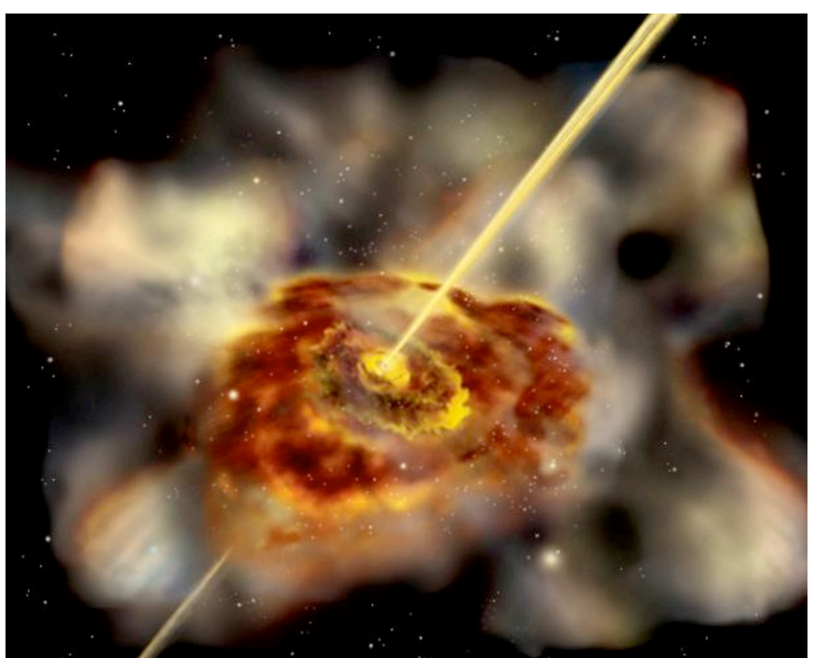
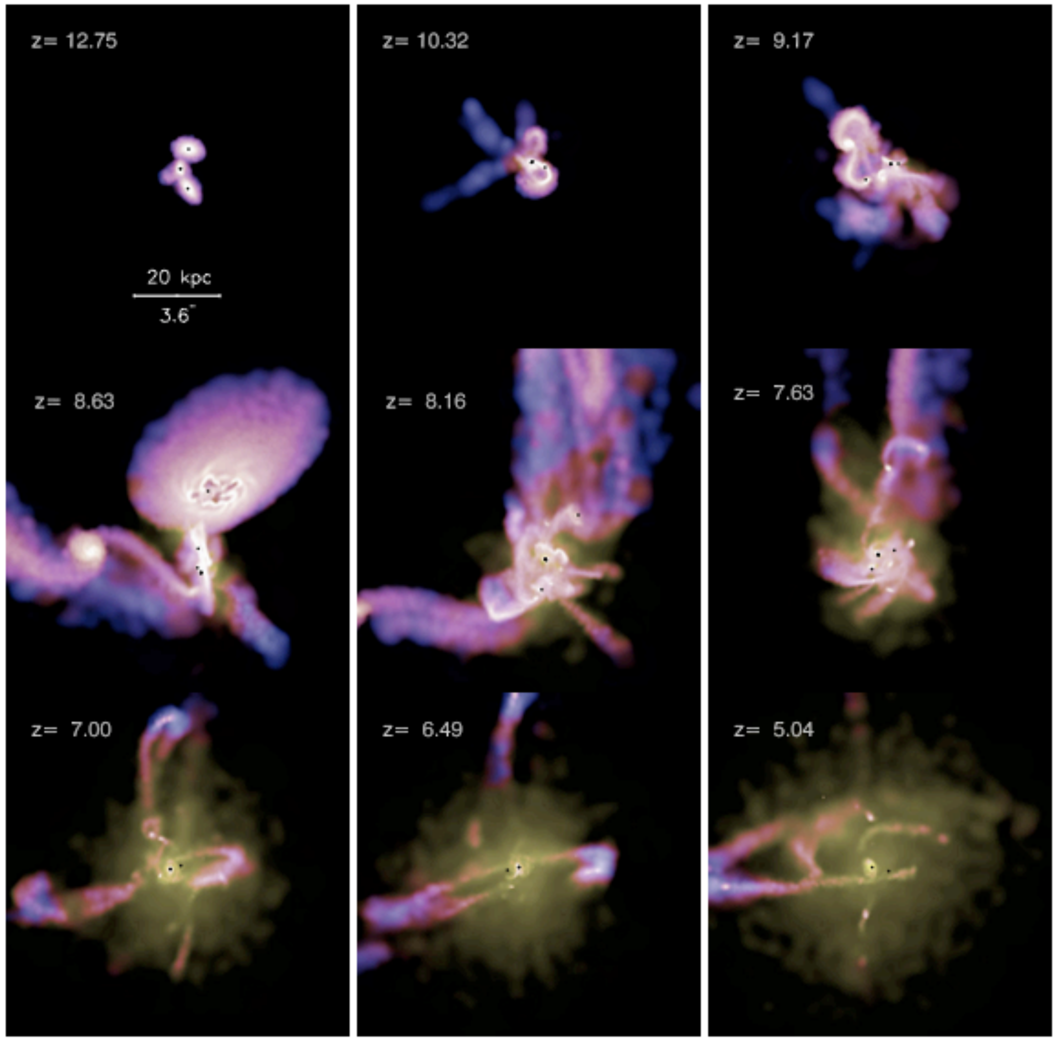
The Most Distant Black Holes

Chris Willott (HIA, Victoria)

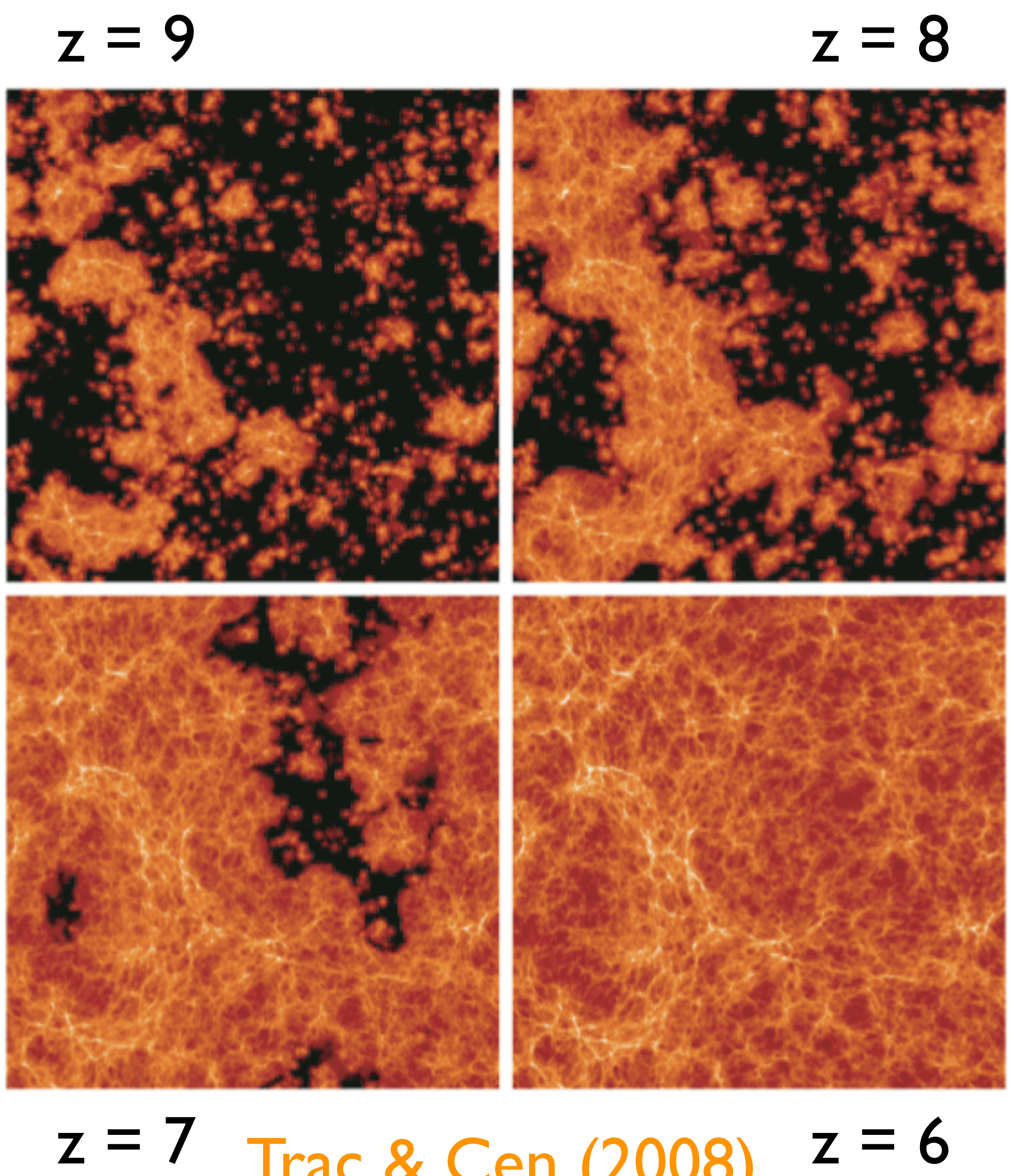


Why Look For the Highest Redshift Quasars?

