FAINT QUASARS AT HIGH REDSHIFT: IMPLICATIONS ON COSMIC RE-IONIZATION AND SUPERMASSIVE BLACK HOLE GROWTH IN THE EARLY UNIVERSE

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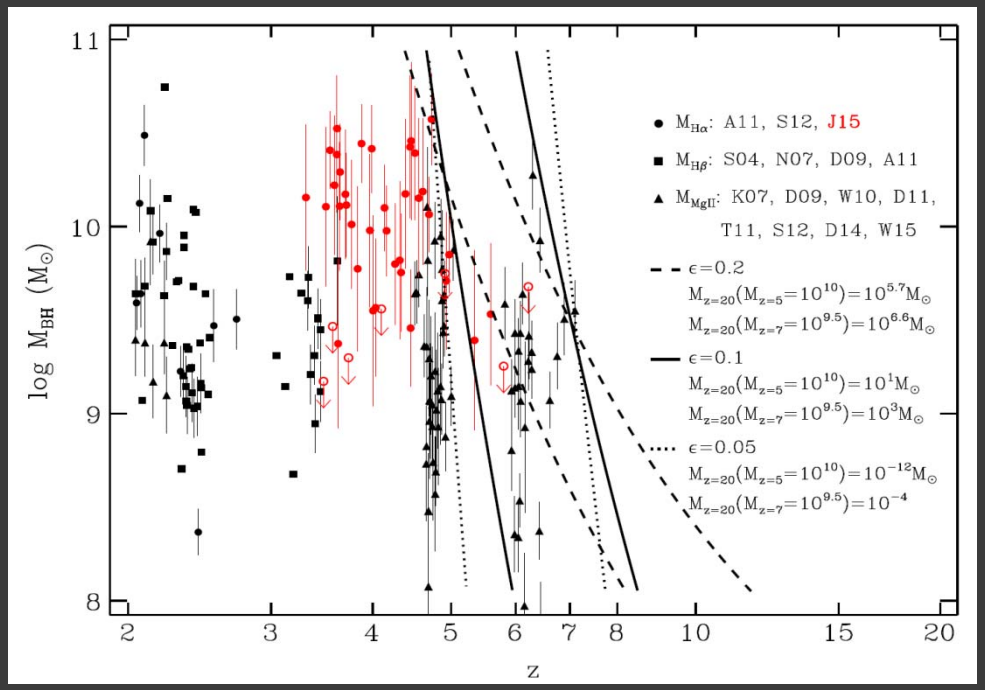
& IMS team

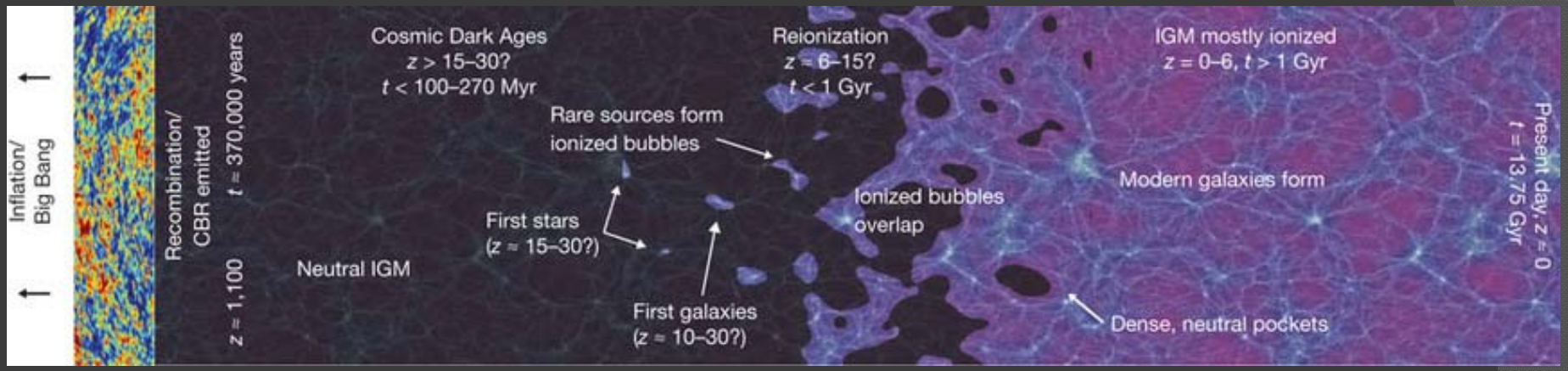
Quasars at high redshift (z > 5)



Jun, Im, et al. (2015)

- A few billion $M_\odot$ BH existed at z > 5
- Main cosmic re-ionization sources?
- How fast were they growing?

