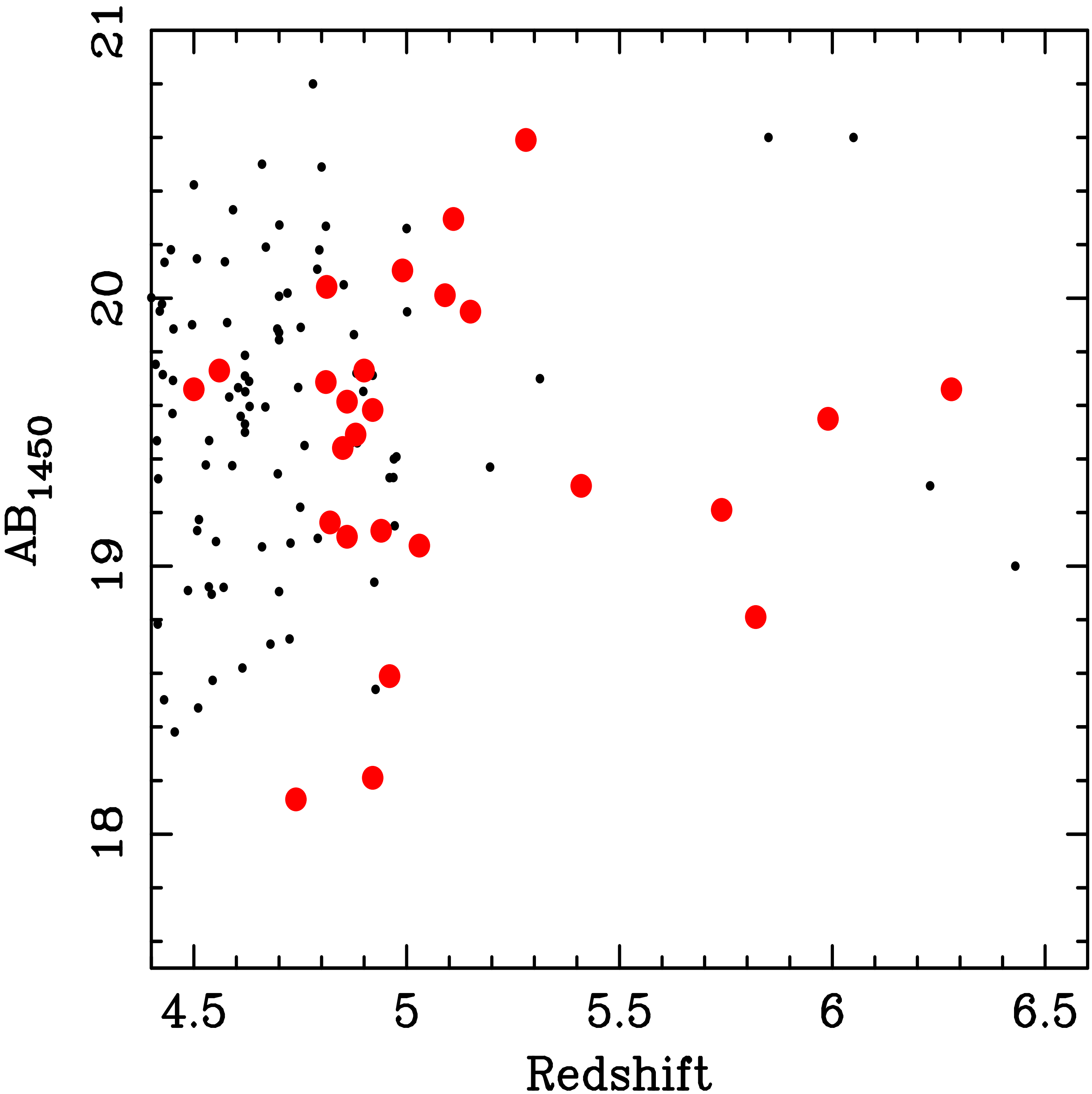
X−rays from the First Massive Black Holes: Current Status and Future Prospects

Brandt, Vignali, Schneider, Alexander, Anderson, Bassett, Bauer, Fan, Garmire, Gunn, Kaspi, Richards, Strauss



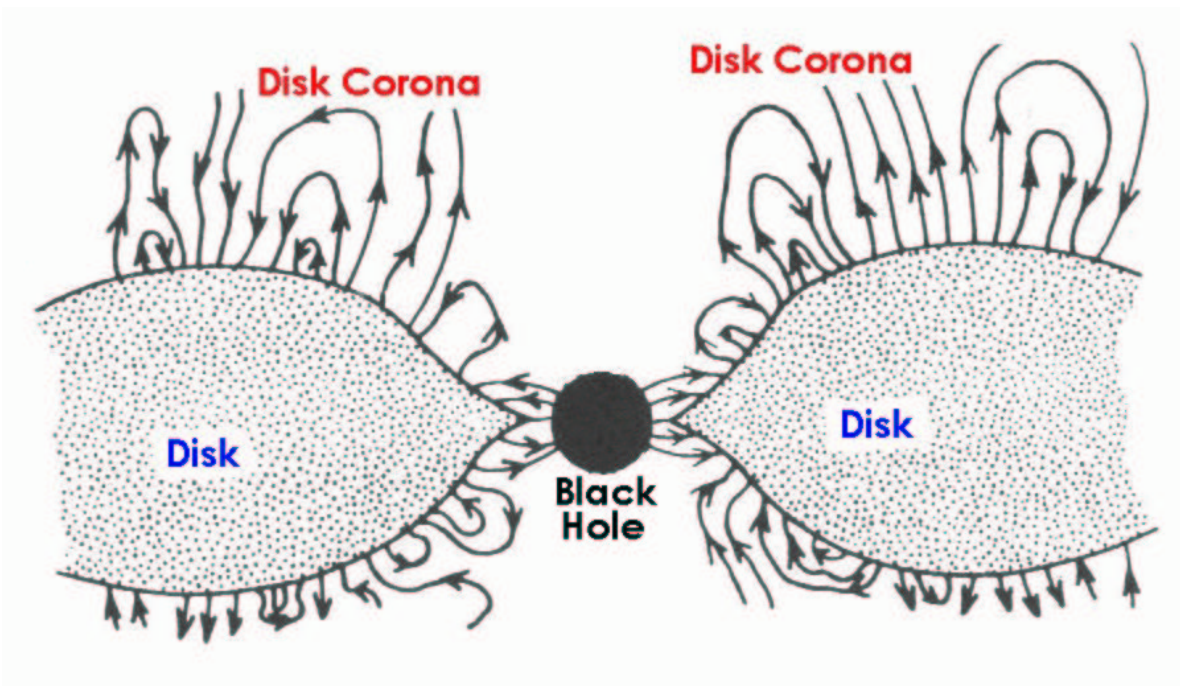
www.astro.psu.edu/users/niel/papers/highz−xray−detected.dat

Overall Importance of X−ray Studies at z > 4

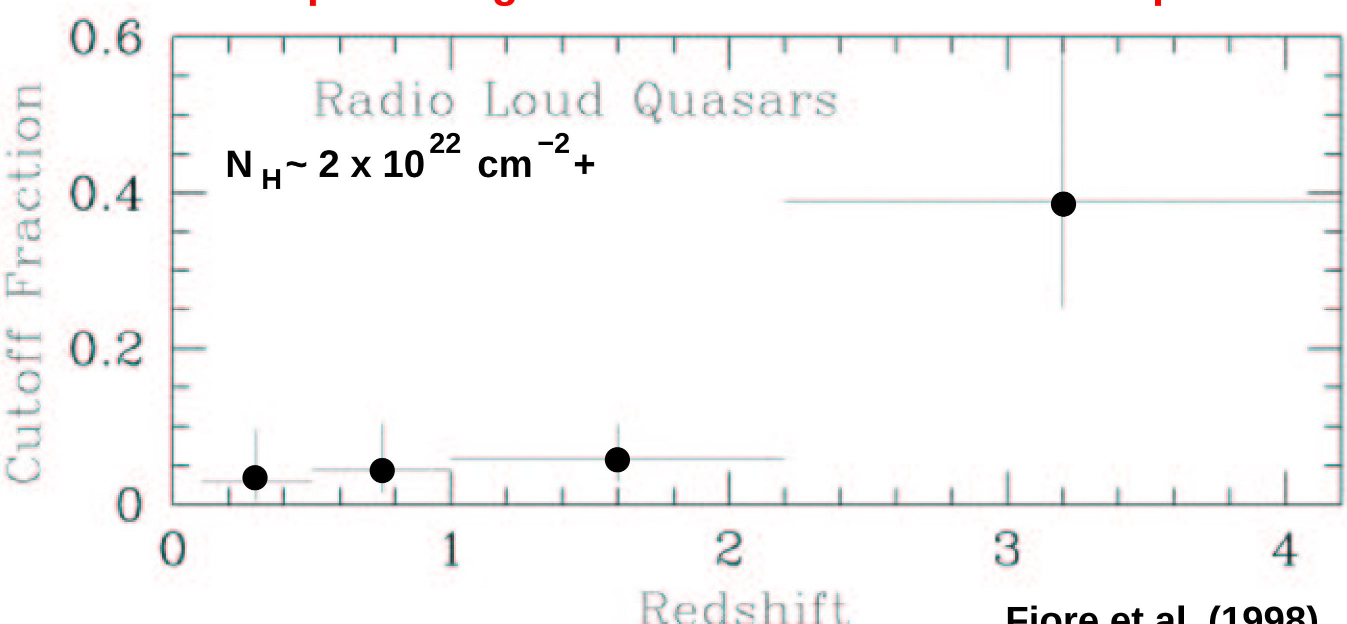
Probe black hole region where accretion + black hole growth occurs.