- Reionization and metal enrichment of IGM
- Quasar luminosity function
- Early growth of supermassive black holes
- Massive galaxy evolution
- Black hole - star formation connection



Li et al. (2007)



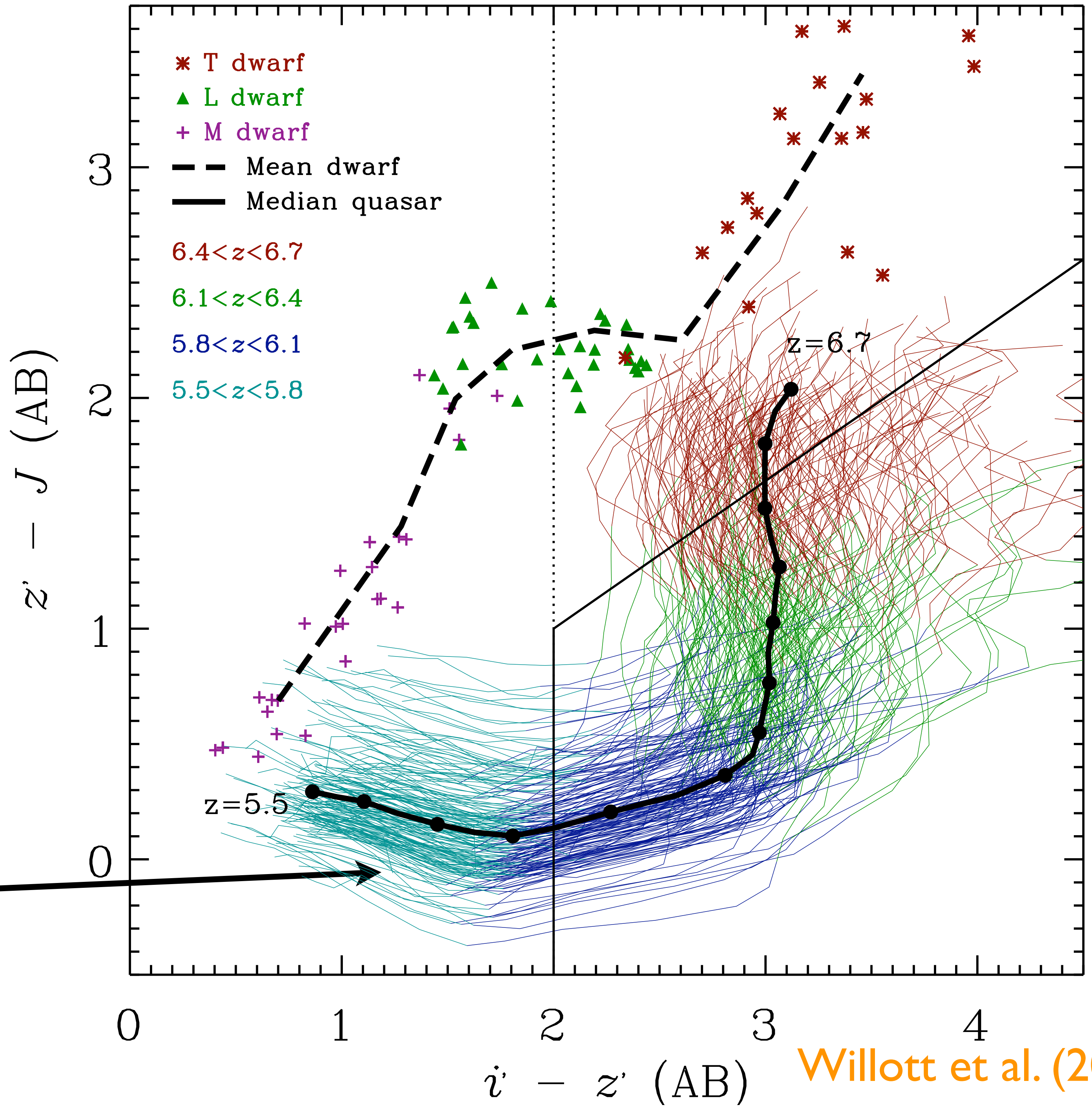
Trac & Cen (2008)

Canada-France High-z Quasar Survey

- Large multi-filter imaging survey with CFHT MegaCam to find z~6 quasars
- Main survey ~800 square degrees to magnitude z'=22.5, i'=24
- Include CFHT Legacy Survey Deep and Wide fields for range of quasar luminosities.
- i'-z' quasar Lyman break selection
- Need J band followup to separate brown dwarfs from quasars
- Spectroscopic followup with Gemini GMOS

Canada-France High-z Quasar Survey

Simulate the expected colours of quasars and brown dwarfs on a colour-colour diagram:

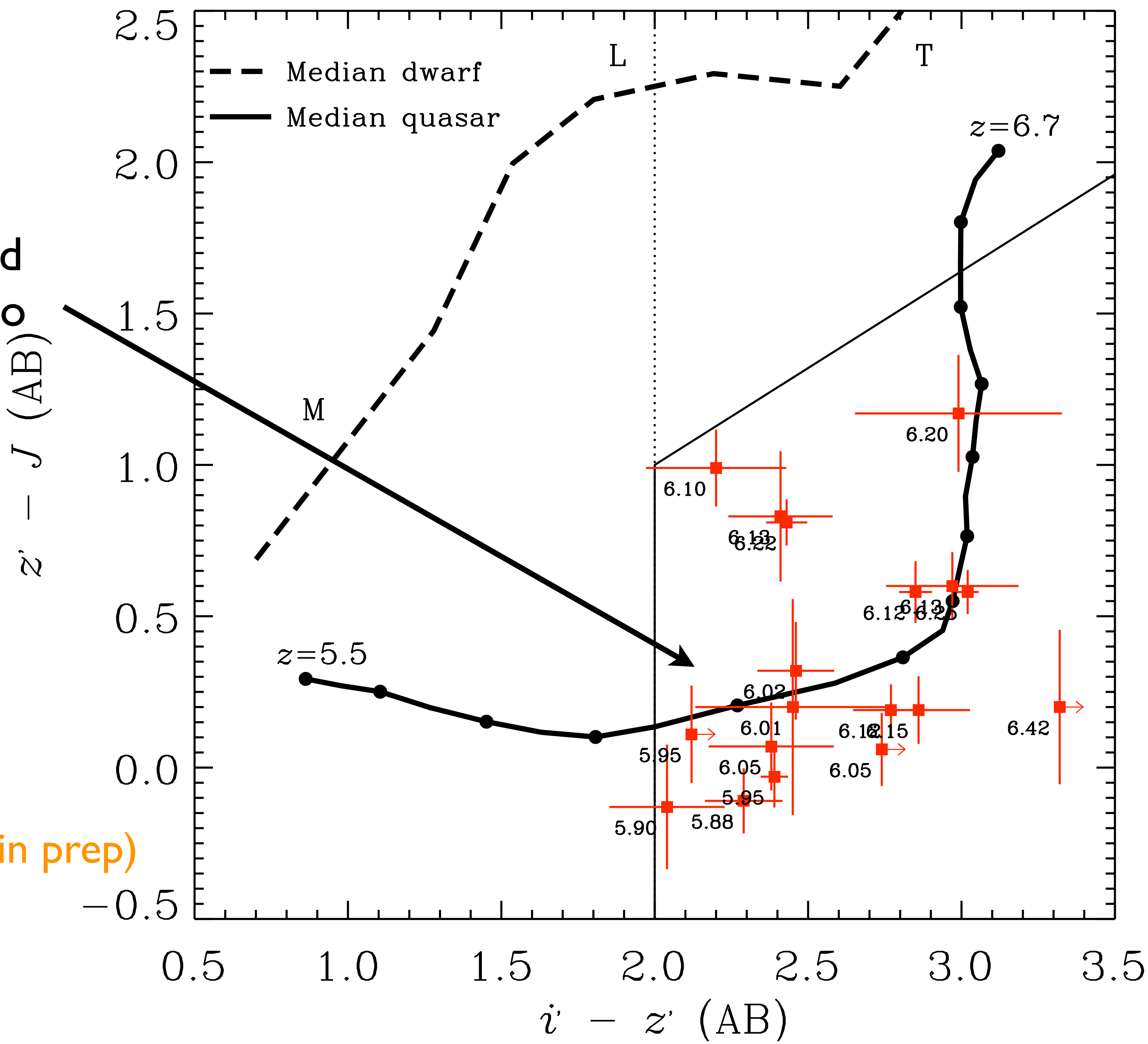


180 quasars from SDSS archive at redshift $3.1 < z < 3.2$ *cloned* to $5.5 < z < 6.7$

Willott et al. (2005)

Canada-France High-z Quasar Survey

CFHQS quasars discovered so far have colours close to predicted track.