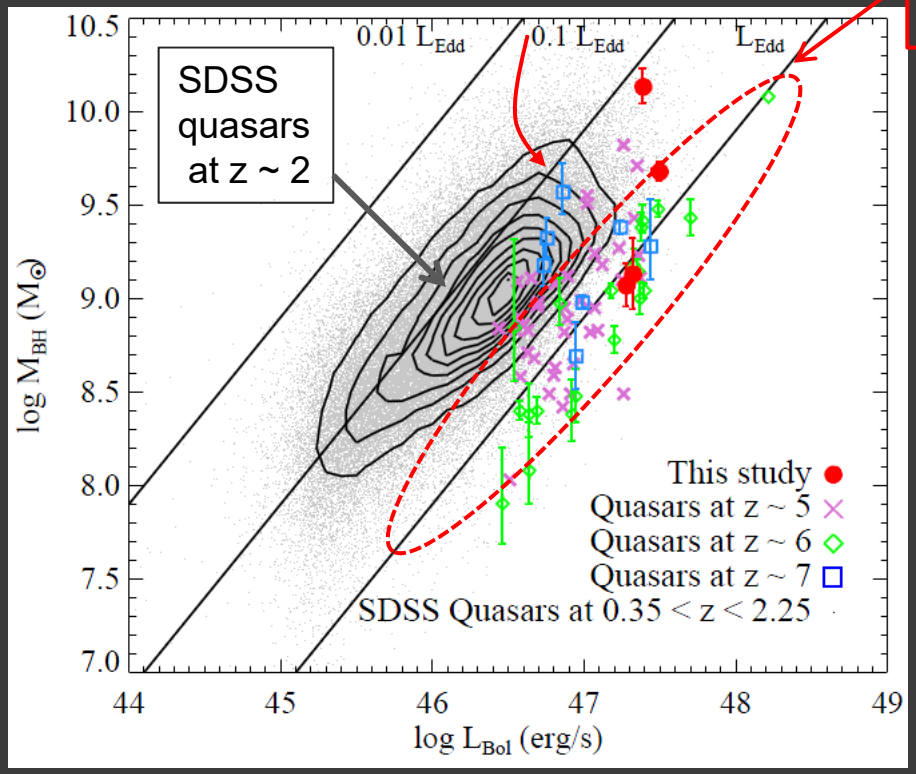
Cosmic IGM re-ionization



Robertson et al. (2010)

- UV photons (LyC, at $\lambda < 91.2$ nm)
- Galaxies: numerous but produce less UV photons
- Quasars: bright but not numerous

Are BHs growing fast in the early universe?



z=5
Jeon, Im, et. al. (2017)
Trakhtenbrot et al. (2011)
z=6
Jiang et al. (2007)
Kurk et al. (2007, 2009)
Wu et al. (2015)
z=7
DeRosa et al. (2014)
Venemans et al. (2015)

