The Roles of Black Holes in the High-Redshift Universe

How did the first massive black holes in the Universe feed and grow?

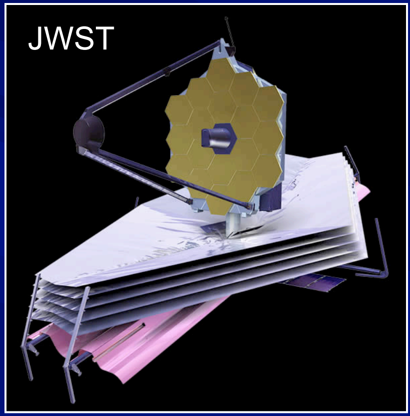
How did feedback from the first massive black holes influence the growth of the first galaxies?

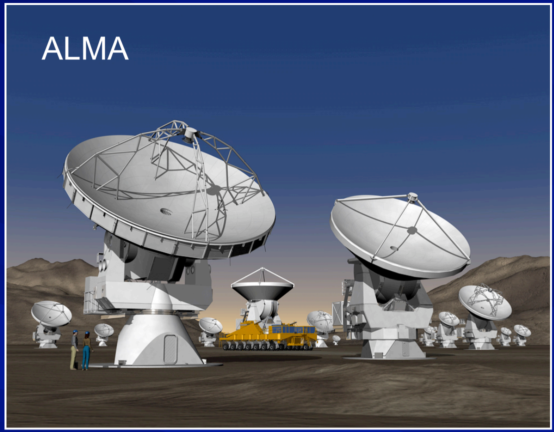
(Andrea Comastri will discuss further key questions related to AGN demography)

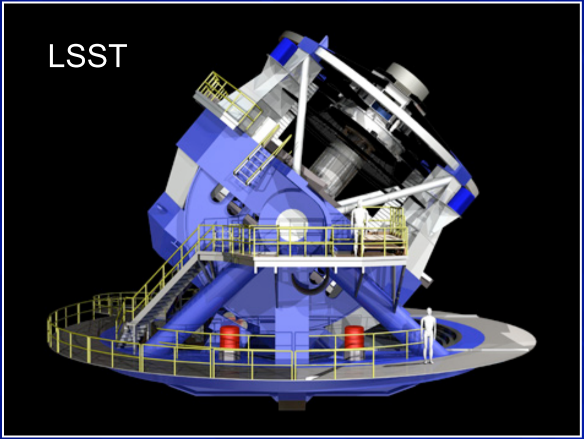
Scientific Issues First

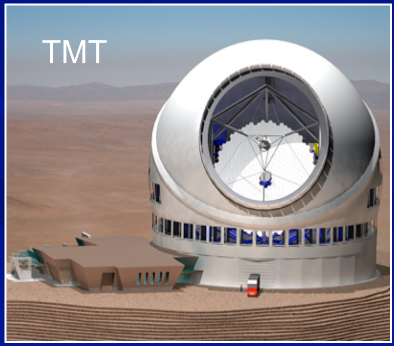
Future Observations of First Galaxies

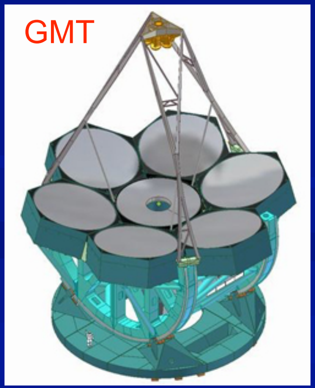
Starlight from First Galaxies

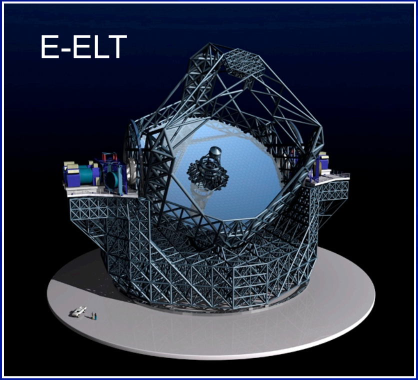






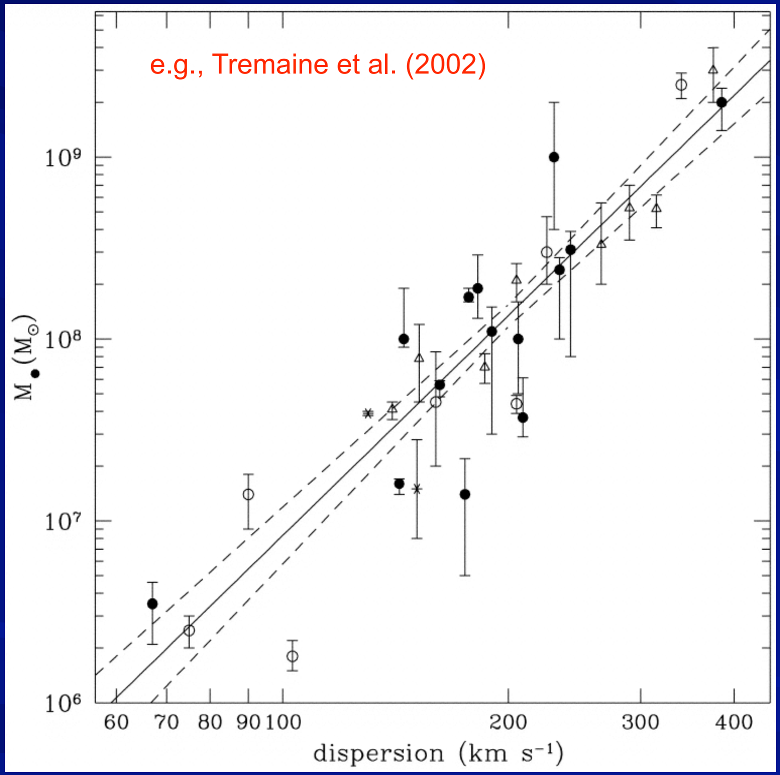


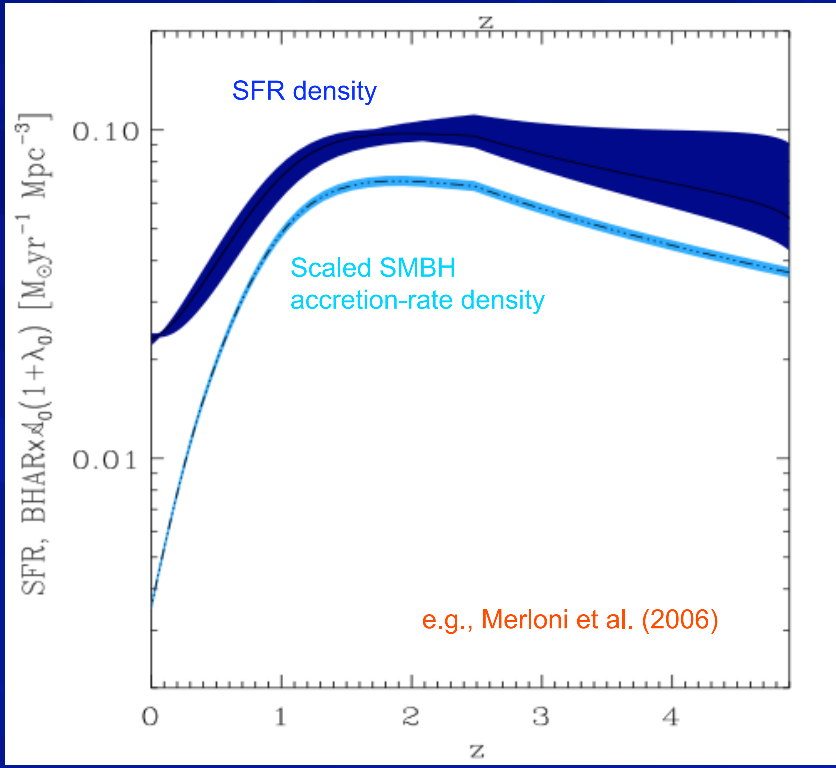




Future Observations of First Galaxies

But also must study accretion light from first massive black holes – integral part of massive galaxies.