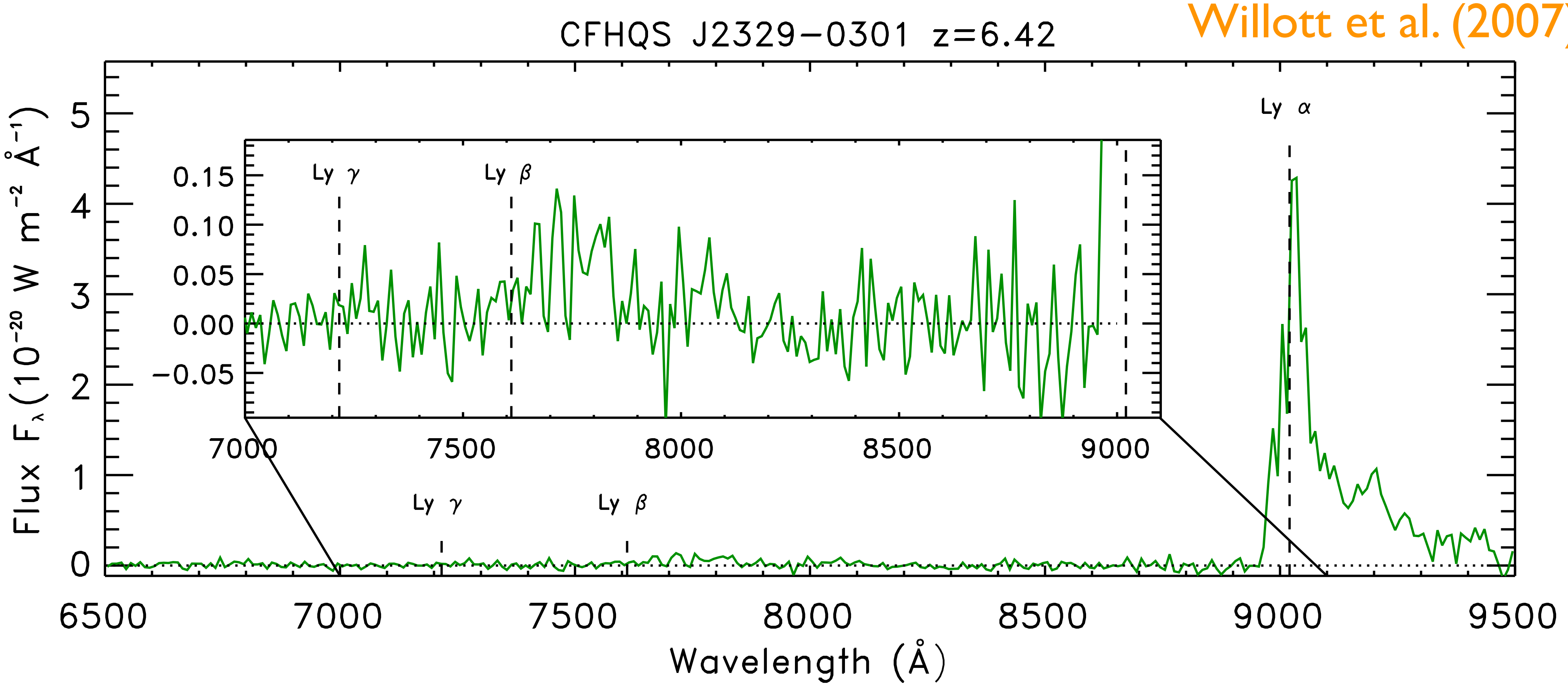
Willott et al. (2007; 2009; in prep)

Canada-France High-z Quasar Survey

- GMOS long-slit spectroscopy of candidate high redshift quasars
- Queue flexibility means rapid spectroscopic followup
- Use nod-and-shuffle to achieve high quality background subtraction
- Future red-sensitive CCD upgrades will improve sensitivity
- 50% success rate (the rest are M/L/T dwarfs).

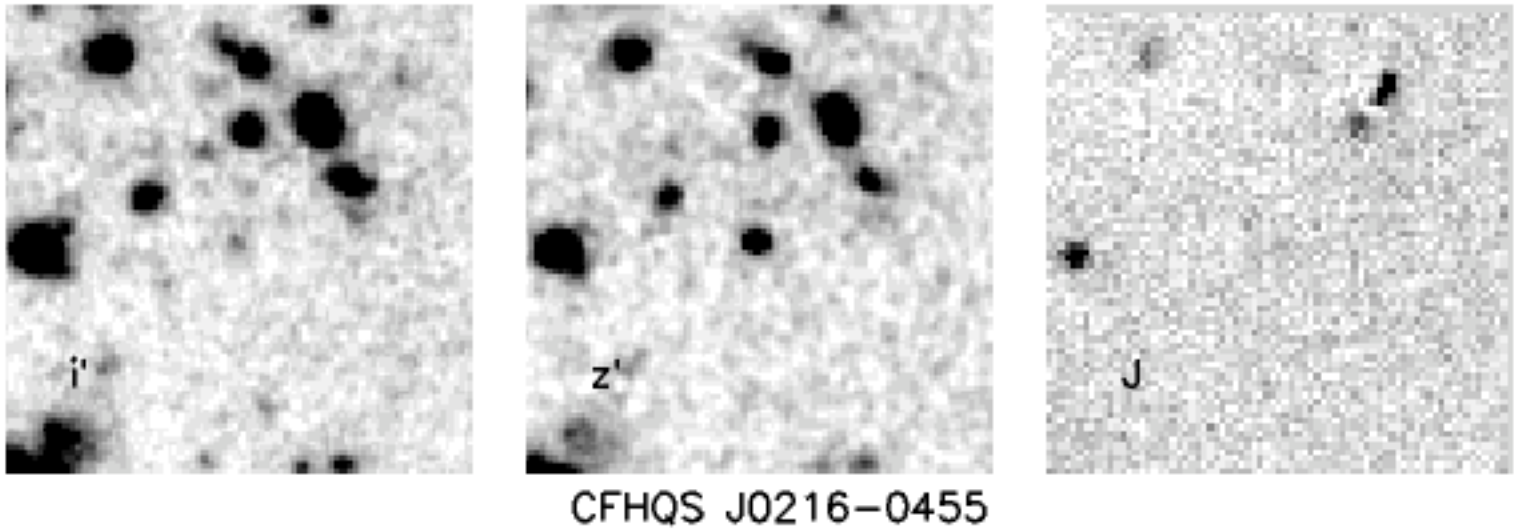
GMOS

Willott et al. (2007)