Are early black holes feeding + growing in same way as local ones?

Number density vs. z − Disk instabilities? Trapping? − Tentative claims



Also probe larger scale environment via absorption



Fiore et al. (1998)

Measured quantities: F_X, L_X α_{ox} Spectral shape: Γ N_H ξ Extent and companions

X−ray and Related Observations

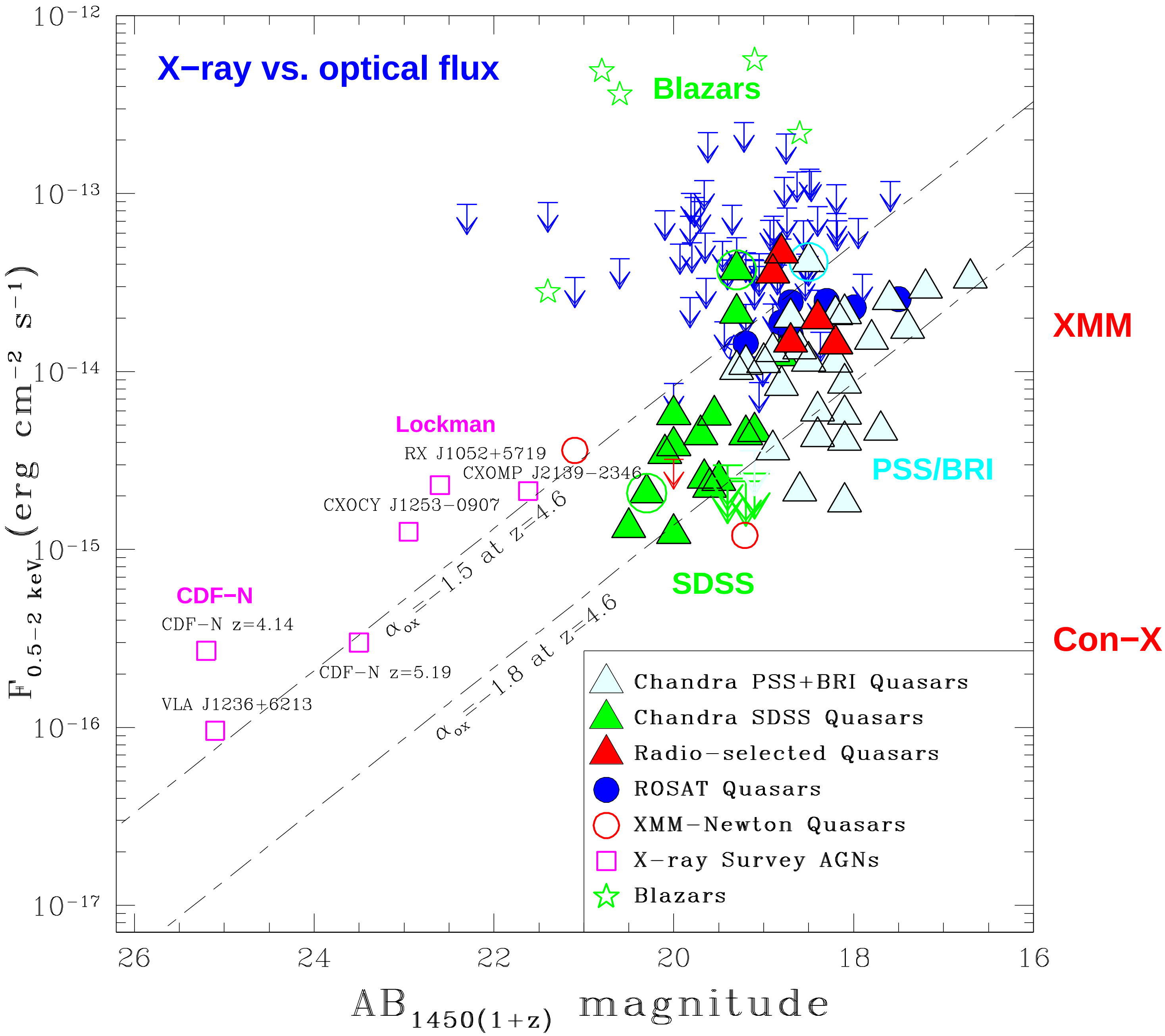
Chandra 4−10 ks snapshots with HET support (> 50)

Highest redshift (z > 4.8) SDSS, Opt. brightest PSS, RLQs, Exotic quasars

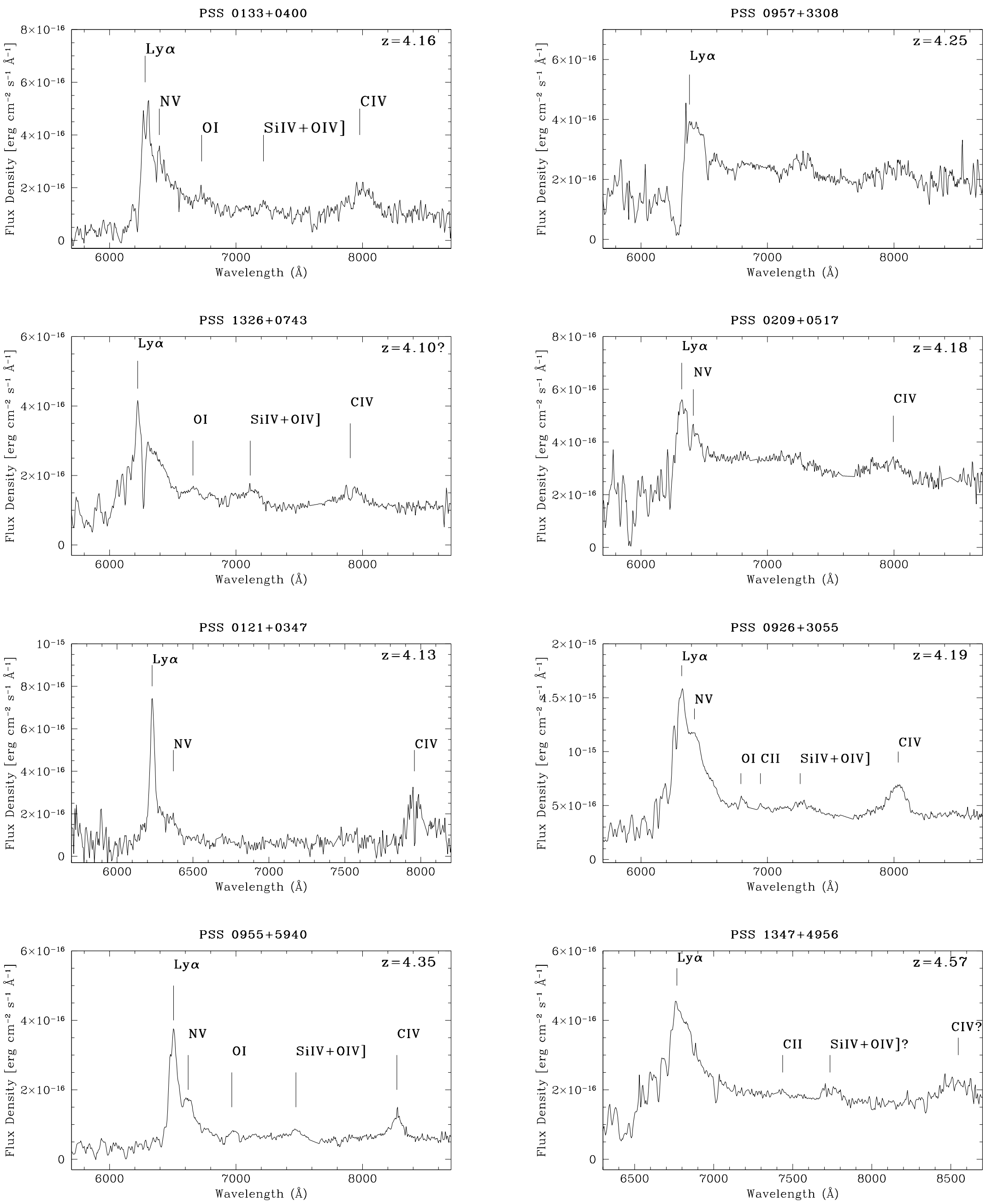
ROSAT, Chandra, XMM−Newton archival data