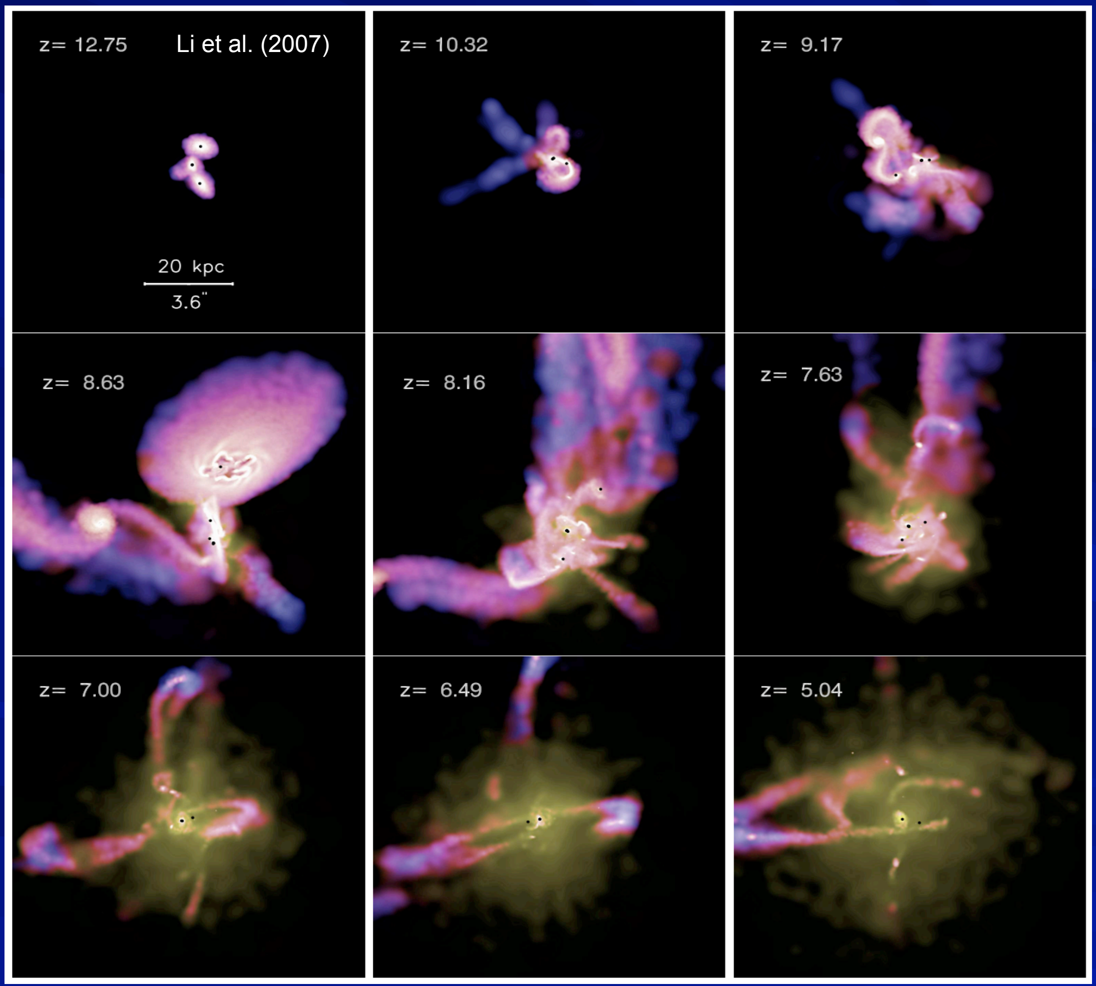




"Binding" energies: E_{SMBH} / E_{Bulge} ~ 100

Mechanisms of SMBH Feedback

Gas density and temperature for high-redshift quasar host



Gas-rich mergers common in most massive halos at high redshifts.

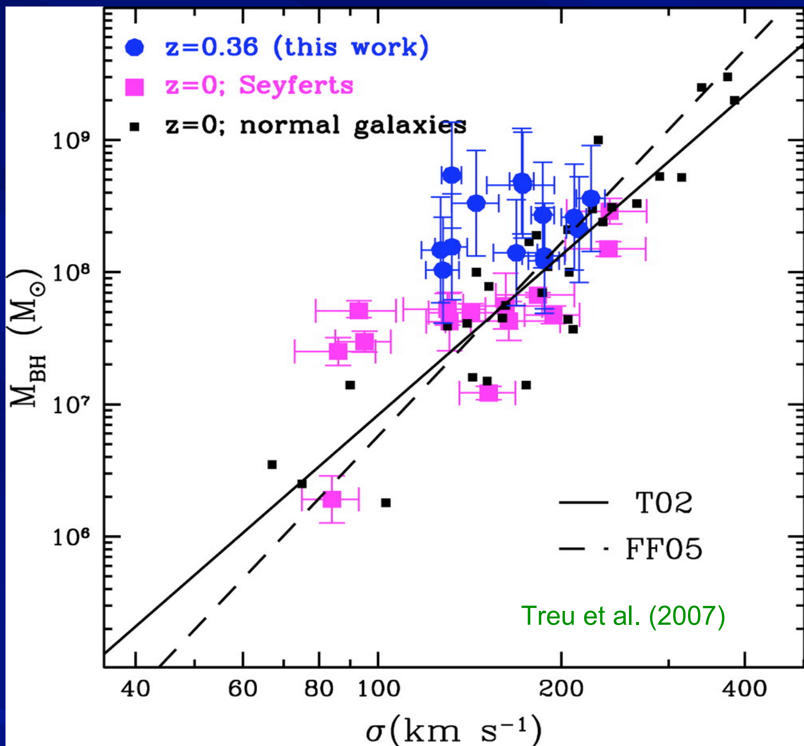
Promote star formation and (obscured) black-hole growth.

Luminous quasar ultimately evacuates gas via a wind, limiting additional star formation and black-hole growth.

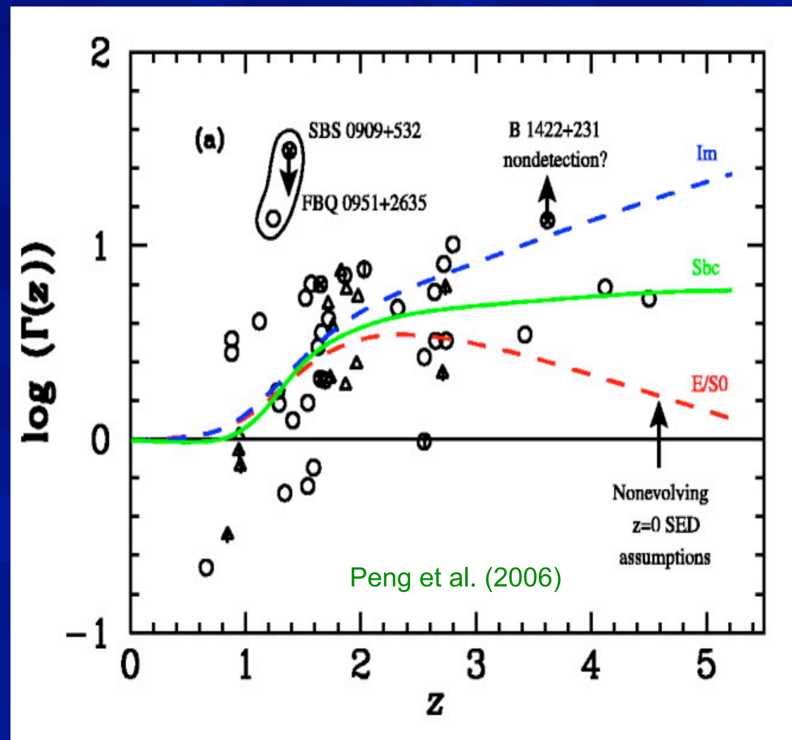
Details remain highly uncertain, so better observations needed.