Canada-France High-z Quasar Survey

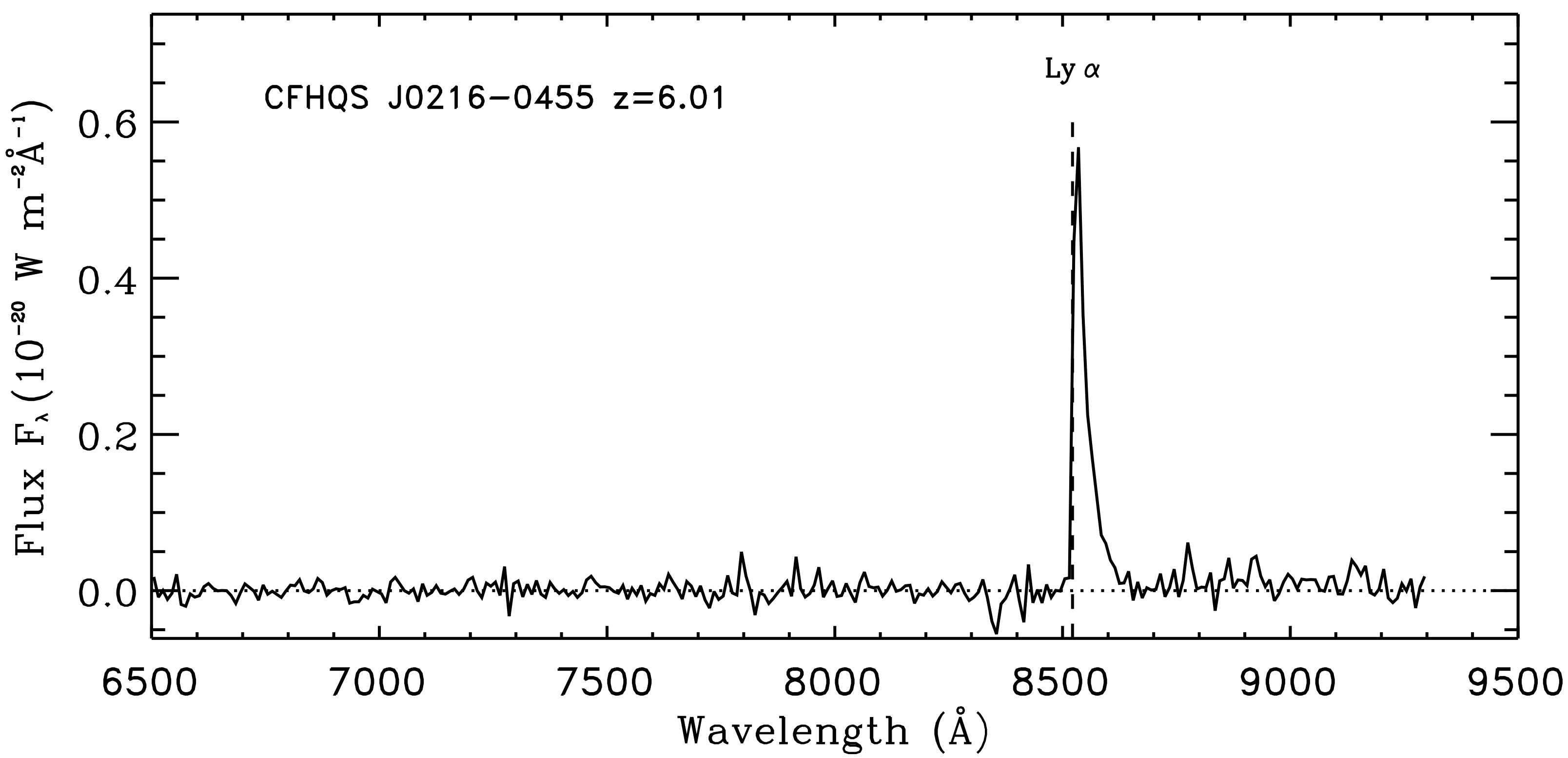
SXDS i’ SXDS z’ UKIDSS J



McLure et al. (2006)

- z’ = 24.4, i’ = 26.8
- M_{1450} = −22.2
- Spitzer 3.6 & 4.5 detected
- XMM-Newton not detected
- VLA not detected

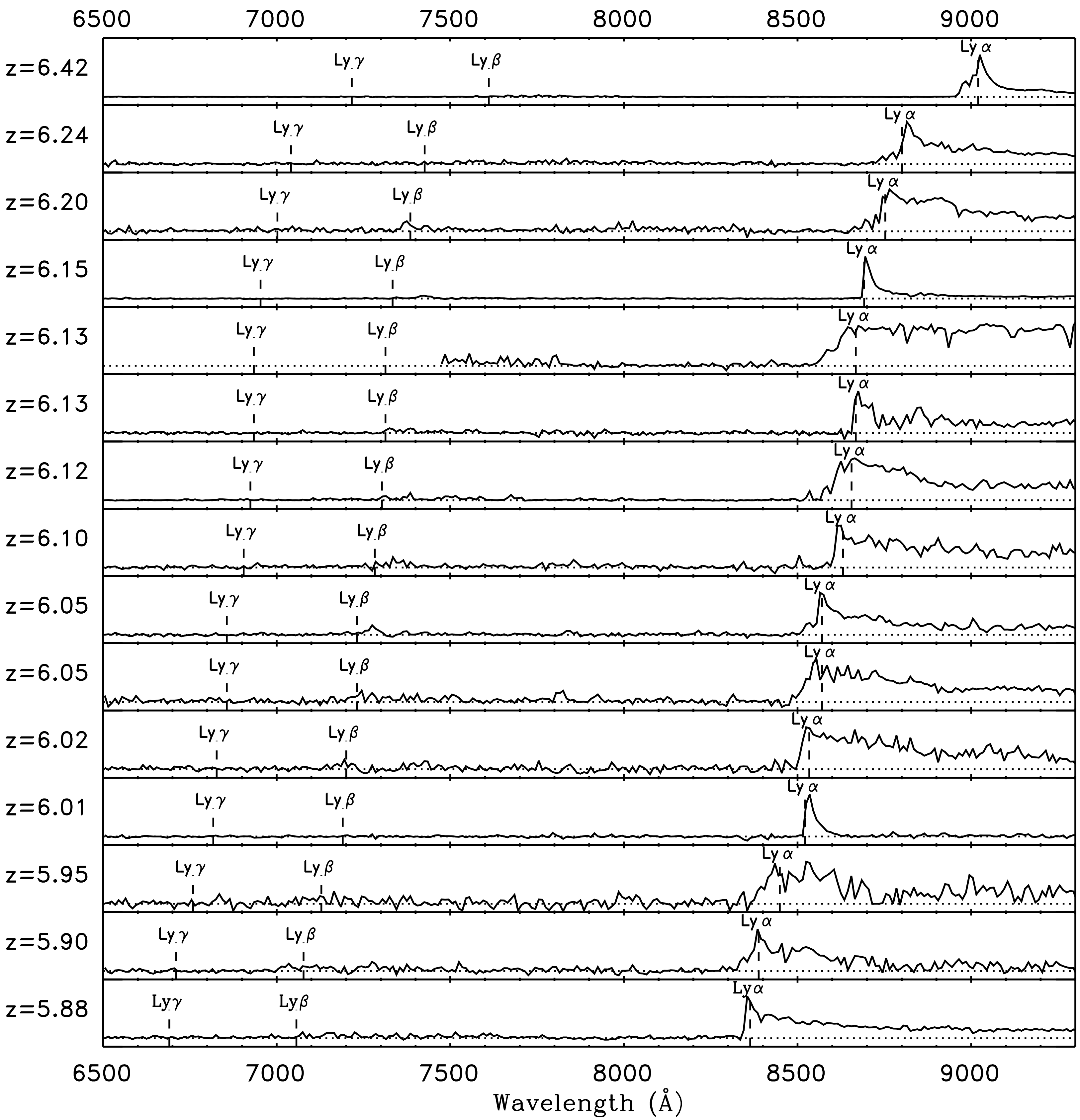
GMOS spectrum



Very faint, low-luminosity quasar with narrow Lyman α line (intrinsic FWHM ~ 1600 km/s).

Willott et al. (2009)