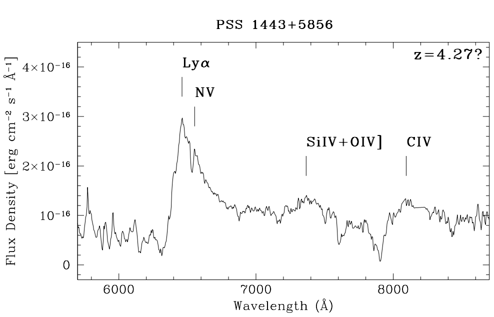
2 Ms Chandra Deep Field−North

Lower luminosity objects, avoid optical selection biases



Hobby−Eberly Telescope Support





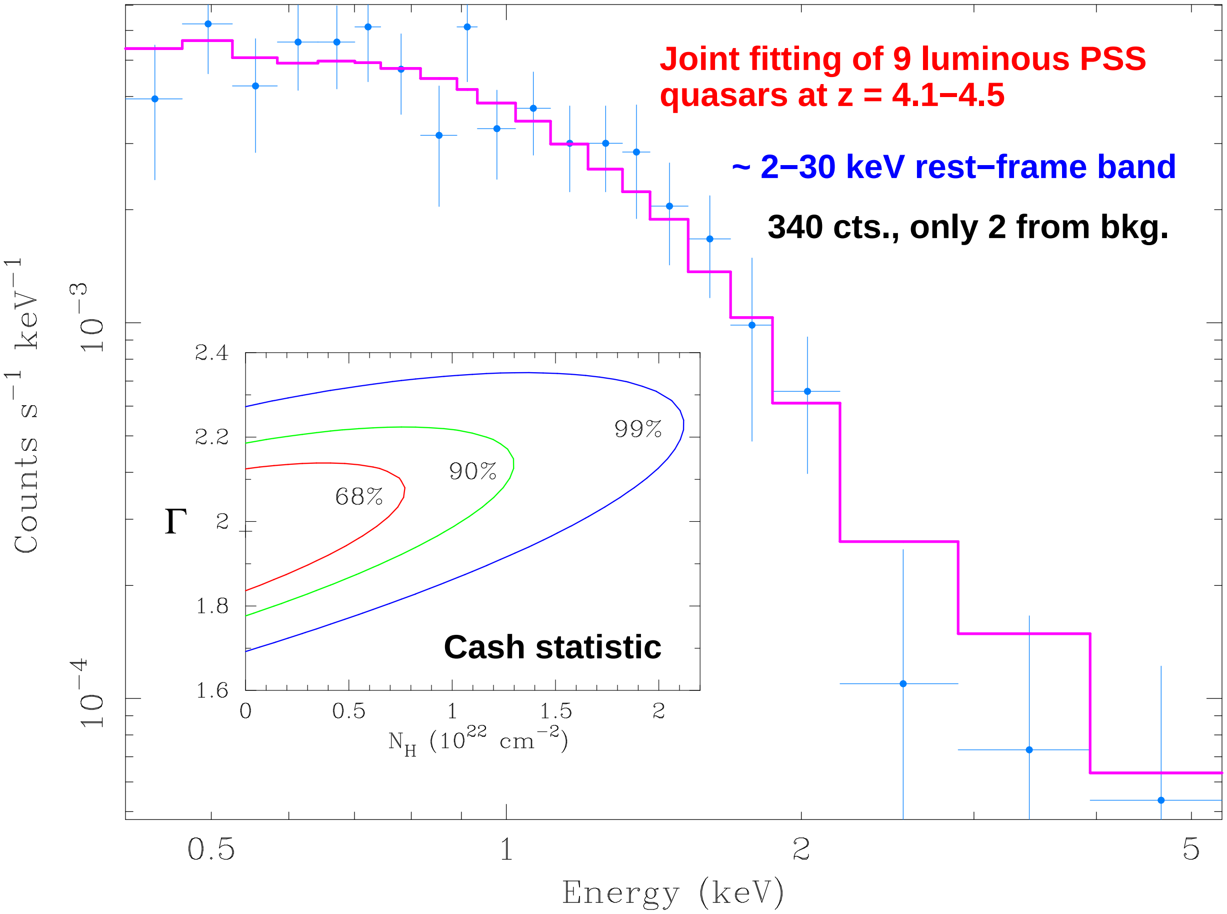
HET spectra of bright, mostly unpublished, DPOSS quasars at z > 4.

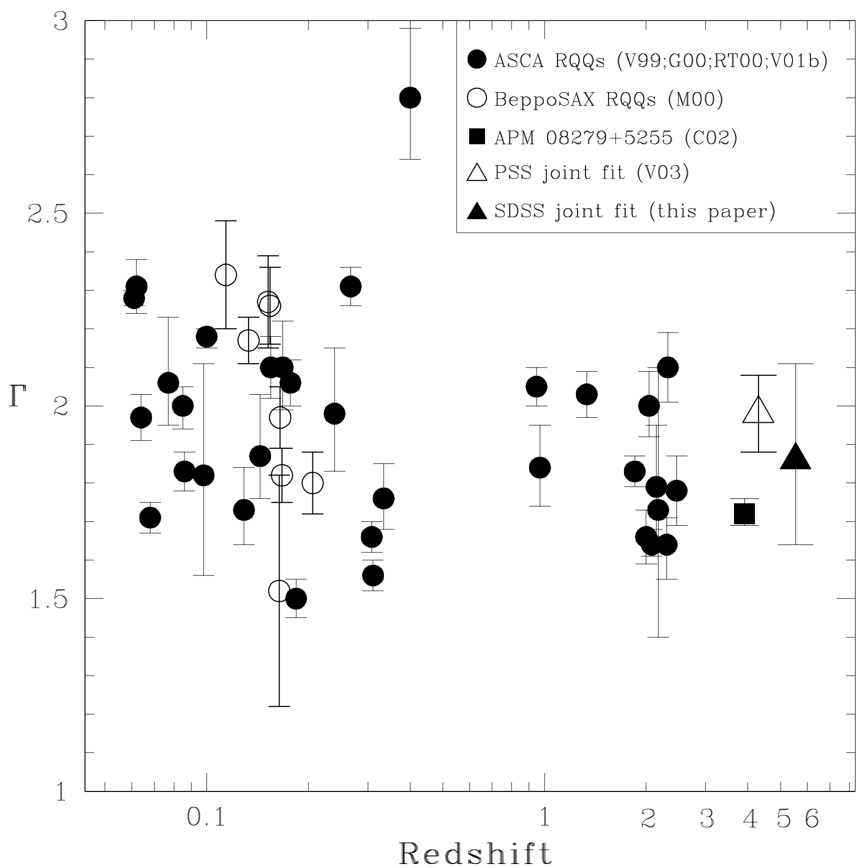
Queue−scheduling makes the HET ideal for near−simultaneous observations.

Prevents SED confusion due to variability.

Vignali et al. (2003)