Black-Hole vs. Host Masses

M_{BH}-σ relation at z = 0 vs. z = 0.36



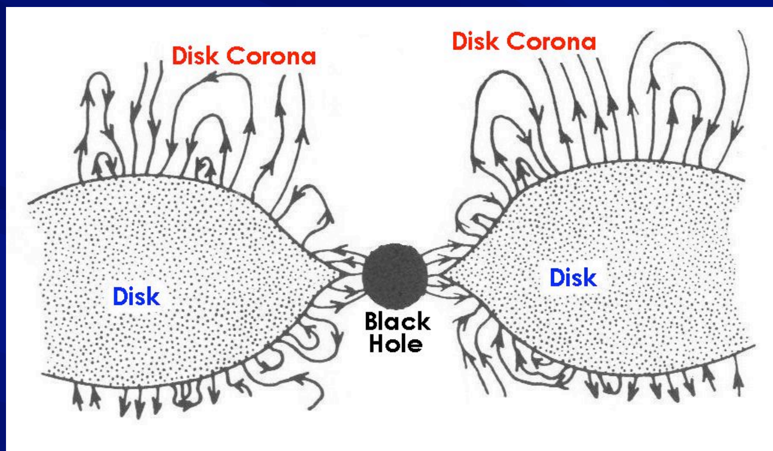
M_{BH} / M_{Gal} (relative to local) versus redshift

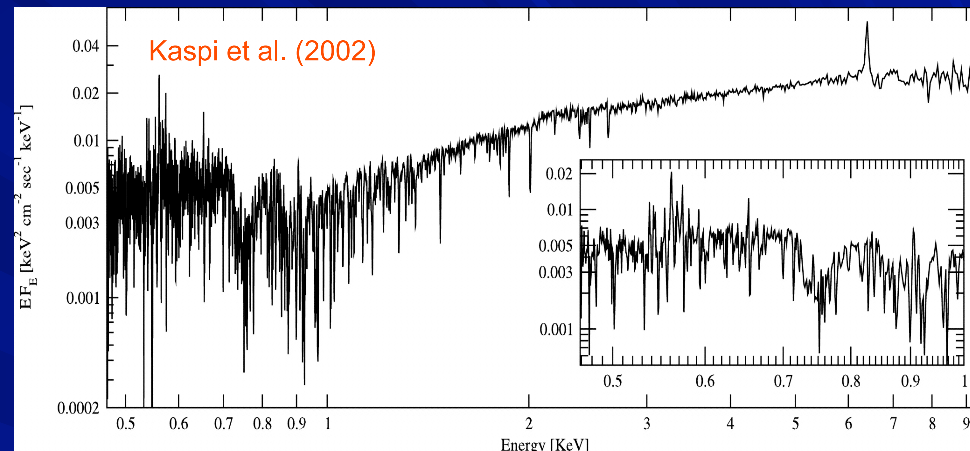


At higher redshift, type 1 AGNs show more black-hole mass per unit host-galaxy mass.

AGN winds likely have stronger effects at high redshifts – lower bulge binding energy and v_{esc}.

Why X-rays?





Conditions in immediate vicinity of SMBH.

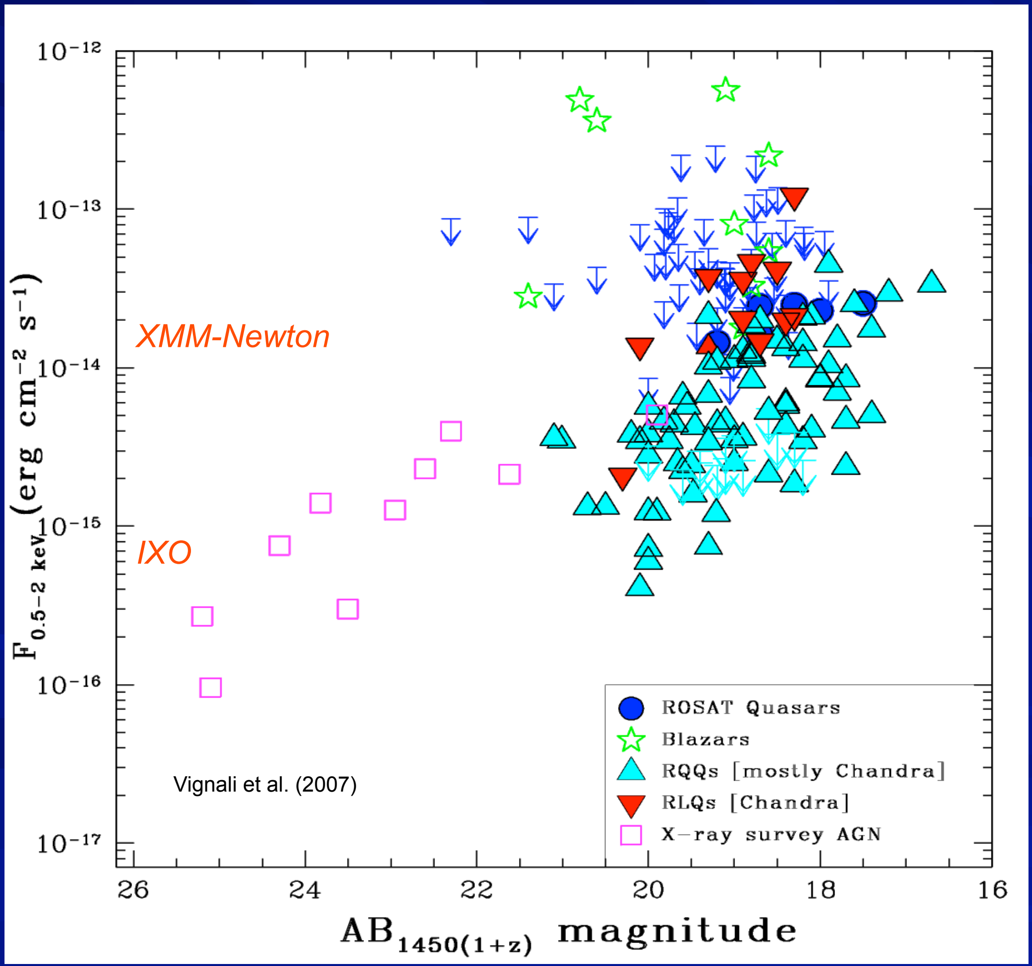
Hot X-ray absorbing components of AGN winds likely carry most of the mass and energy.

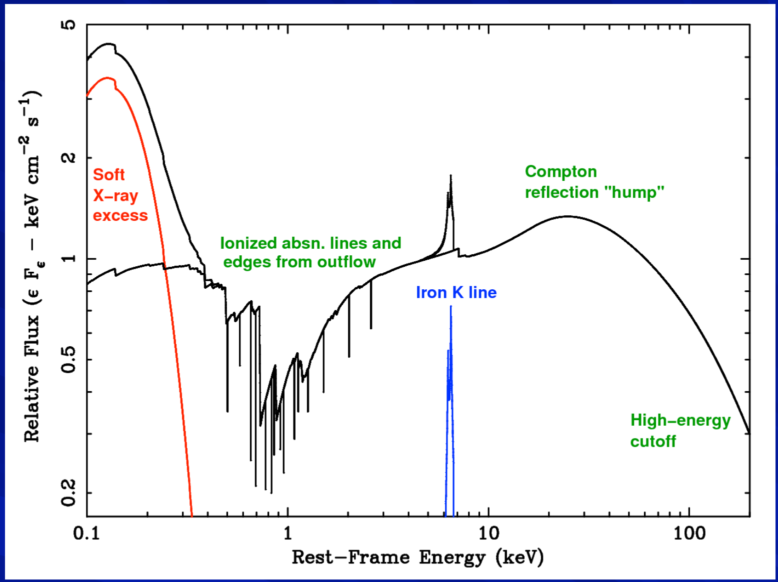
Also universal, penetrating, and undiluted by host galaxy.