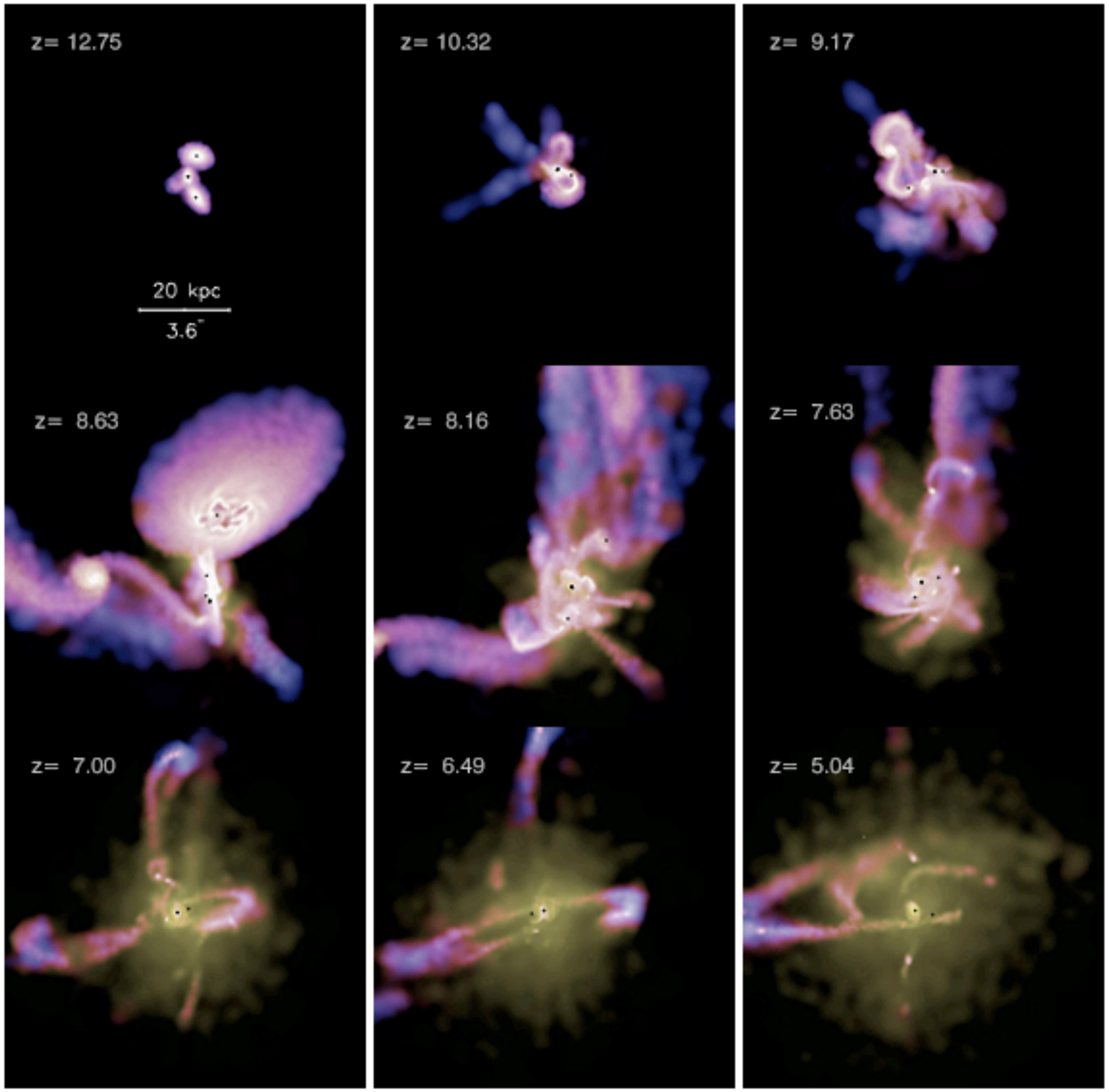
Canada-France High-z Quasar Survey

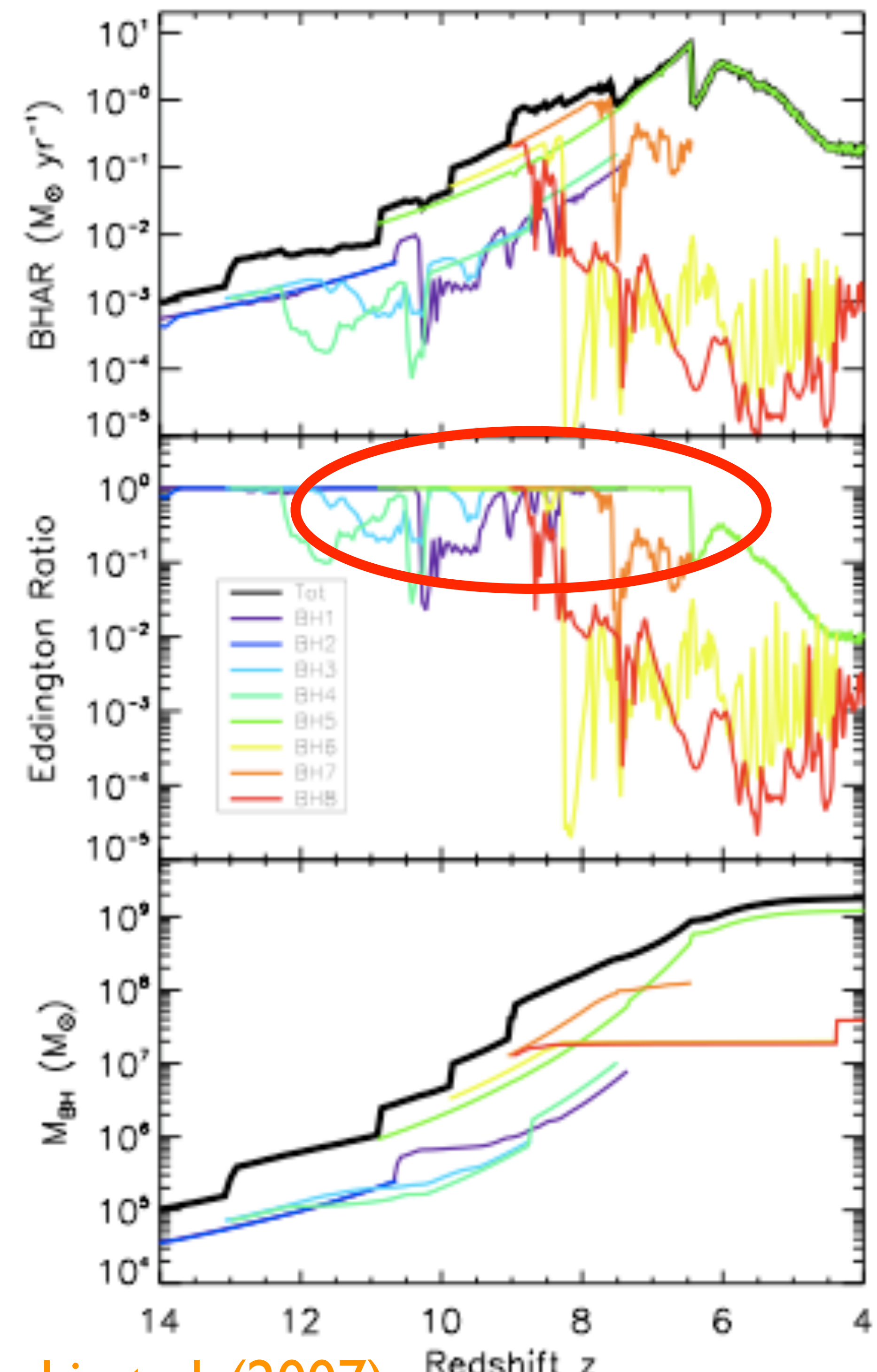


- 17 CFHQS quasars so far.
- Other Gemini/Subaru z~6 searches:
  - SDSS (Goto)
  - CFHT (Hall)
  - UKIDSS (Warren, Patel, Chiu)
  - PanStarrs (Chambers)

Near-IR spectroscopy and black hole growth

How do black holes grow so quickly?

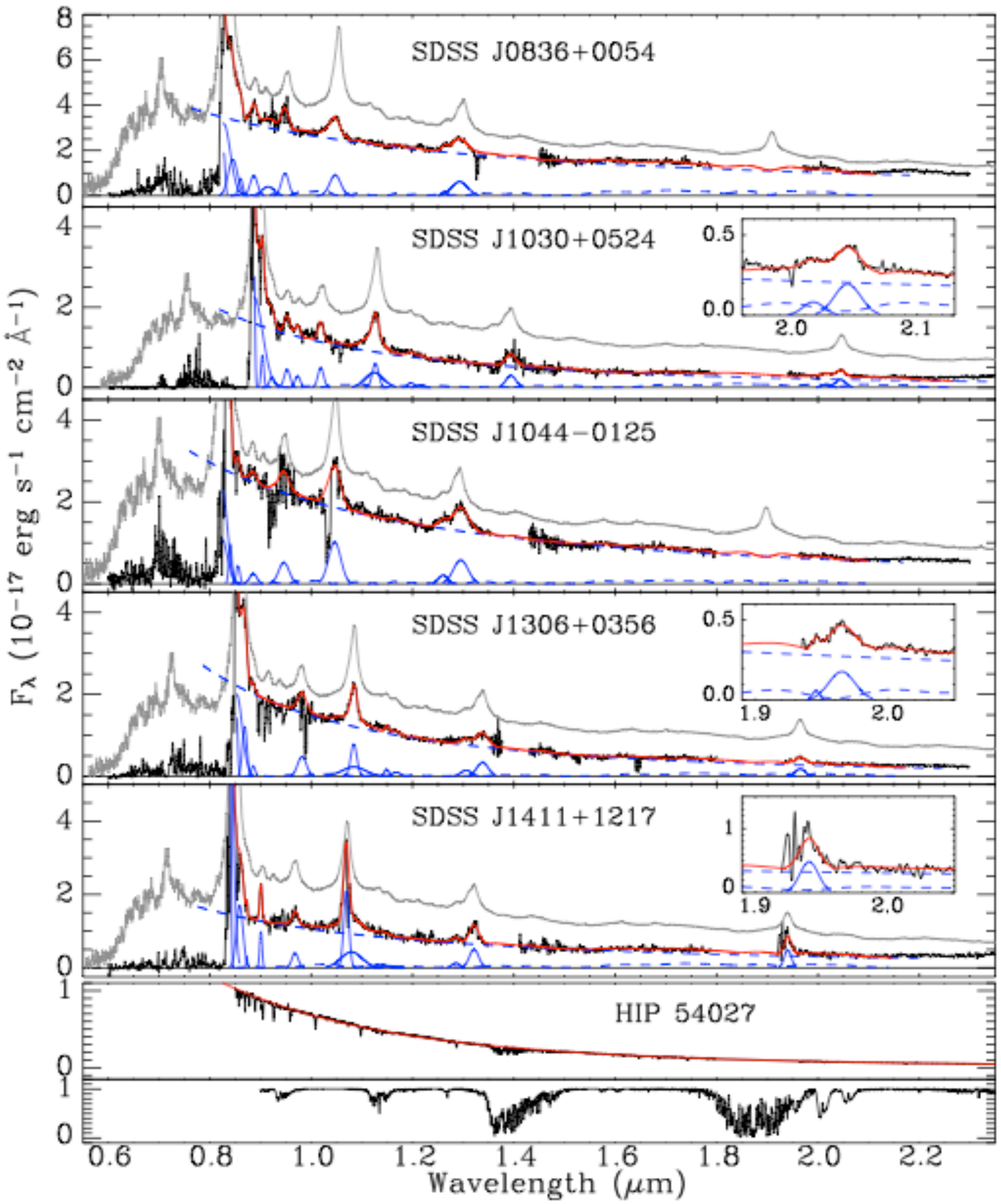




Li et al. (2007)