X−ray Spectroscopy at z > 4

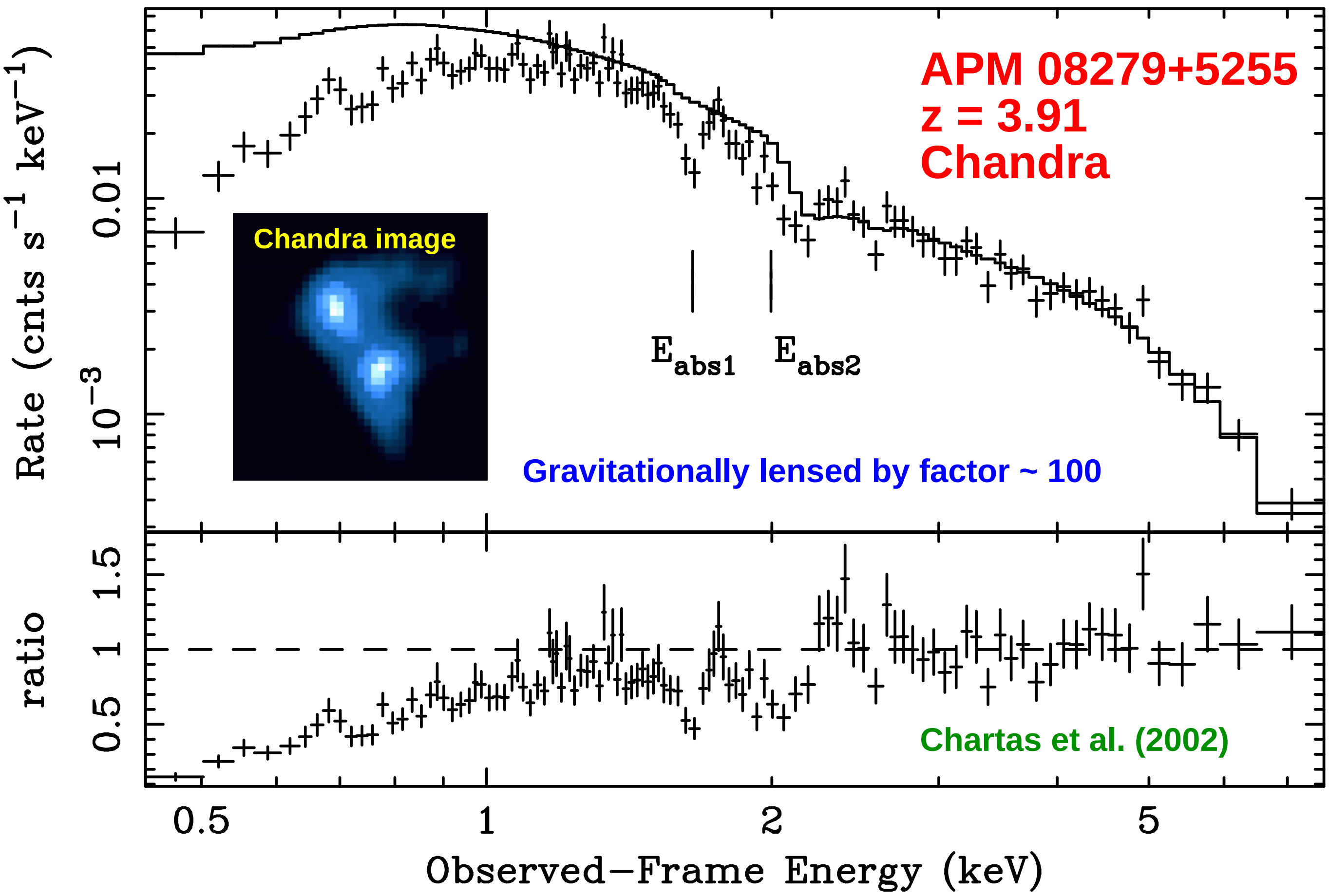


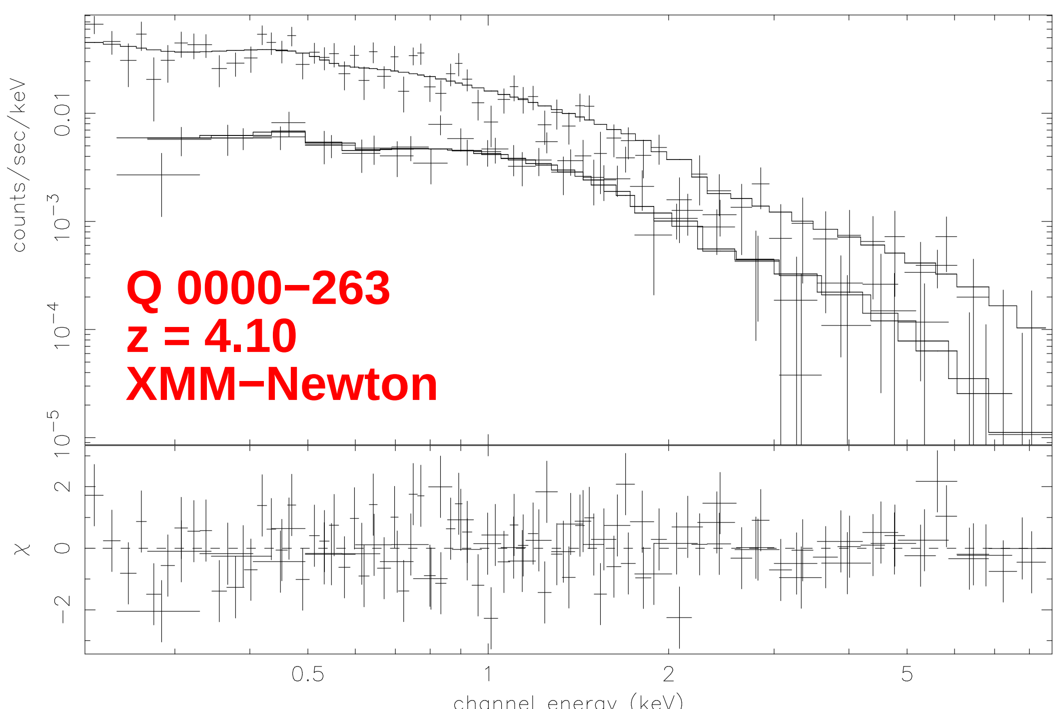


No evidence for evolution of the X−ray power law out to z ~ 4−5.

Vignali et al. (2003)

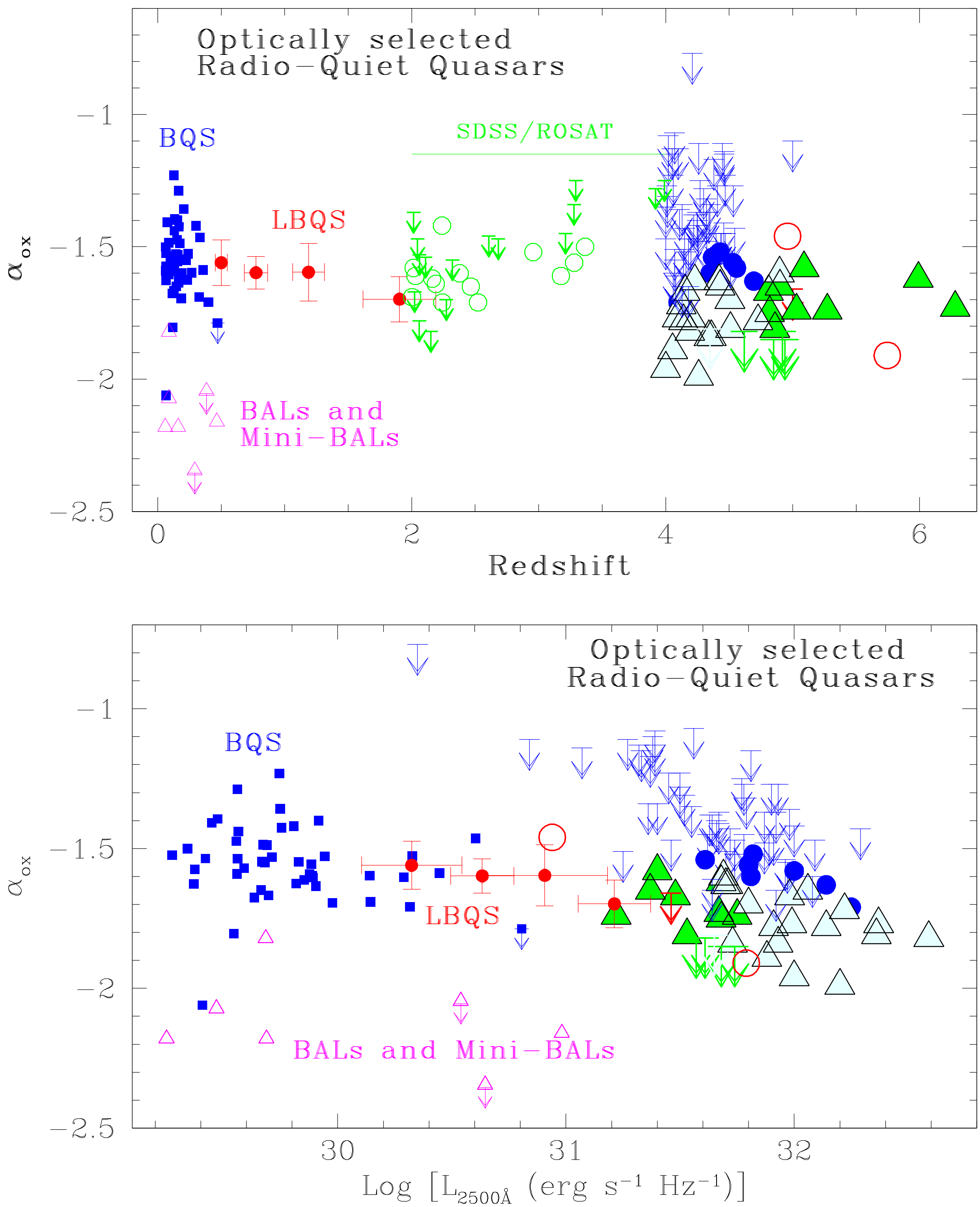
Single−Object X−ray Spectra at High Redshift





Ferrero et al. (2003)

X−ray Contribution to SED



Partial correlation analysis of ~150 SDSS+PSS RQQs spanning z = 0.16−6.28 indicates luminosity effect primary.