Roles of IXO

IXO Needed for Effective X-ray Spectroscopy of Most $z > 4$ AGNs

X-ray vs. Optical Flux for $z > 4$ AGNs

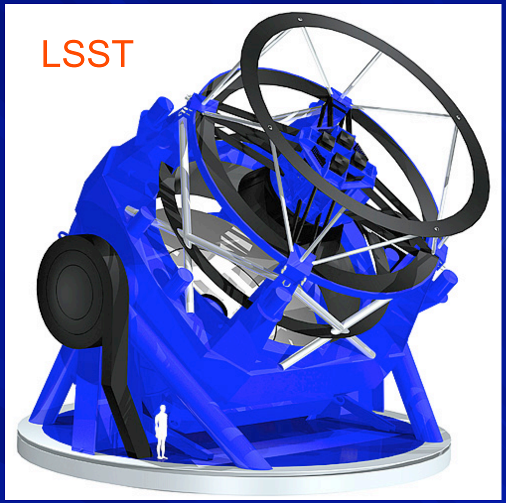




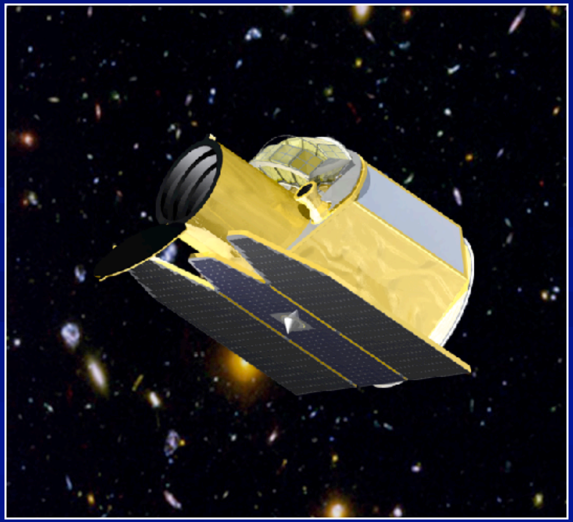
Photon starvation prevents use of spectral diagnostics.

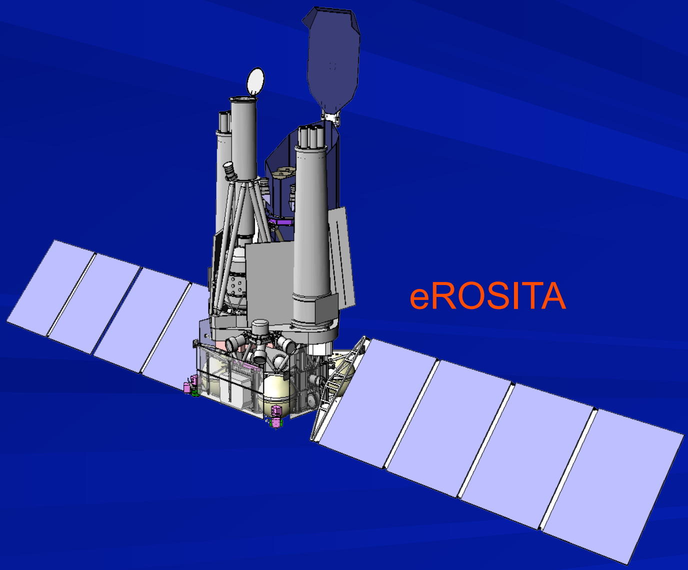
IXO can probe to ~ $10^7\ M_{Sun}$ at $z > 4$ with spectroscopy.

Abundant High-Redshift Targets for IXO



JANUS





Expect ~ 30000+ AGNs at $z > 4$ by time of IXO

LSST alone will deliver ~ 1100 AGNs at $z \sim 6.5$-7.5

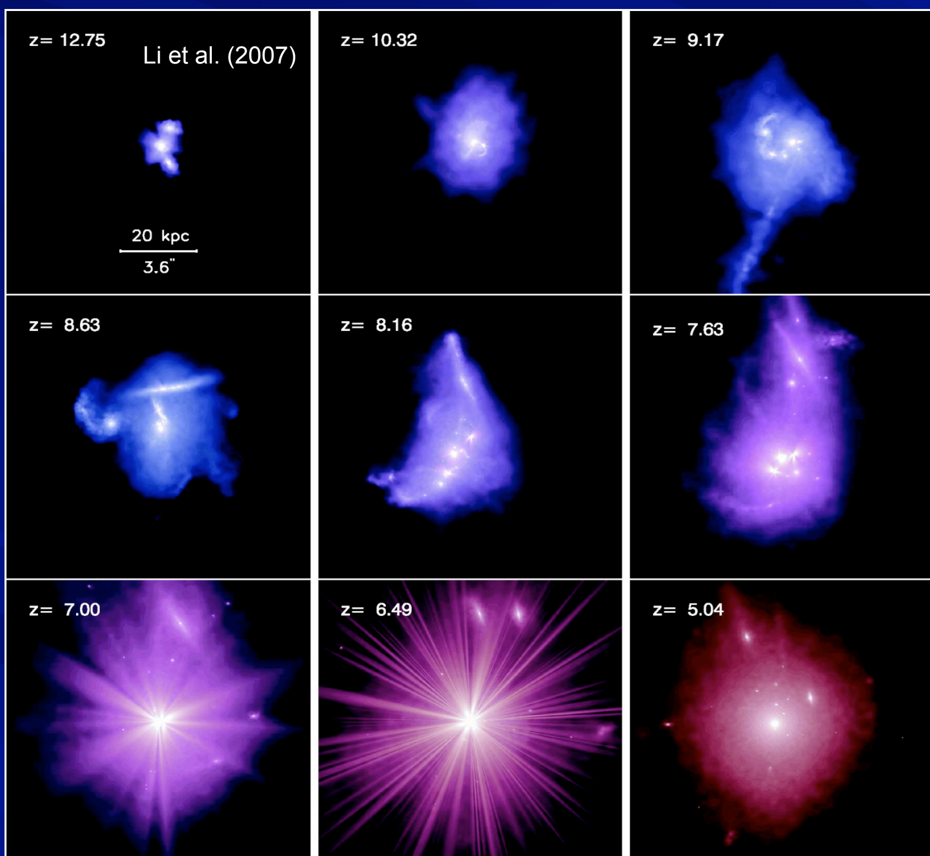
AGN redshift frontier should be at $z > 8$ or greater

How did the first massive black holes in the Universe feed and grow?

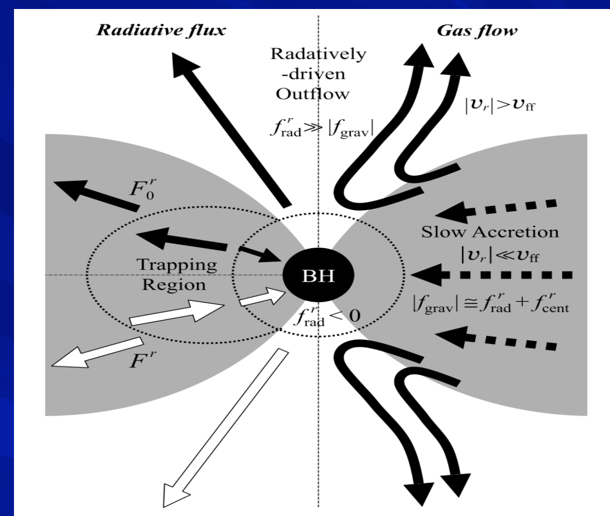
Growth of the First Quasars

Theoretically challenging to grow the most massive black holes observed at *z* = 4-6.5, hosted by luminous quasars.