Near-IR spectroscopy and black hole growth

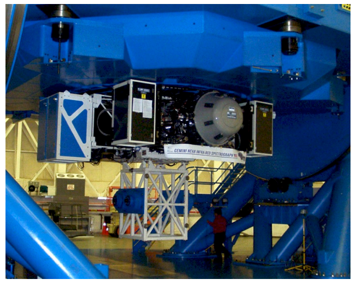
GNIRS
GEMINI NEAR INFRA-RED SPECTROGRAPH

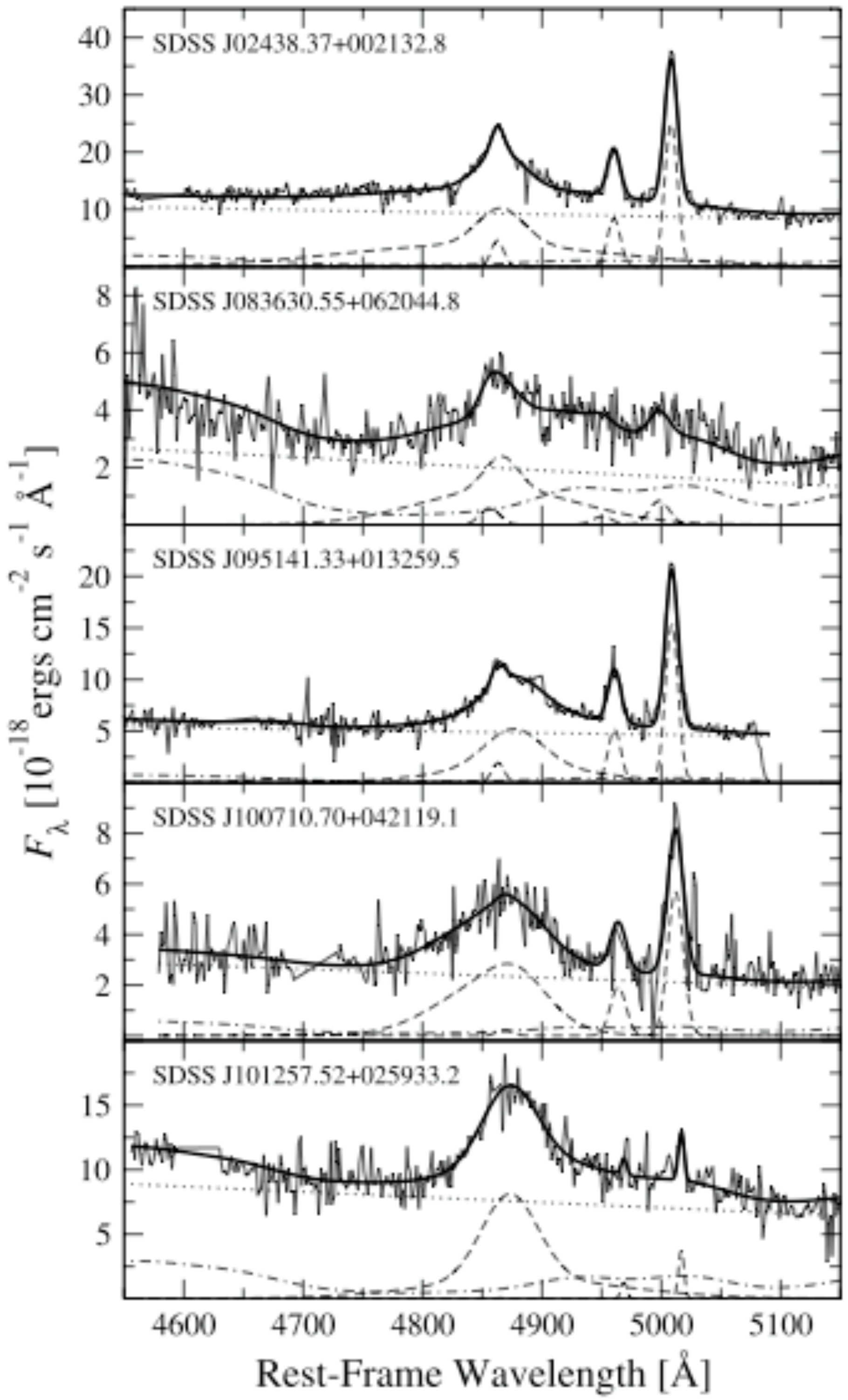


Jiang et al. (2007)

- GNIRS - full near-IR spectrum at R~1700
- Ideal for studying rest-frame UV spectra of high-z quasars
- Science:
  - Black hole masses
  - Broad line region metallicity evolution
  - IGM metallicity evolution
  - Dust reddening

Near-IR spectroscopy and black hole growth

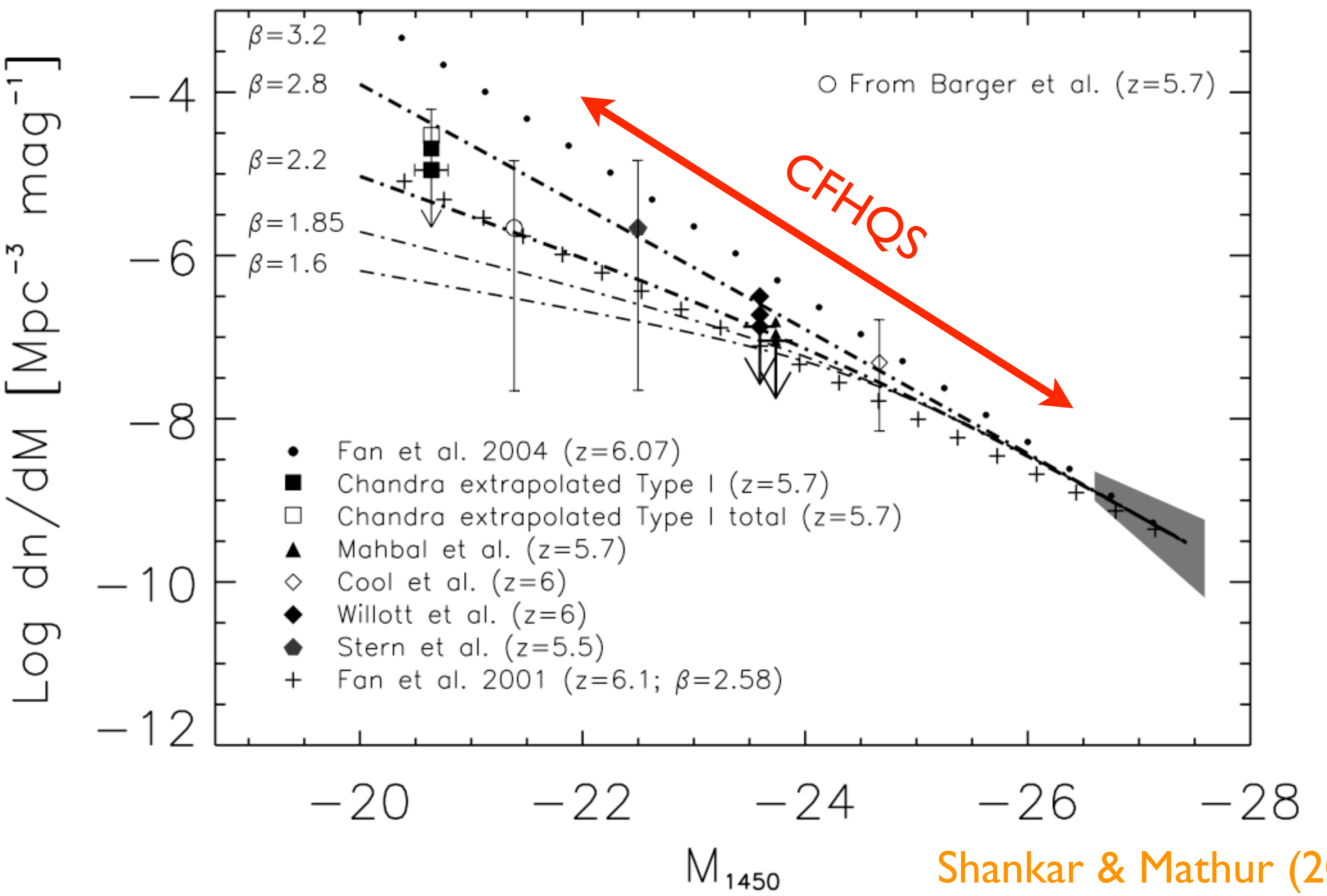




Netzer et al. (2007)

- GNIRS study of Hβ lines in high redshift (z~3) quasars.
- Black hole masses determined by virial method from line width and luminosity.
- Wide range of Eddington fractions ($0.01 < L/L_{Edd} < 1$).
- Low accretion rate quasars with large black hole masses cannot be built up at that rate in the age of the Universe.