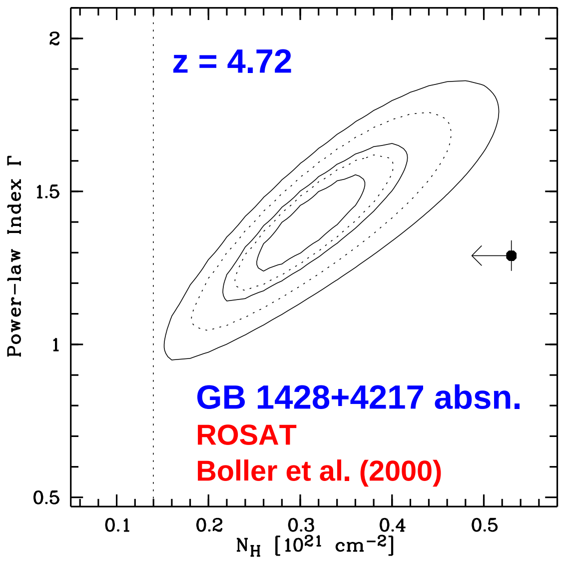
Vignali, Brandt, & Schneider (2003)

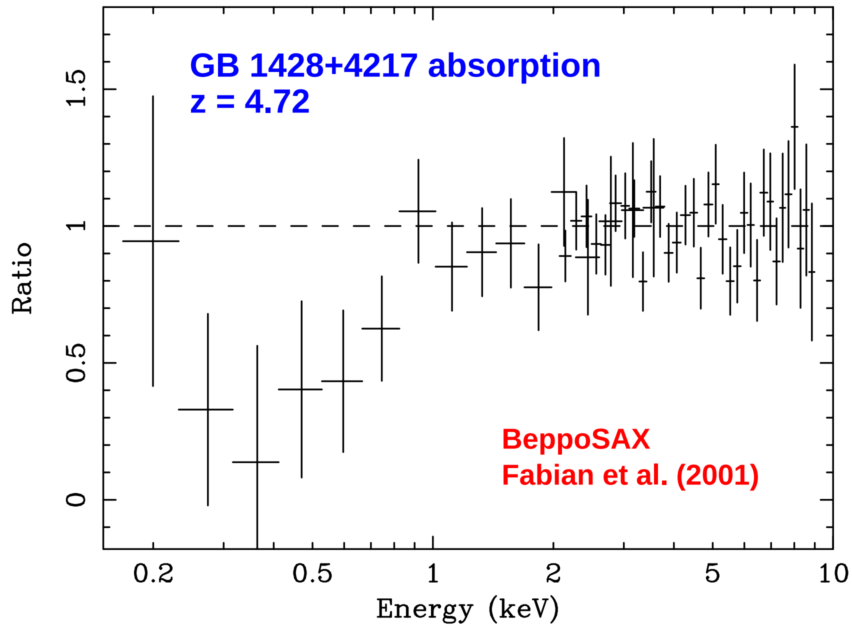
Blazars at the Highest Redshifts

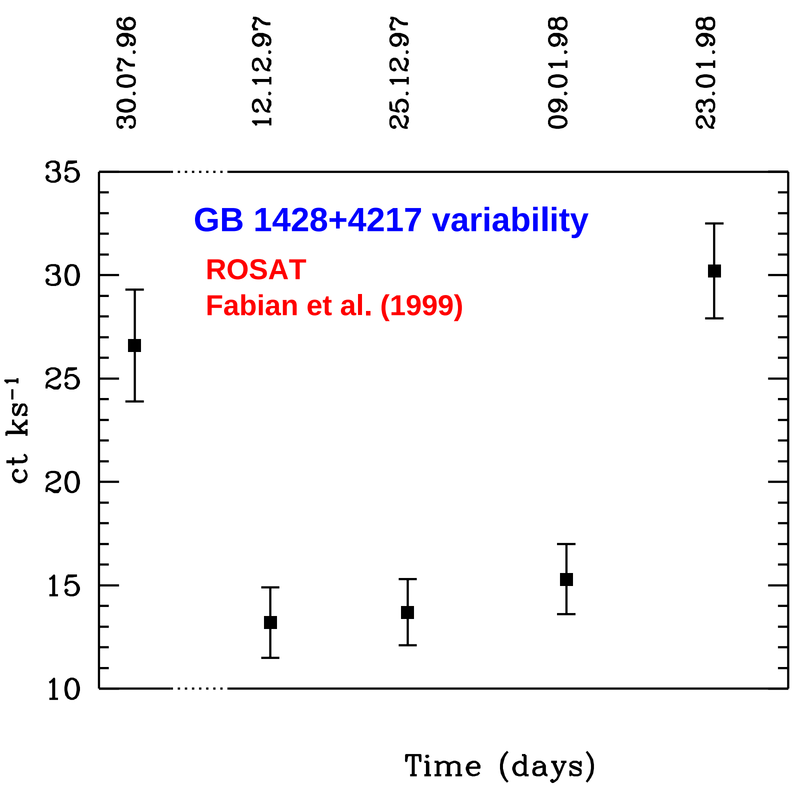
Often X−ray bright enough for moderate−quality spectra.

5 published − 3 show evidence for likely X−ray absorption.

Jets not accretion disk. Probably not majority population.







GB 1508+5714 (z = 4.30)
- Mathur & Elvis (1995)
- Moran & Helfand (1997)
- Telis et al. (2003)

RX J1028.6−0844 (z = 4.28)
- Zickgraf et al. (1997)
- Yuan et al. (2000)

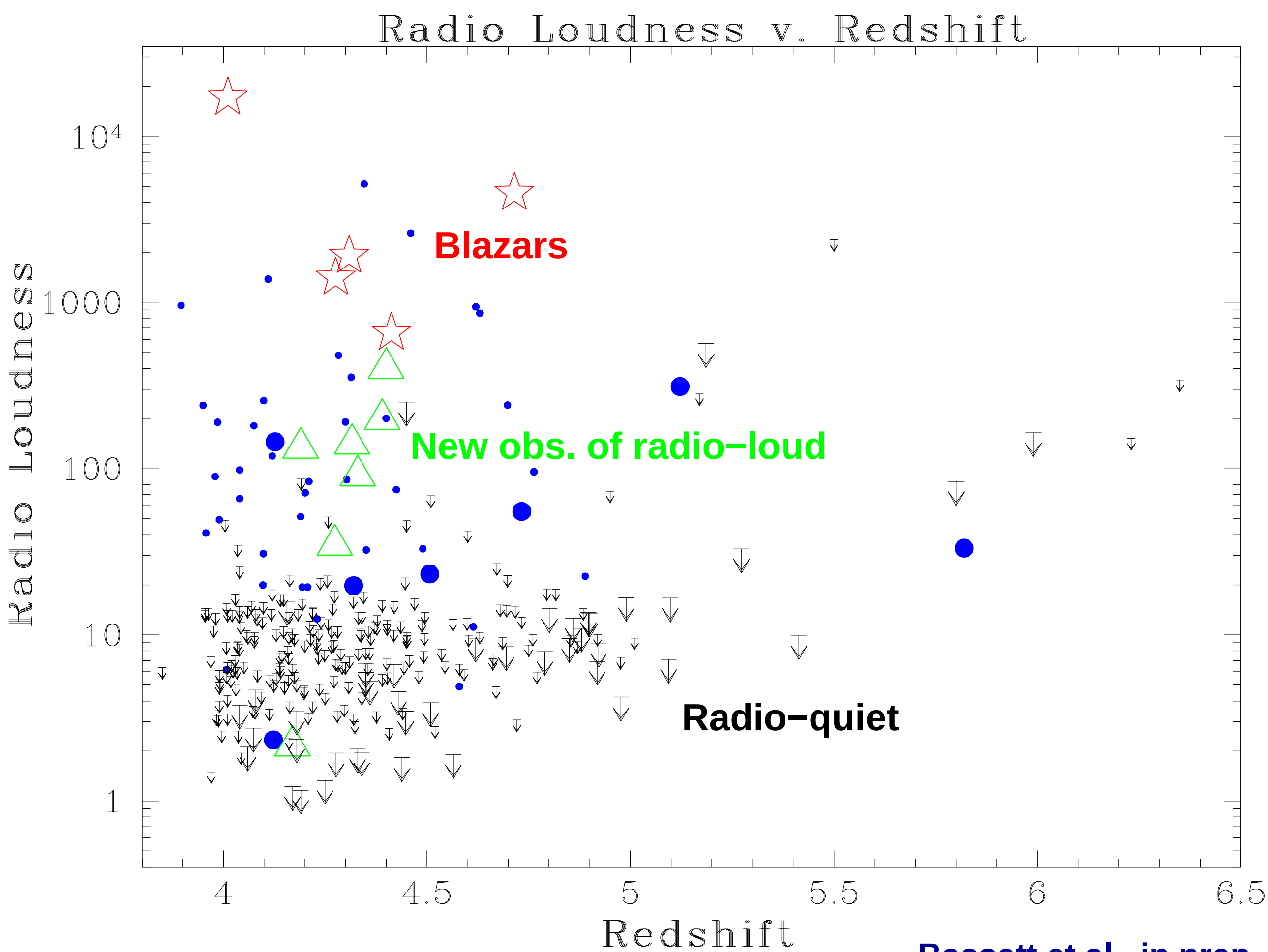
PMN J0525−3343 (z = 4.40)
- Fabian et al. (2001)

GB 1713+2148 (z = 4.01)
- Vignali et al. (2003)

Ongoing Chandra Survey of z > 4 RLQs

Want to "bridge" the X−ray observation "gap" between z > 4 radio−quiet quasars (R < 10) and blazars (R > 1000).