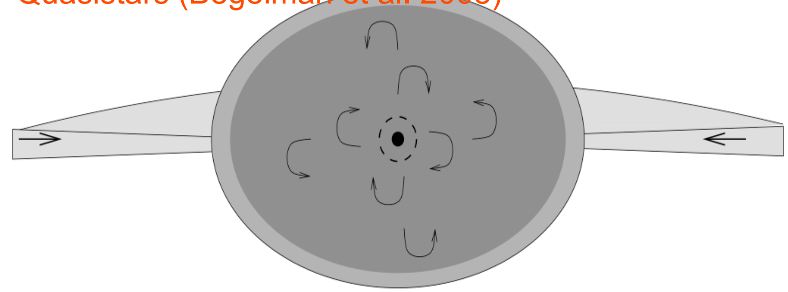
Stellar density and SSFR for high-redshift quasar host



Super-Eddington accretion? (Ohsuga & Mineshige 2007)

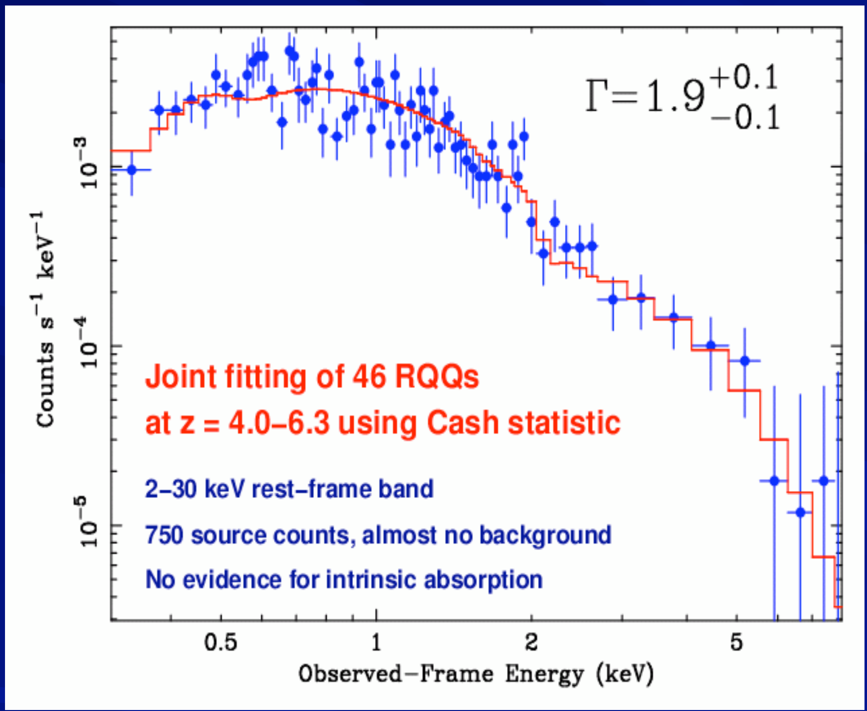


Quasistars (Begelman et al. 2008)

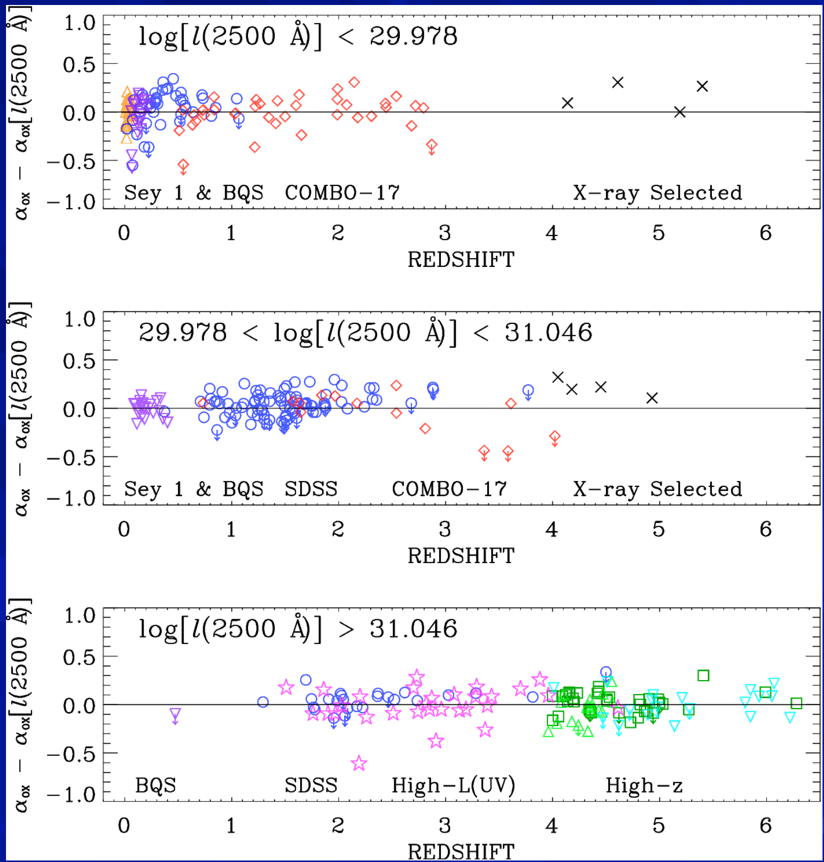


Accretion Mechanisms – Current Data

Basic Chandra and XMM-Newton Joint Fitting – e.g., Vignali et al. (2005)



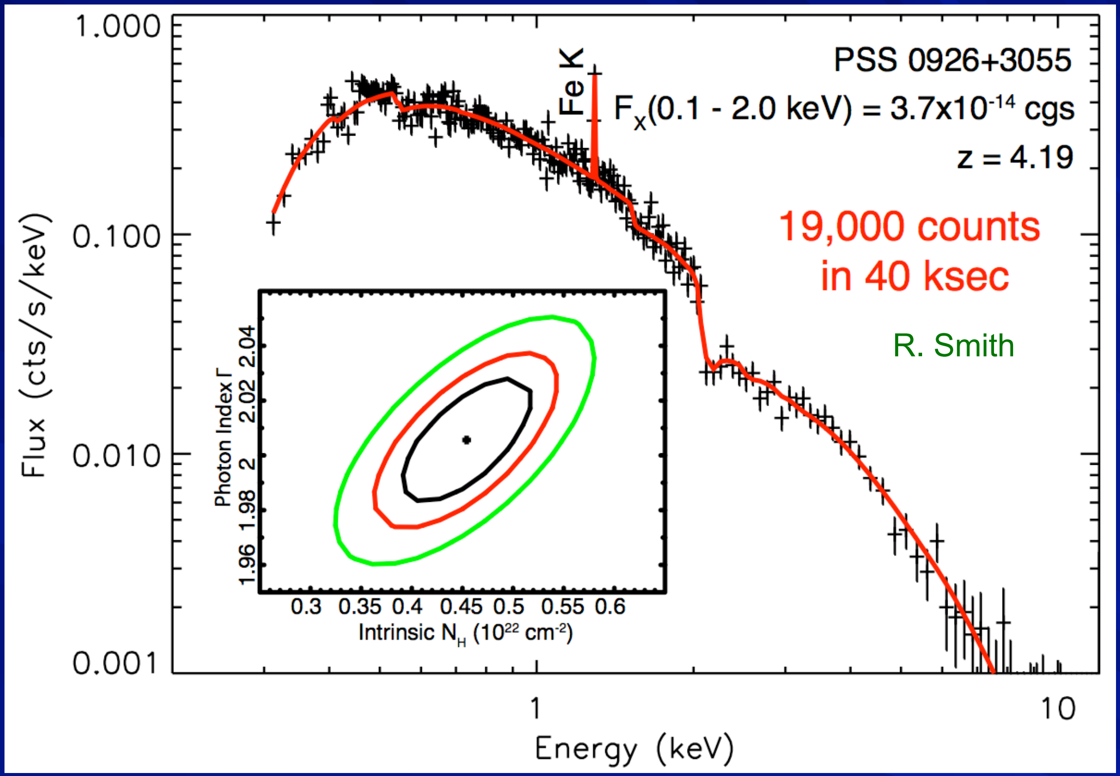
L_X / L_{Opt} – e.g., Steffen et al. (2005)



Constraints on X-ray spectral evolution of high-redshift AGNs a subject of debate.