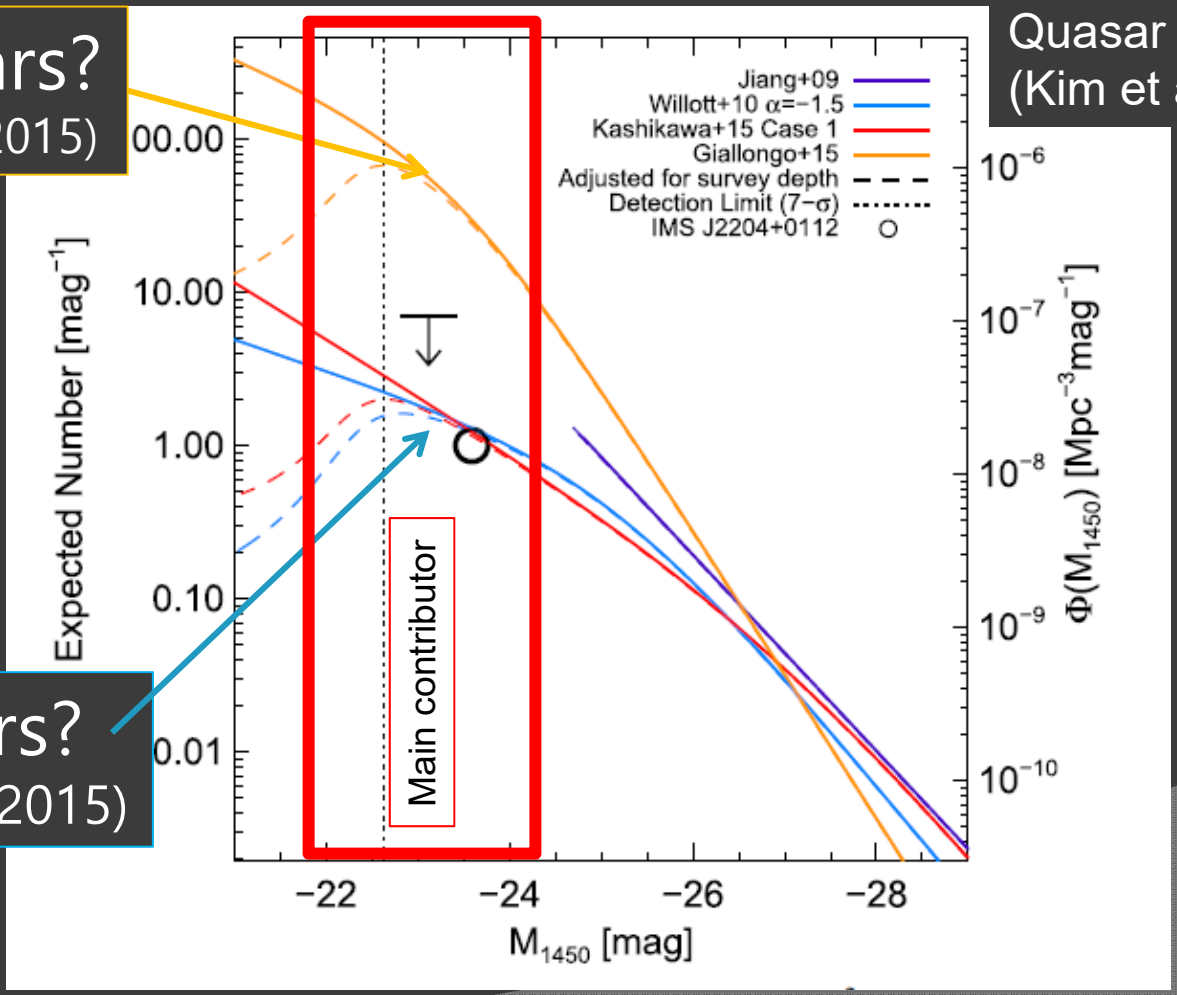
- Maximal accretion (L/L_{Edd} ~ 1; Willott et al. 2010) for z ~ 6 quasars (vs L/L_{Edd} ~ 0.1 @ z=2)
- Or simply a tip of iceberg?

What are the main sources that illuminated the early universe?

Many quasars?
(Giallongo et al. (2015)

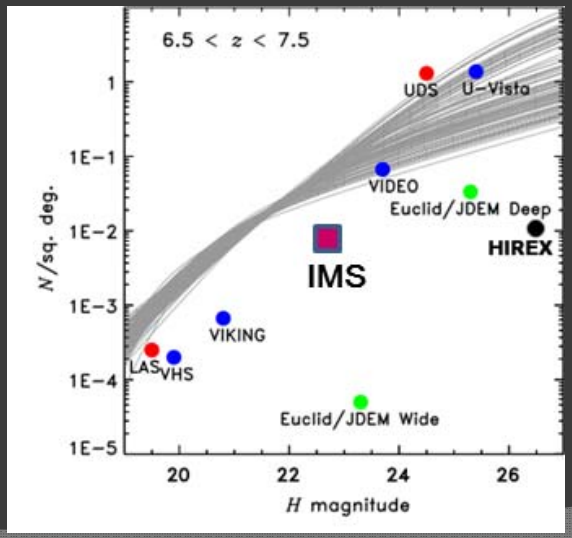
Few Quasars?
(Kashikawa et al. 2015)

Quasar LF
(Kim et al. 2015)