Also want to increase the number of X−ray blazars at high z.



Bassett et al., in prep.

6 observations to date − all detections and often X−ray bright
7 more observations accepted

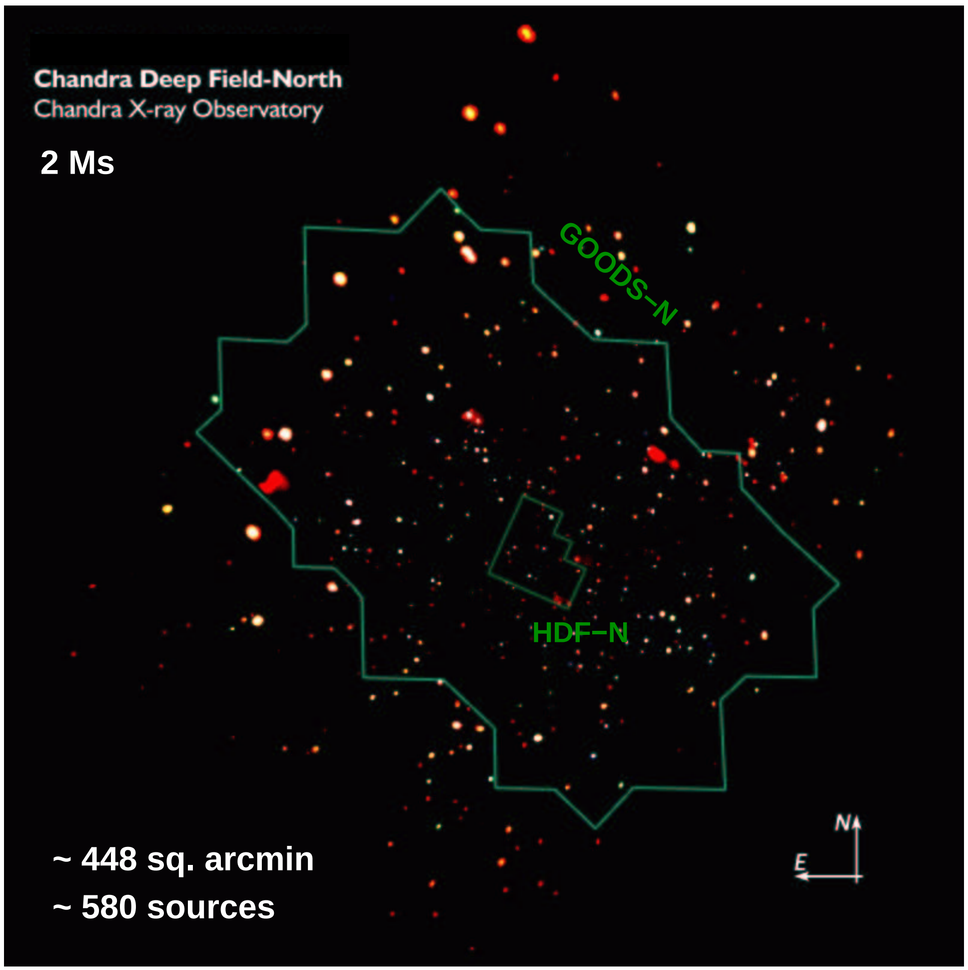
Correlation studies to determine if z > 4 jets different (e.g., CMB)
X−ray absorption studies with XMM−Newton

High−Redshift AGN in Deep X−ray Surveys

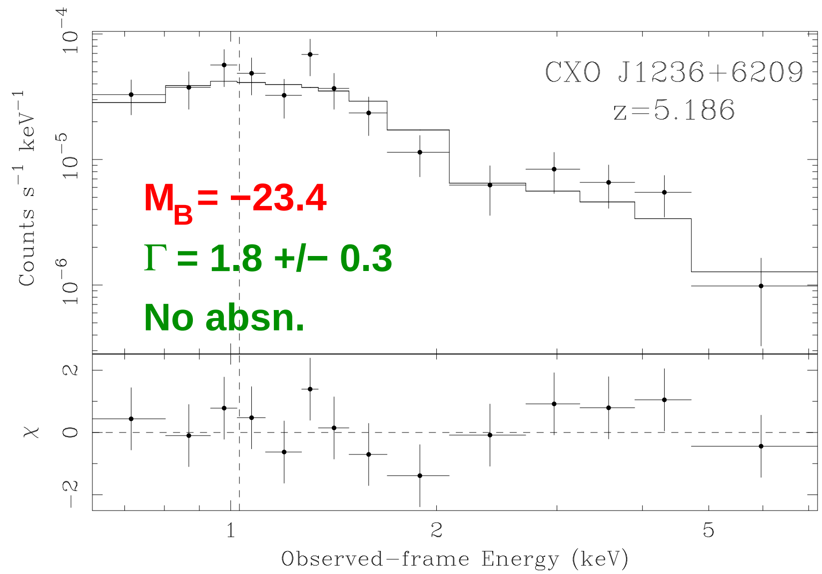
Deep X−ray surveys effectively probe z > 4 AGN with X−ray lum. > 30 times smaller than those from wide−field optical surveys (e.g., SDSS).

More representative than highly lum. quasars.

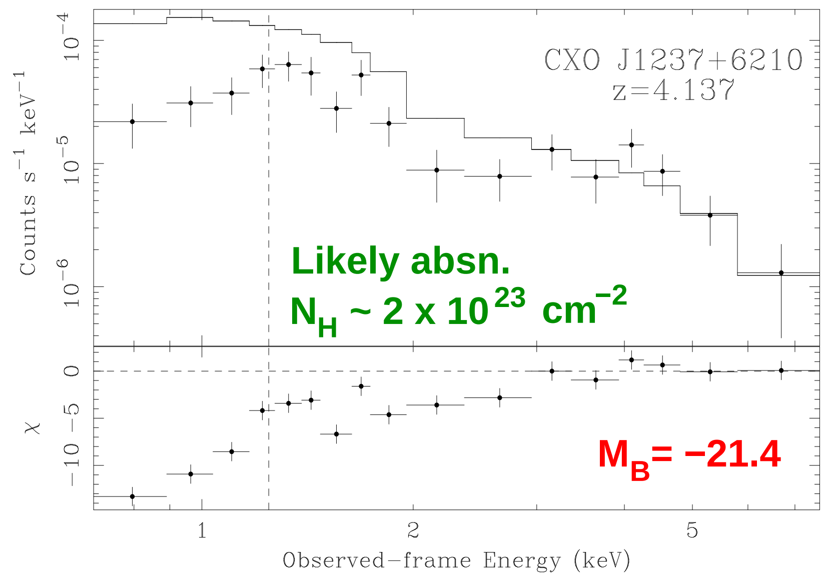
Access hard rest−frame X−rays (2−40+ keV) so absorption bias minimized.