All current studies suffer from poor photon statistics.

Accretion Mechanisms - IXO



X-ray continuum shape – L / L_{Edd} indicator

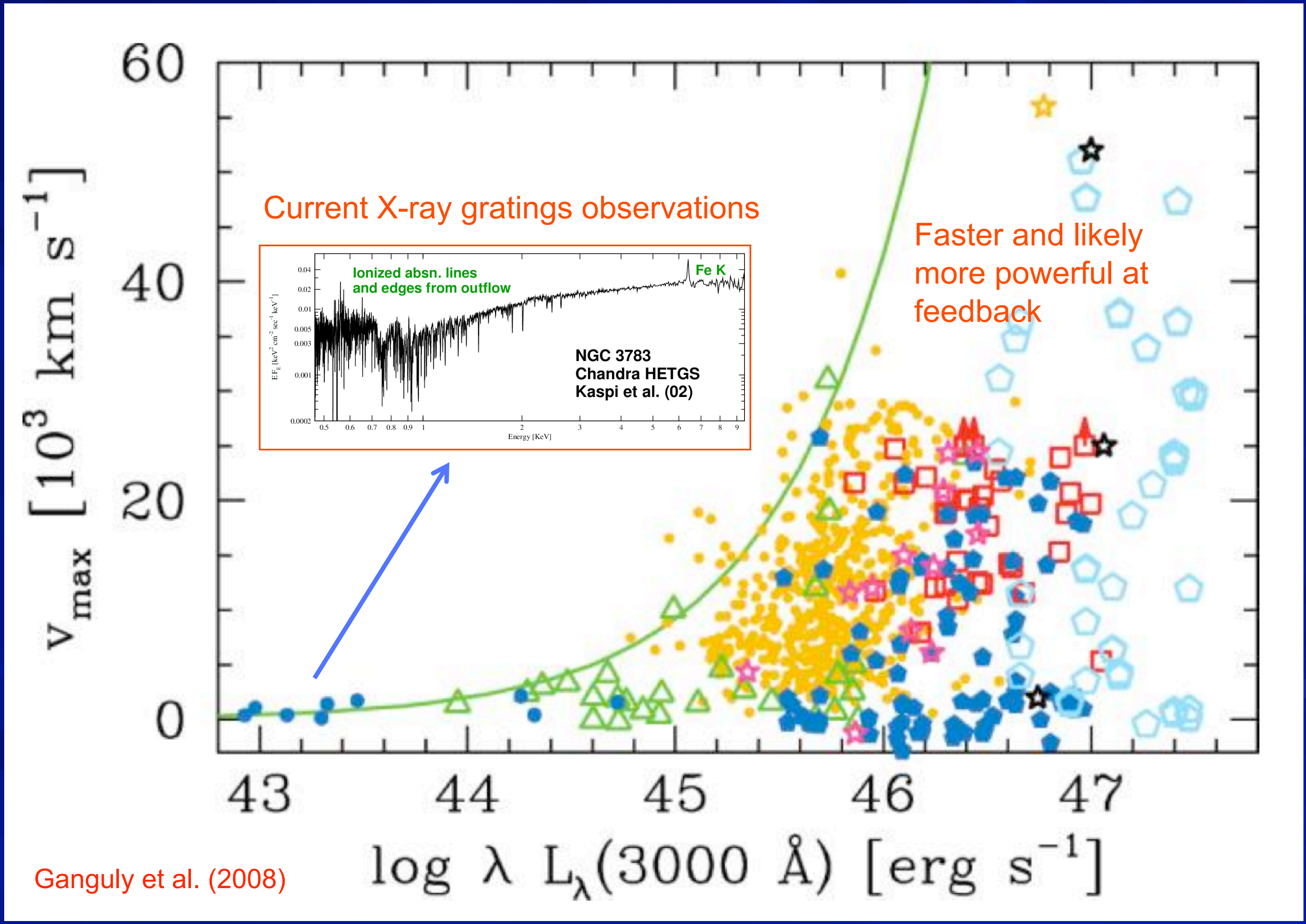
Iron K lines – Disk ionization, rotation, Baldwin effect, multiple SMBHs

Compton-reflection continuum – Disk ionization, coronal isotropy

X-ray variability – Relations to SMBH mass and L / L_{Edd}

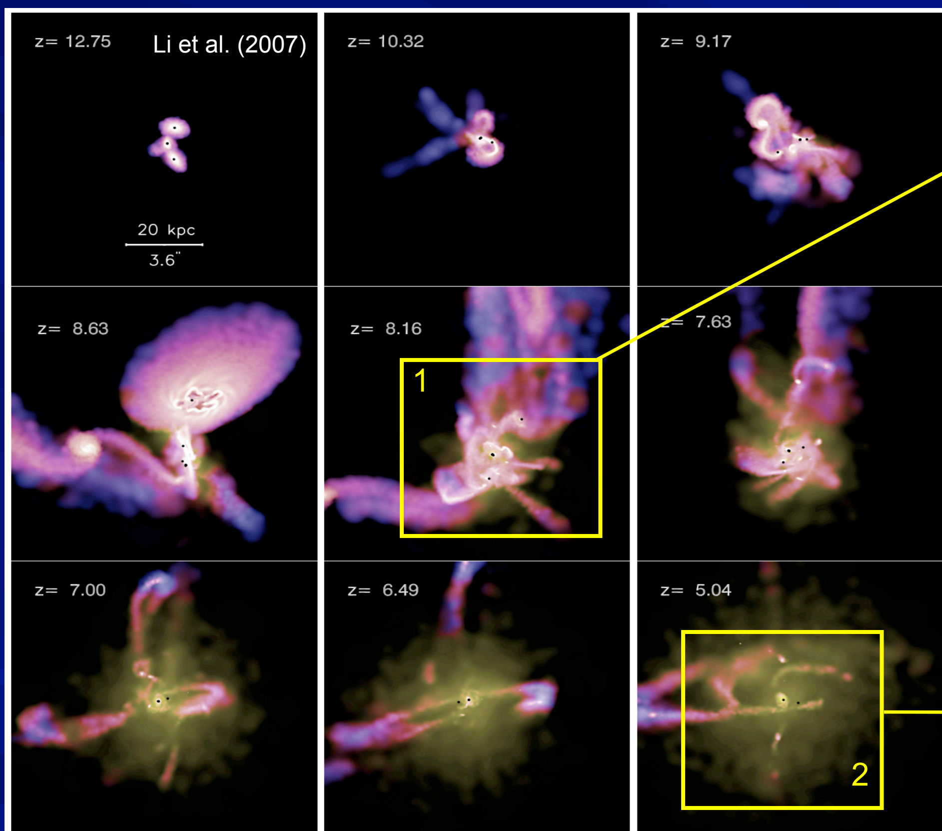
How did feedback from the first massive black holes influence the growth of the first galaxies?