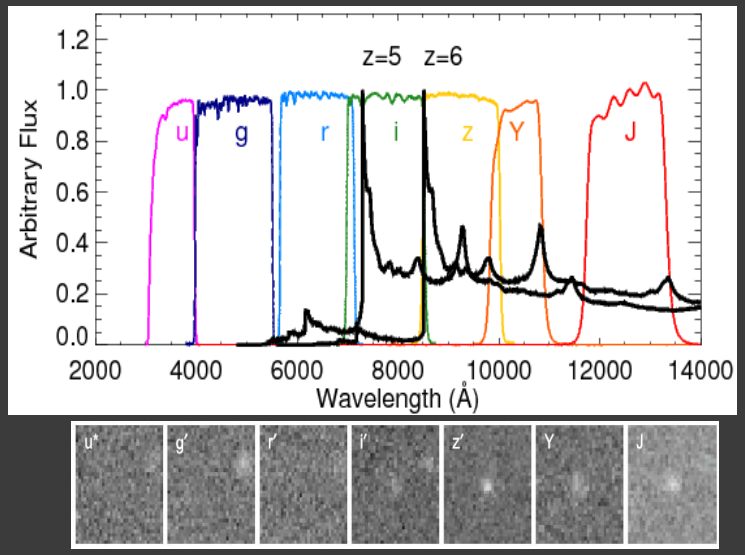
Infrared Medium-deep Survey (IMS)

- Imaging survey at J < 23 AB mag, 120 deg^2 (+ Y-band data)
- UKIRT WFCAM observation (2009 ~ 2013)
- CFHT ugriz imaging data (z ~ 24 AB mag)
- High-z quasars, galaxy clusters, transients



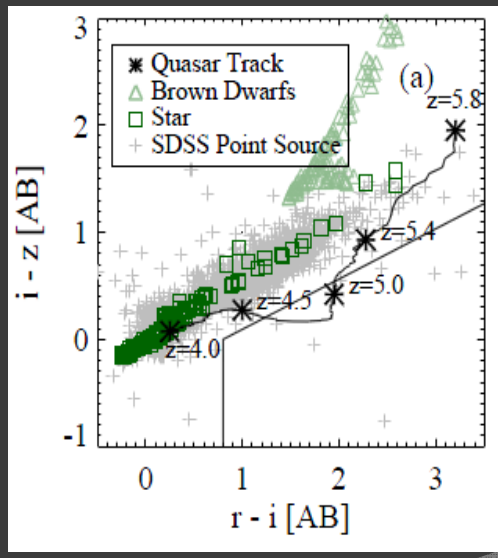
Selection of high redshift quasars

- Quasar Candidate Selection
  - Color selection
    - Using **red color** of high-z quasars due to Lyman break
    - Using **blue color** of AGN continuum
  - Visual Inspection

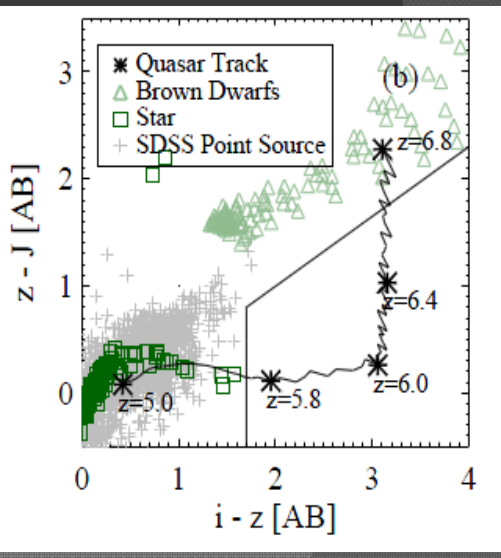


IMS J2204+0112 (Kim+15)