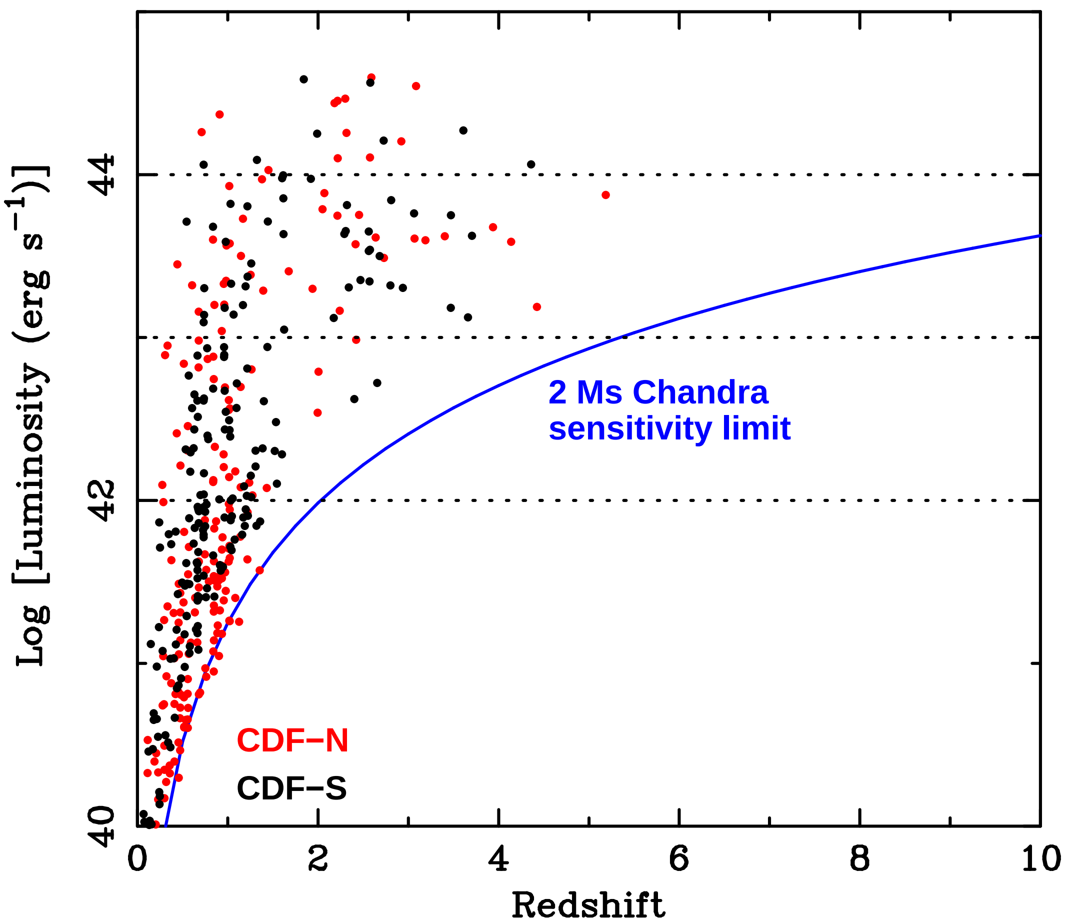
Accretion processes and environments

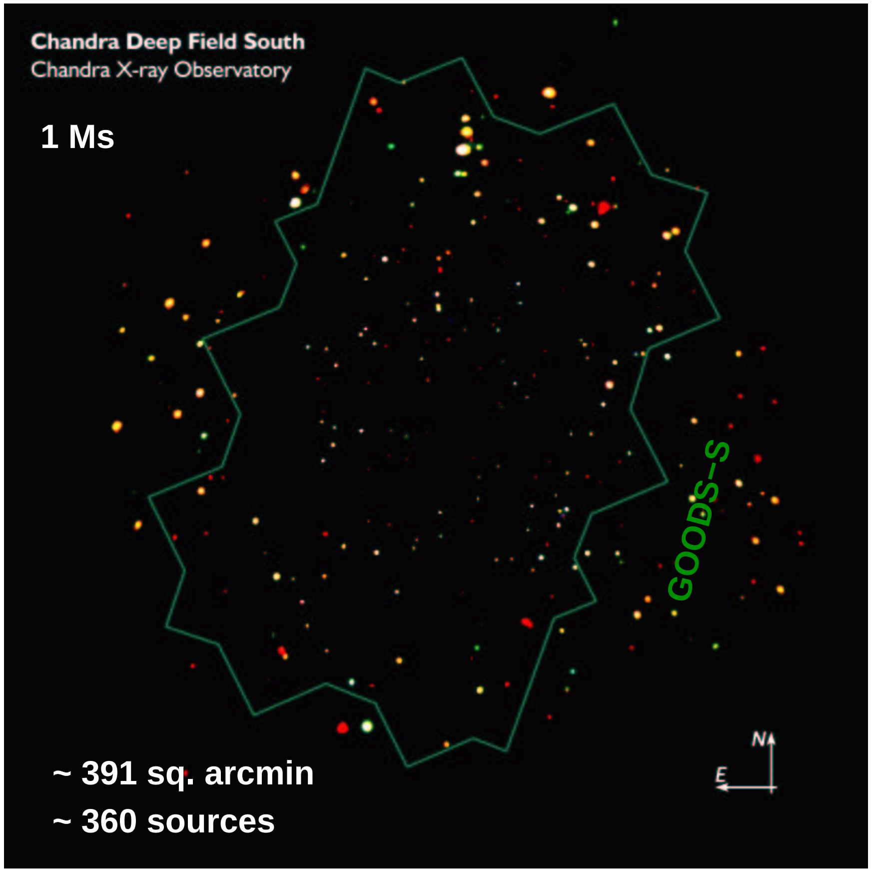


Vignali et al. (2002)



X−ray Constraints on Very High Redshift AGN





Chandra can detect moderate−lum. AGN to z ~ 10+

Constrain sky density exploiting Lyman break.

Alexander et al. (2001), Barger et al. (2003),
Cristiani et al. (2003), Koekemoer et al. (2003)

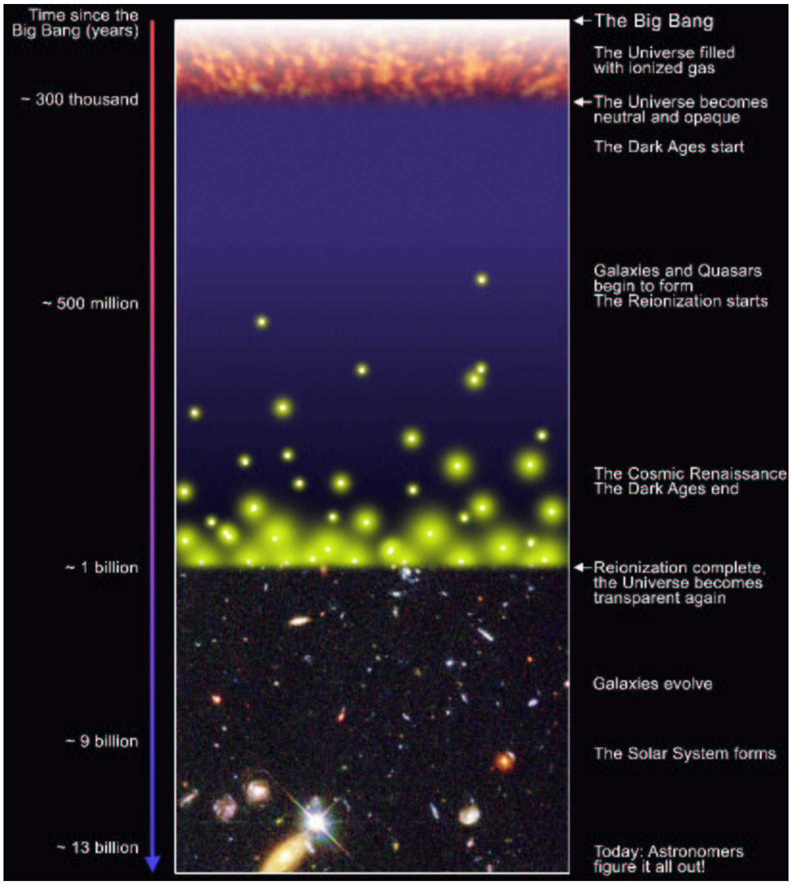
No more than ~ 10 AGN at z > 6.5 per Chandra field.

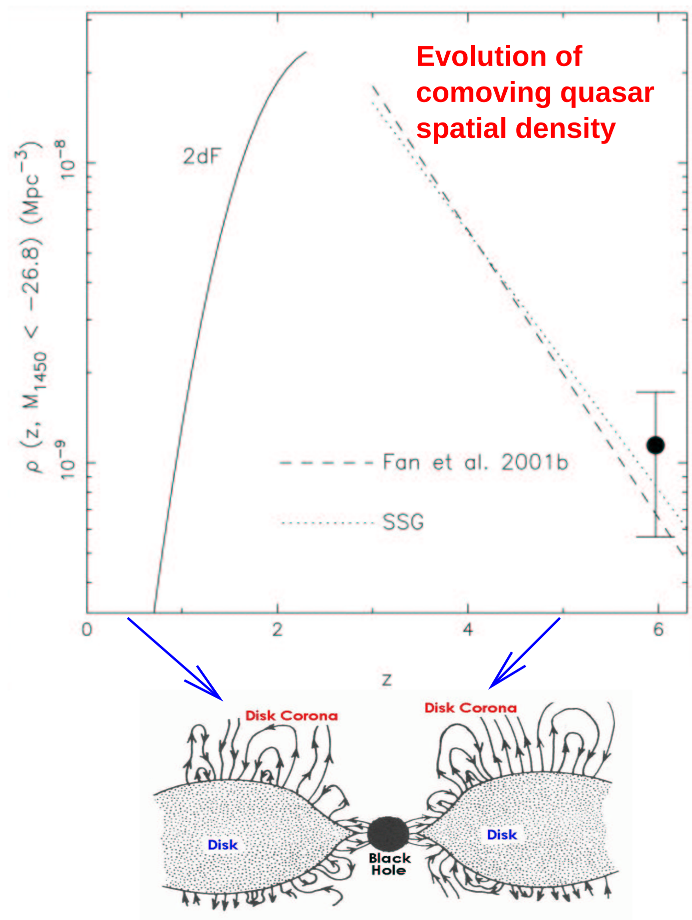
Moderate−lum. AGN unlikely to have reionized Universe, in agreement with optical extrapolations.