The Range of AGN Outflows

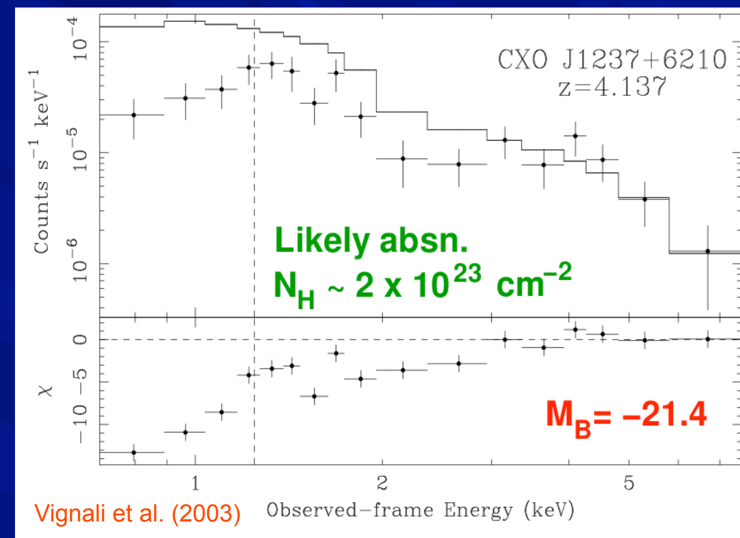


Environments and Effects on First Galaxies

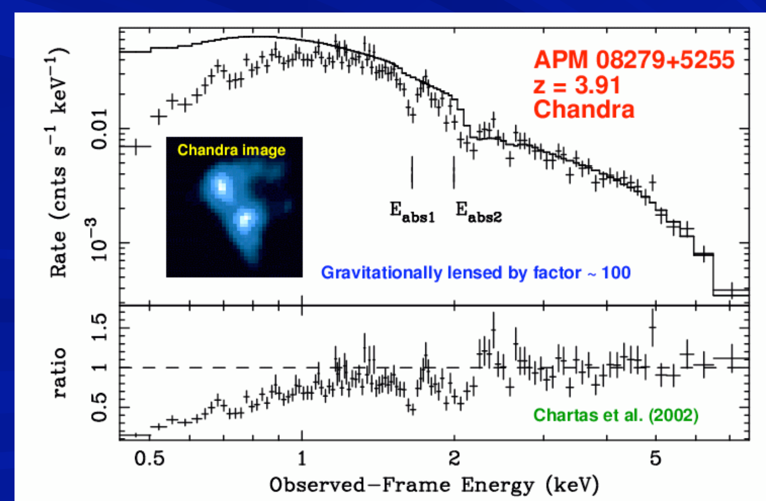
Gas density and temperature for high-redshift quasar host



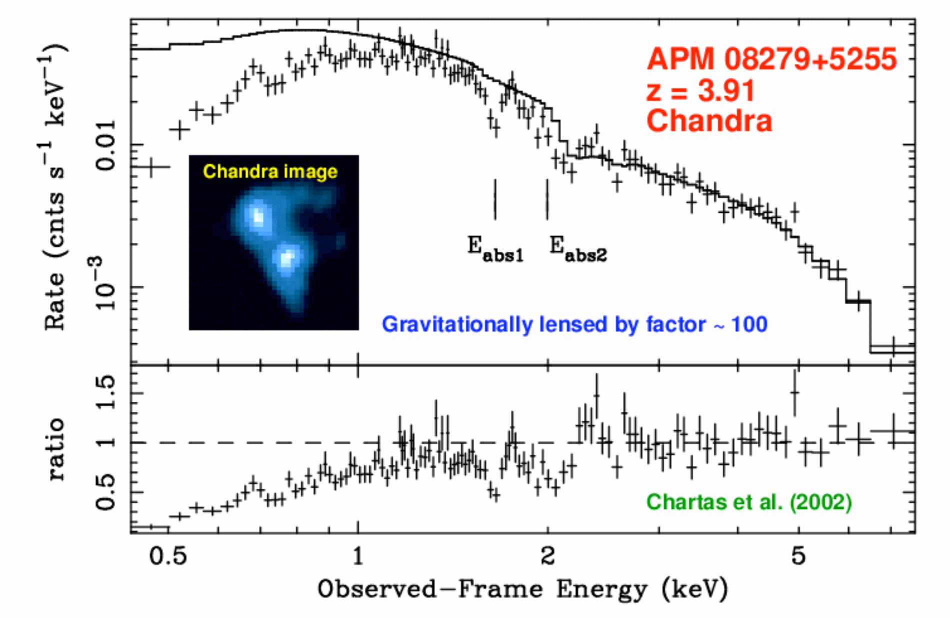
1. An Obscured Protoquasar?

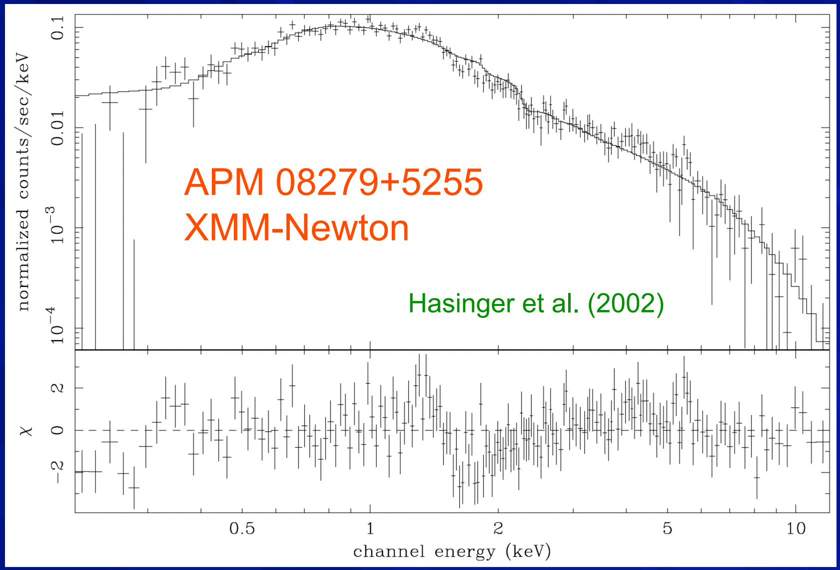


2. X-ray BALs showing high-redshift feedback in action?



X-ray Absorbing Outflow from APM 08279+5255





Absorption features at 8-18 keV in rest frame - X-ray BALs from iron K?

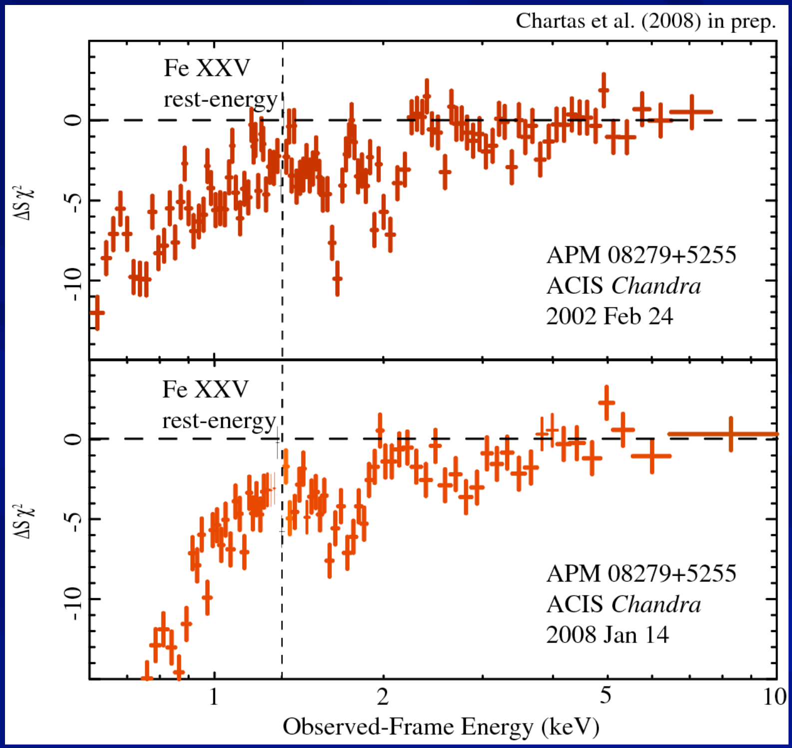
Implied X-ray velocity is *v* ~ 0.2-0.4*c* and higher. Much higher than for UV BALs.