Quasar luminosity function

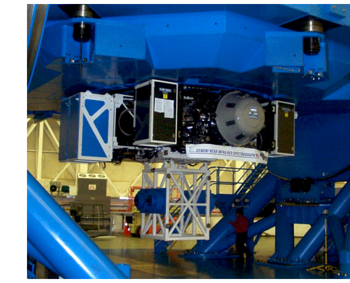


Shankar & Mathur (2007)

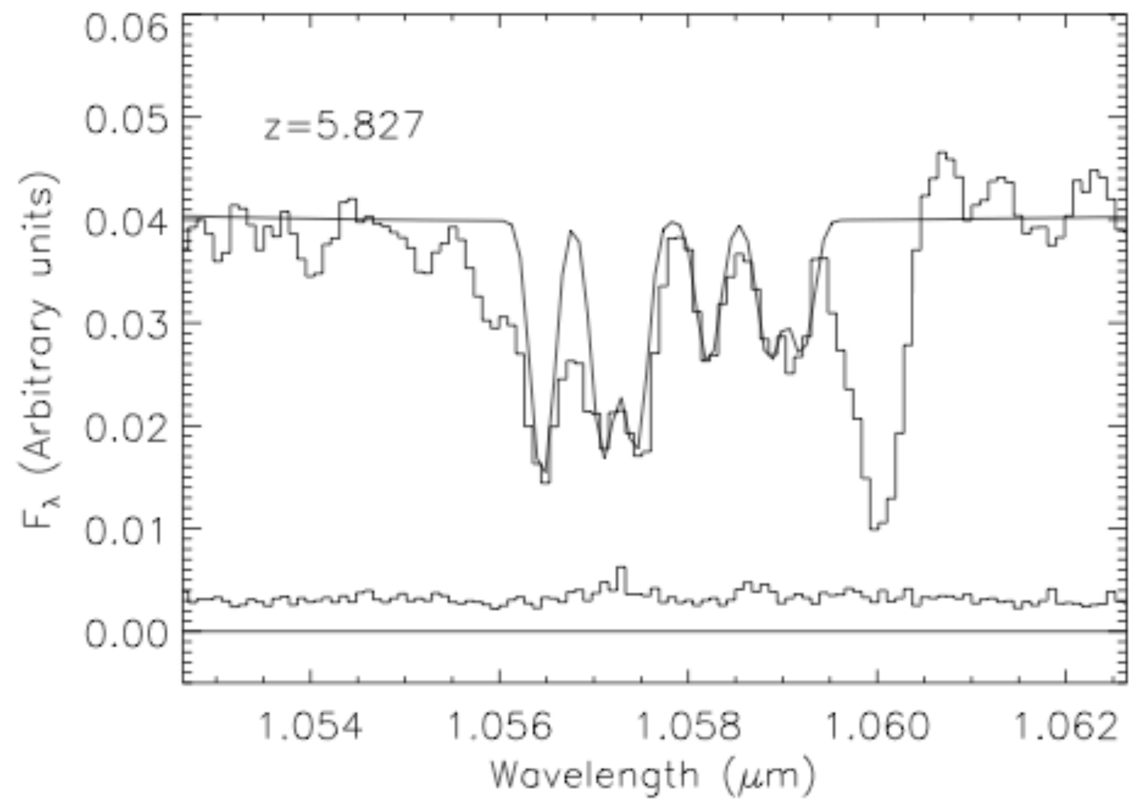
Combine quasar luminosity function with black hole mass - luminosity relation to get black hole mass function at z>6.

Near-IR spectroscopy and the Intergalactic medium

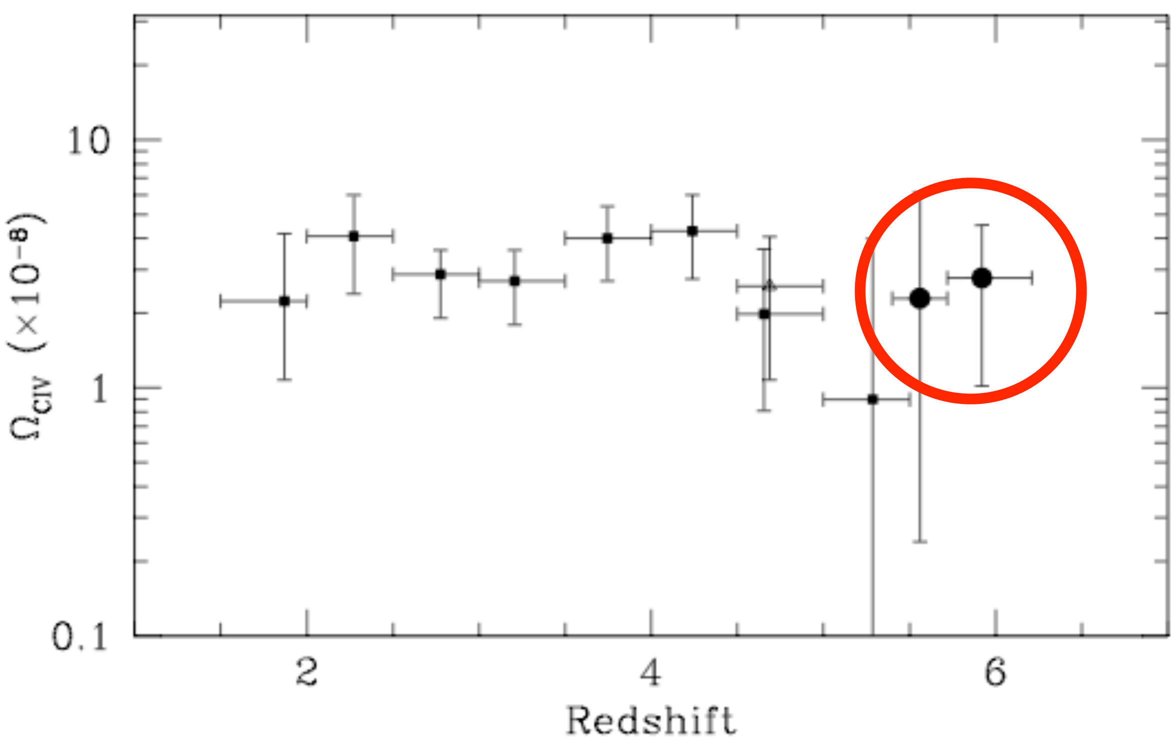
GNIRS
GEMINI NEAR INFRA-RED SPECTROGRAPH



Study of C IV absorbers in z~6 SDSS quasar near-IR spectra at resolution R=5000.



Simcoe et al. (2006)

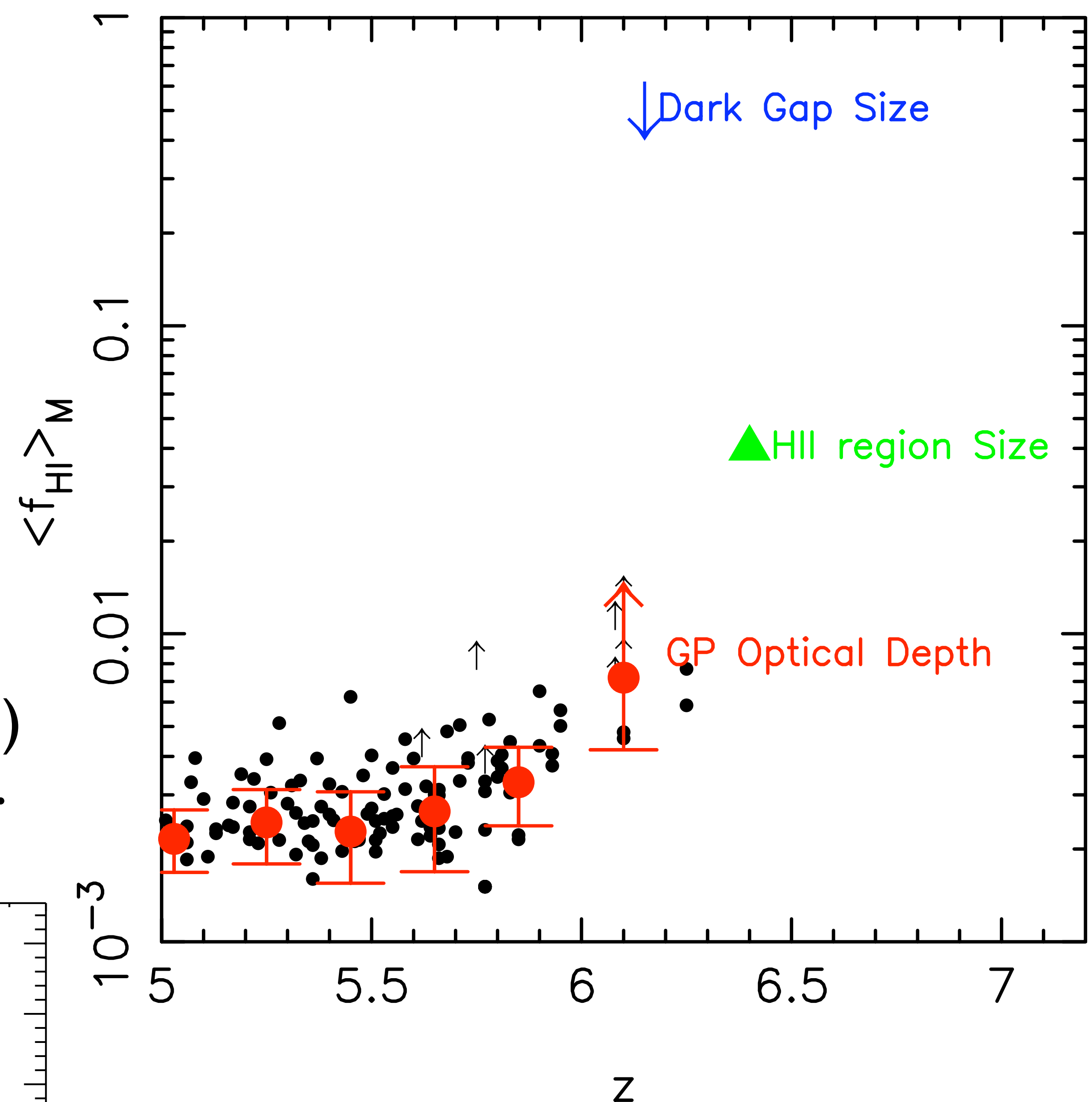


No evolution in C IV number density to z=6.