First stars? Decaying particles?

Source statistics still poor. Need more solid angle with deep (~ 1/3 Ms) coverage to pin down XLF.

General Conclusions





Quasars at z ~ 4−6 and z ~ 0−2 have reasonably similar X−ray and broad−band spectra.

(After accounting for luminosity effects)

Small−scale X−ray emission regions of quasars insensitive to large−scale environmental differences from z ~ 0−6.

No hints for different accretion/growth mechanisms.

(e.g., accretion−disk instabilities or radiation "trapping")

X−ray emission appears to be a universal property of quasars, even at z ~ 4−6.

Hopefully ultradeep X−ray surveys can push to z ~ 5−15+.

Future Prospects for "Snapshot" and Deep Surveys

Improve coverage at z > 5

~ 100 at z > 5 expected from full SDSS

~ 30 at z > 6 expected from full SDSS

Minority populations

No−line quasars, BALQs, RLQs

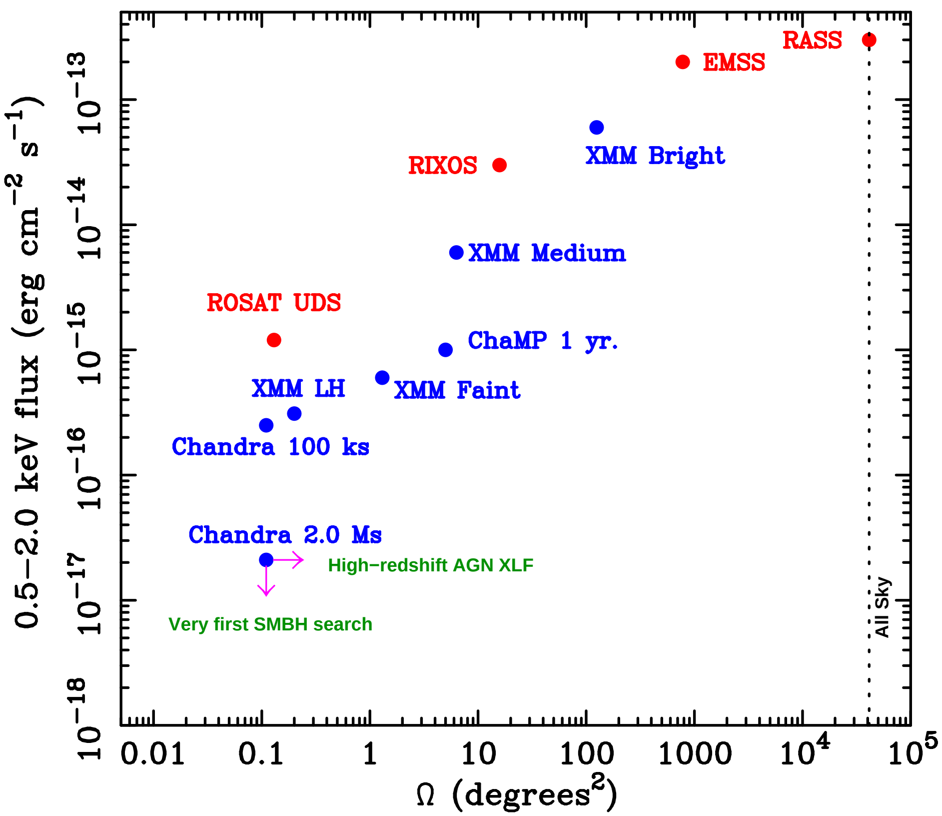
Better X−ray spectral constraints

XMM−Newton, Con−X, XEUS

X−ray variability studies

X−ray imaging

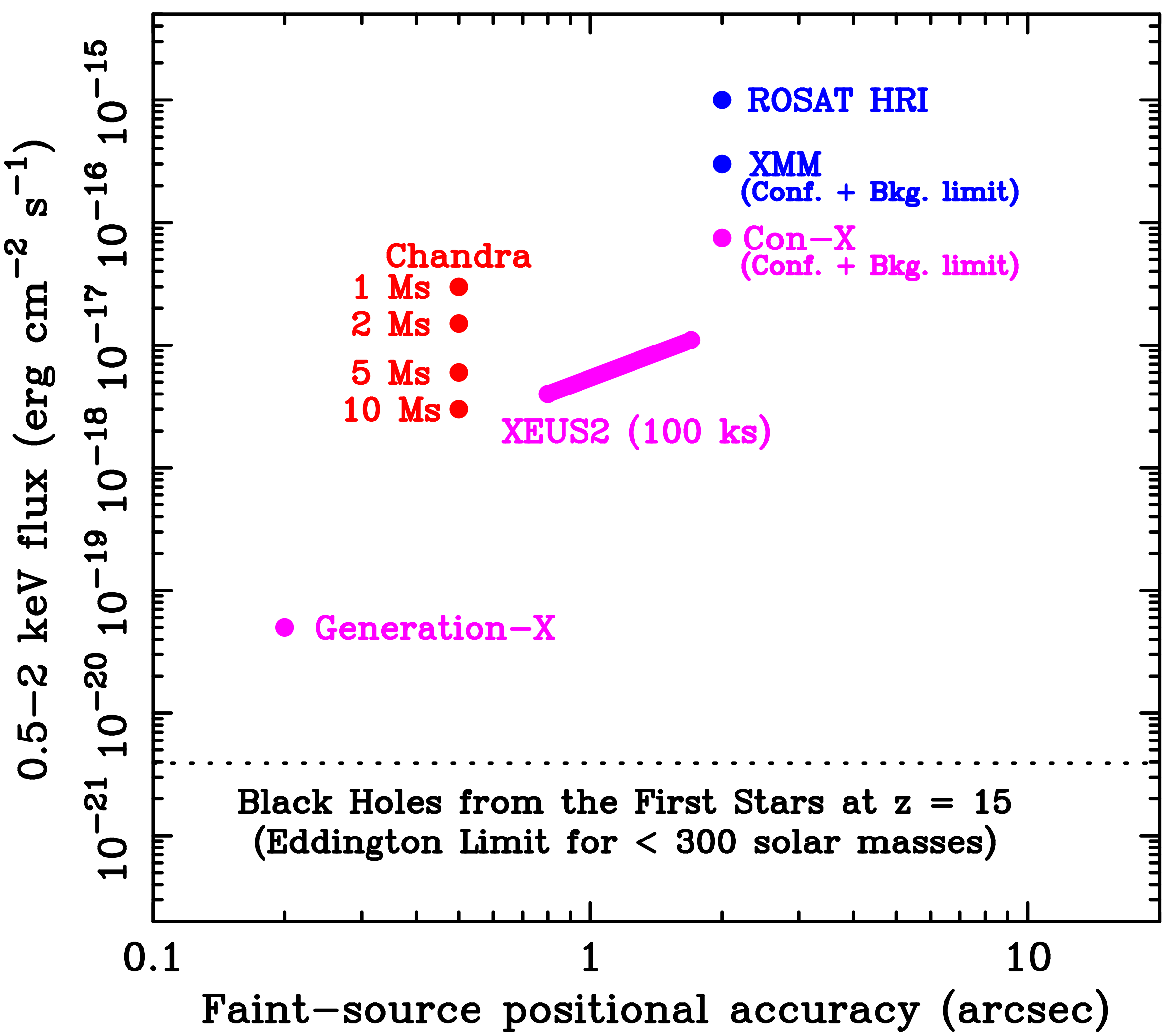
Jets, clustered AGN in high−z LSS



Chandra can go significantly deeper and wider with best positions for ~ 20 yr.

Follow−up of very high−redshift AGN candidates in the near−infrared.

X−ray Detectability of Black Holes from the First Stars and Proto−Quasars



Sample rest−frame 8−30 keV emission at z ~ 15 where X−rays are expected from current data.

But need incredible sensitivity and angular resolution.

Generation−X can detect ~ 4000 solar mass black holes at z ~ 15 (in between first stars and first quasars).