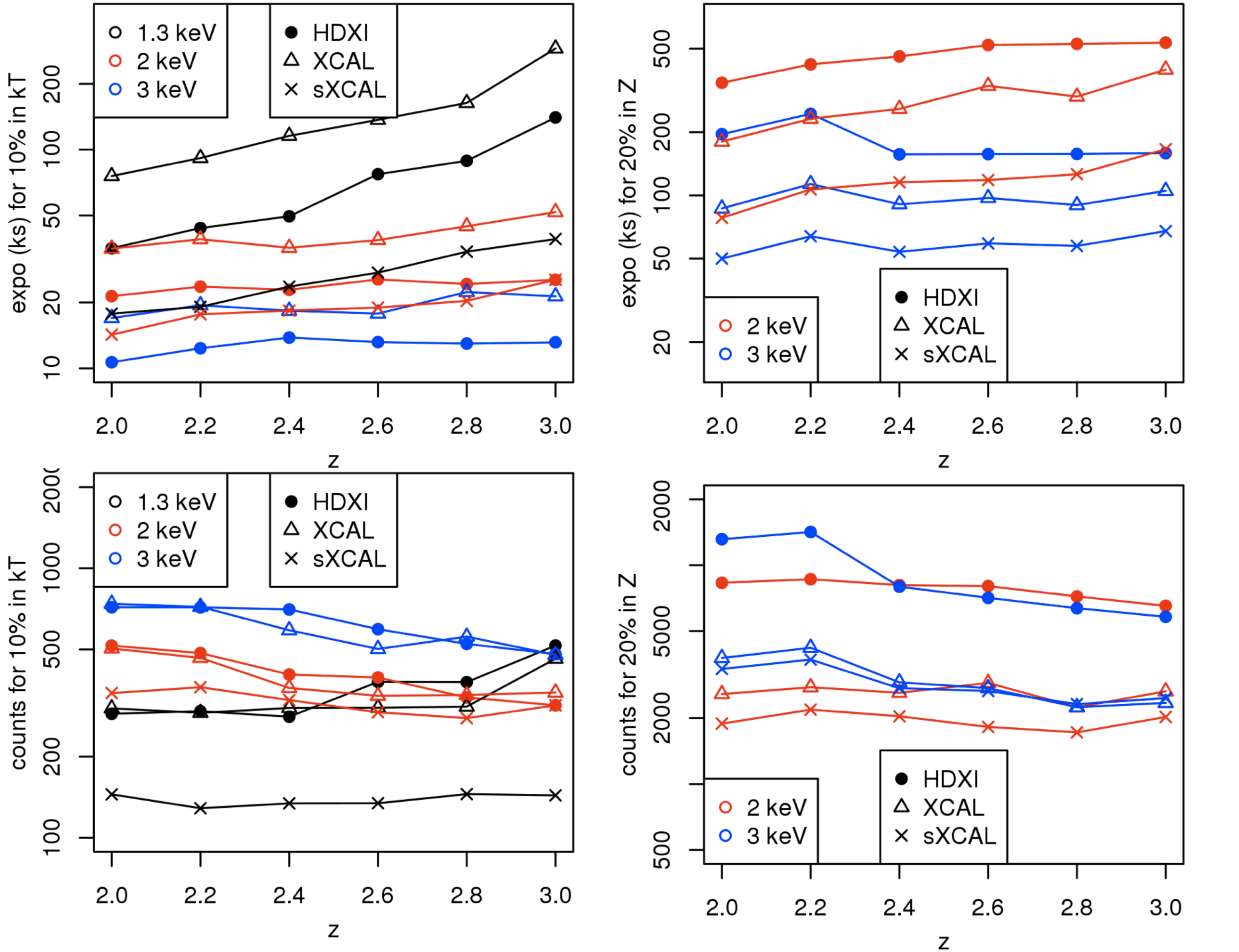
- Use supplied RMFs, ARFs, backgrounds from SIMX
- Galactic absorption with N_H=3e20/cm^2
- Input kT, Lx consistent with current (R_{500}) scaling relations, abundance=0.3 solar
- Solid angle of simulated spectra correspond to radii R<R_{500}
- "Blank-sky" type background treatment (using cstat), assuming 1Ms background spectrum
- Fake spectra are grouped to ≥1 count/channel, as standard for cstat
- Full energy range (0.05-10.0 keV) used in the fits
- N_H and redshift fixed; kT, abundance and normalization free
- "Fractional errors" are median error bars from many Poisson realizations / input values