Heavy element enrichment began < 1 Gyr after the Big Bang.

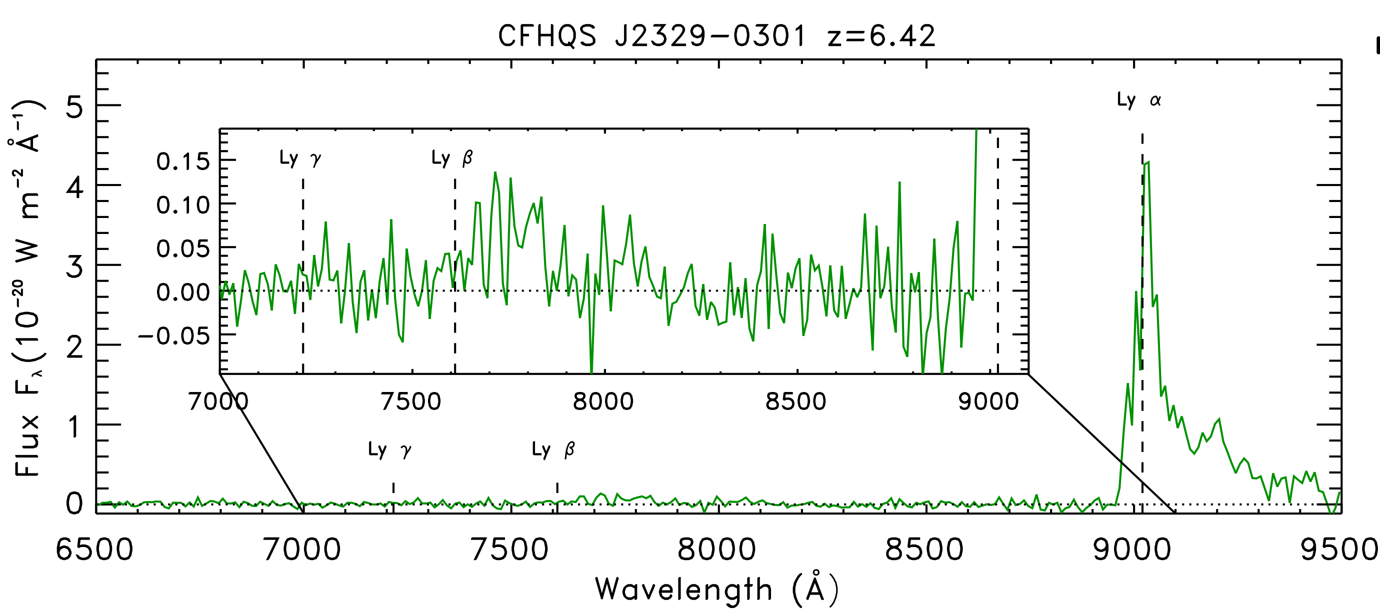
Future programs

Observations of z~6 quasars, Lyman α galaxies and the CMB suggest that if we get to just slightly higher redshifts, we will see a marked change in the IGM ionization state.



Fan et al. (2006)

But it gets hard at z>6.4 due to Lyman α moving out of the optical waveband (z' band) where traditional CCDs have been effective.

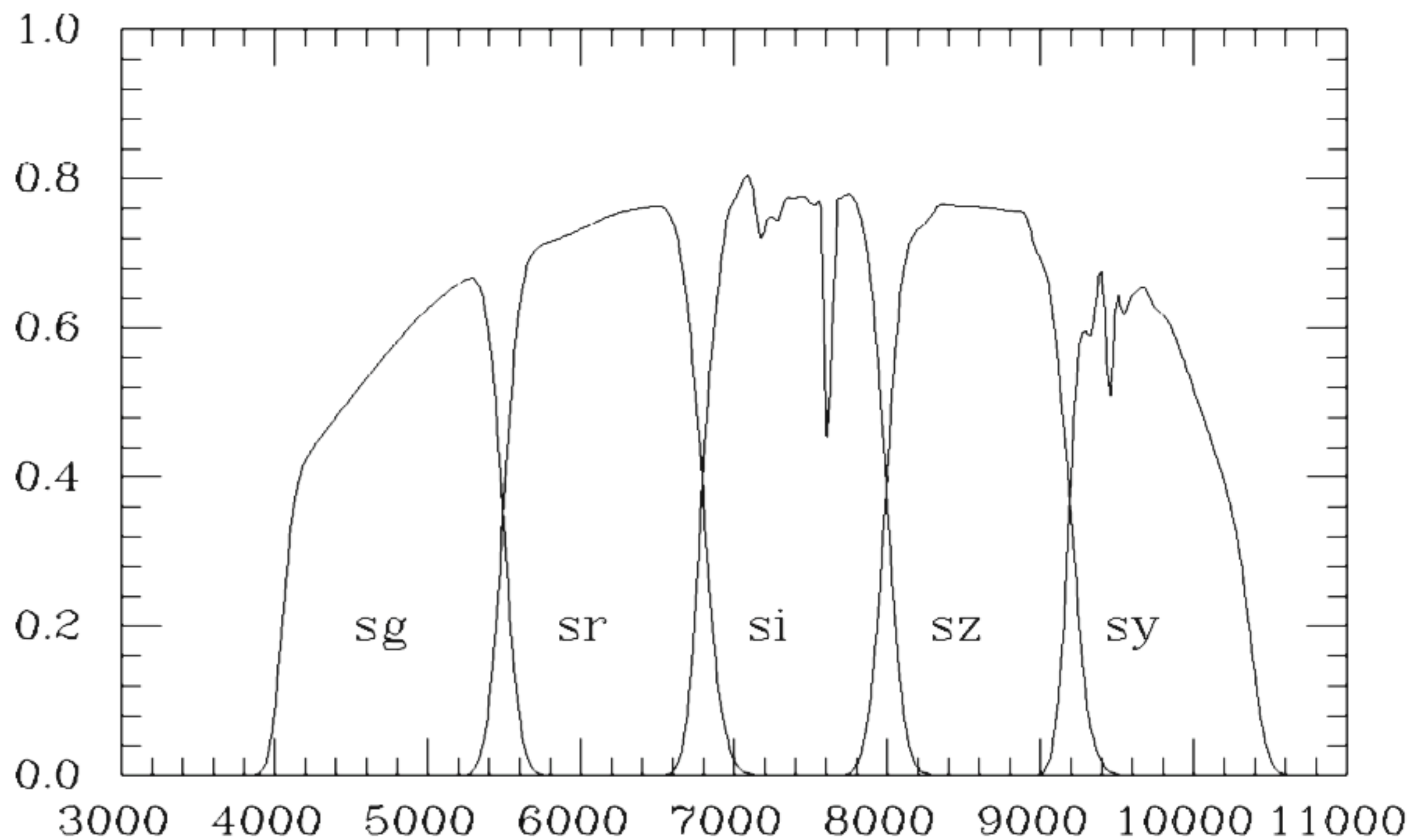


Future programs

Pushing to higher redshifts...

Also

- UKIDSS
- VISTA
- PanStarrs
- **HyperSuprime**



300 sq deg survey with HyperSuprimeCam to i=26.4, z=25.8 and y=25.3 would find ~100 quasars at z~6 like CFHQS J0216-0455 and ~10 at z~7.

Conclusions

- Most distant quasars offer much information on black hole growth, galaxy formation, reionization and IGM metal enrichment.
- Colour selection using optical and near-IR filters is still the only method to find large numbers of the highest redshift quasars.
- Deep surveys now able to find low luminosity quasars at z=6.
- Black hole mass measurements show Eddington-limited accretion at z=6.
- Future projects will push out to z=7 and maybe z=8, but getting to higher redshifts will be very difficult.