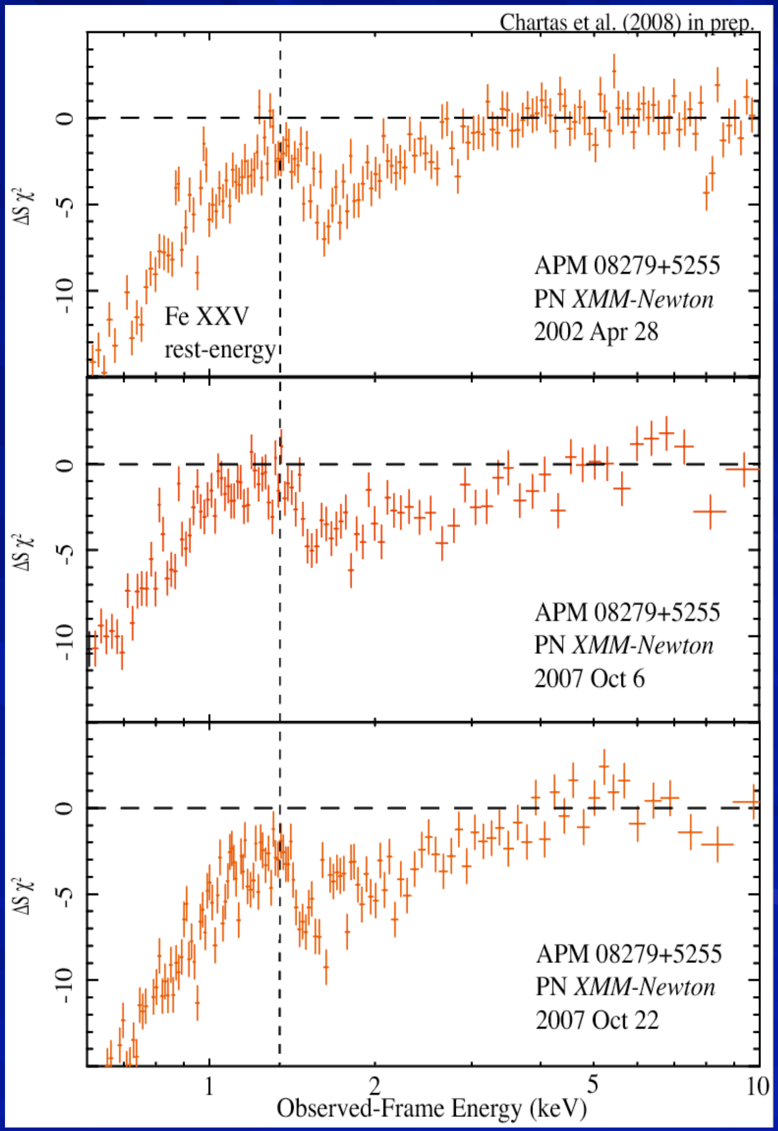
X-ray absorber in BAL quasars in state of outflow? As for Seyfert galaxies.

Kinetic power of outflows is potentially very large. High-redshift feedback in action?

Such features could be present, but currently undetected, in many other BAL quasars.

Observed Variability - APM 08279+5255



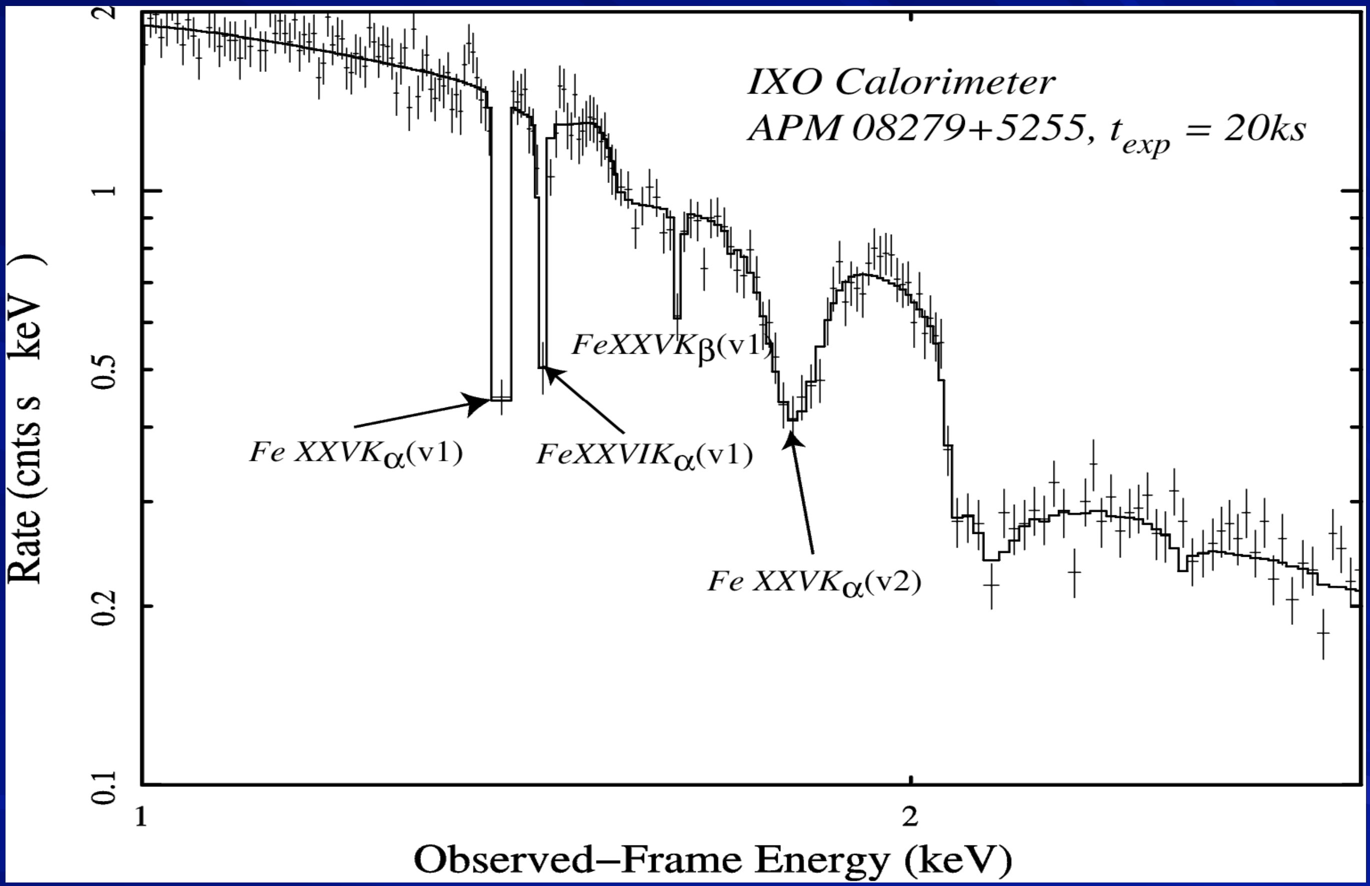


2007-2008 data confirm the absorption features.

Variability now seen in multiple Chandra and XMM-Newton observations, as expected.

Line energies and strengths change on timescales down to ~ days.

IXO Simulation – APM 08279+5255



Multiple components of the X-ray BALs can be studied in detail in 20 ks IXO exposures.

The Roles of Black Holes in the High-Redshift Universe

How did the first massive black holes in the Universe feed and grow?

How did feedback from the first massive black holes influence the growth of the first galaxies?

(Andrea Comastri will discuss further key questions related to AGN demography)