Counts required to deliver a given precision



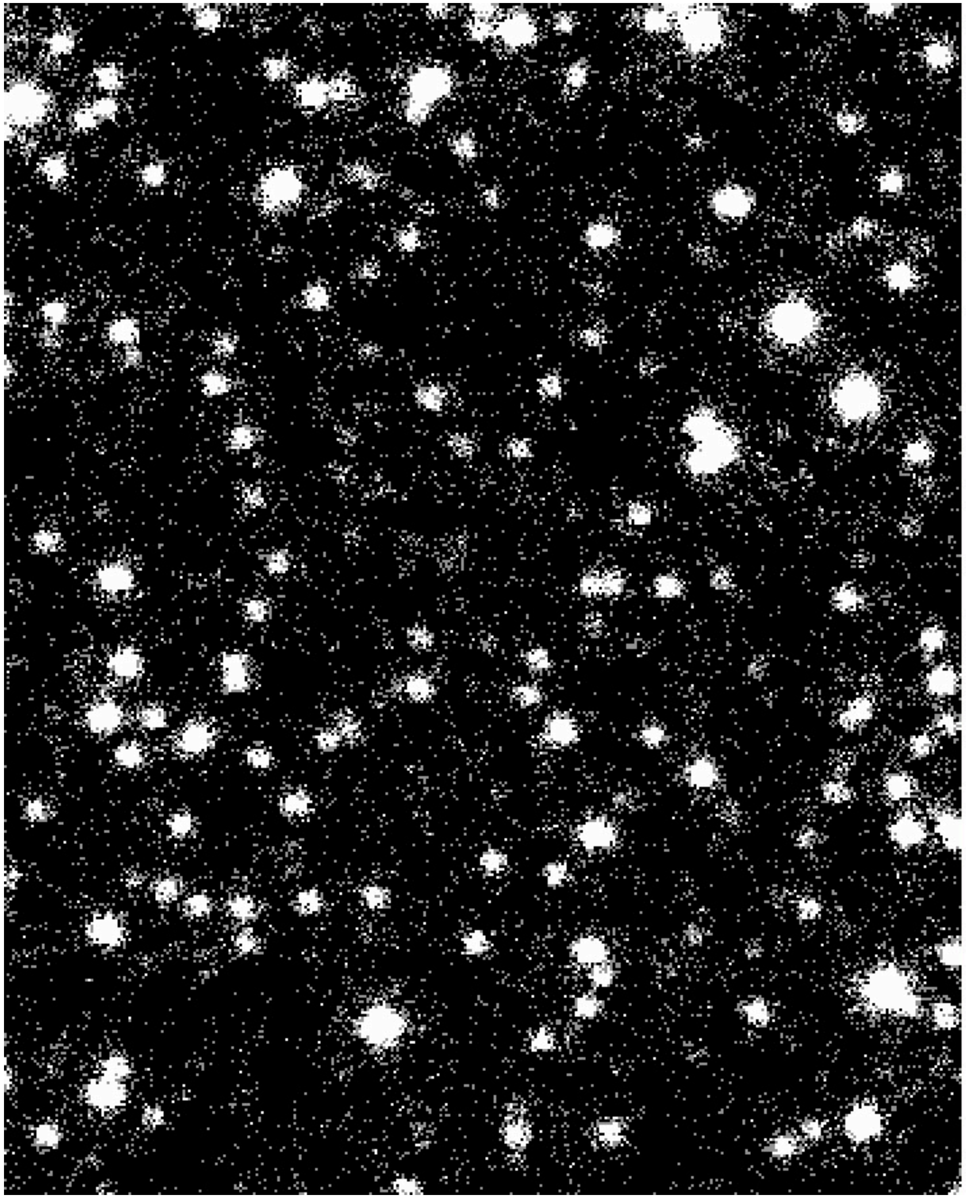
XCAL with enhanced soft response → 2x shorter exposures

(sXCAL uses HDXI ARF with XCAL RMF and background)



Deep Field Observations

~3.5" PSF



XRS HDXI (~1 Ms)