Quasars at z=5

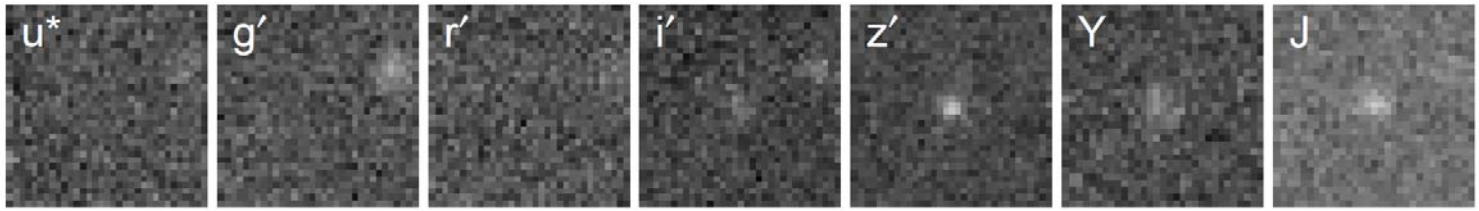


Quasars at z=6

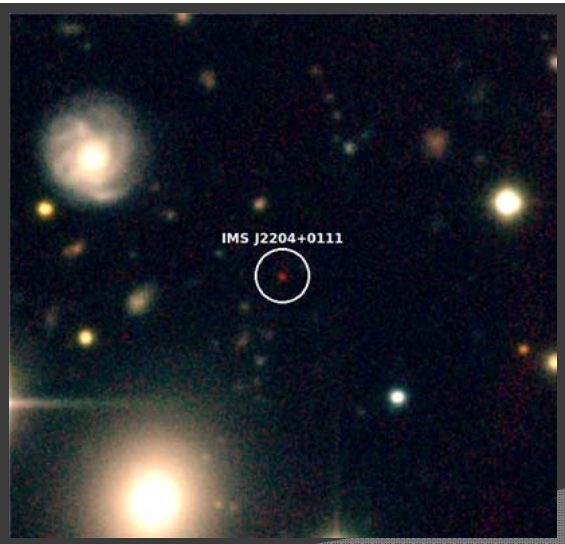


Jeon+17 (Fan+06; Willott+09)

Faint quasar candidate at z ~ 6 IMS J2204+0112



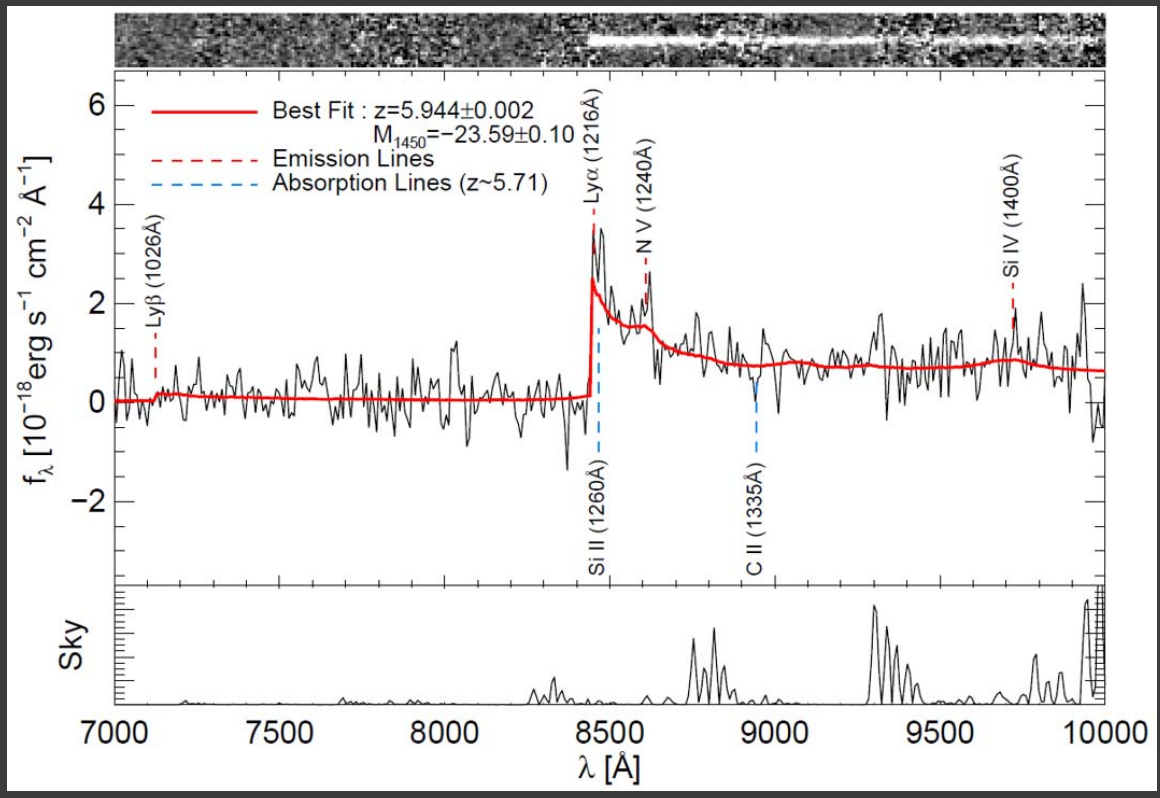
R.A. Dec. (J2000.0)	i'	z'	Y	J	Redshift	M_{1450}
22:04:17.92 +01:11:44.8	25.26 ± 0.15	22.95 ± 0.07	23.10 ± 0.09	22.34 ± 0.08	5.944 ± 0.002	-23.59 ± 0.10



Kim et al. (2015)

GMOS Spectrum of IMS J2204+0112

Gemini-S GMOS obs. 2015 July

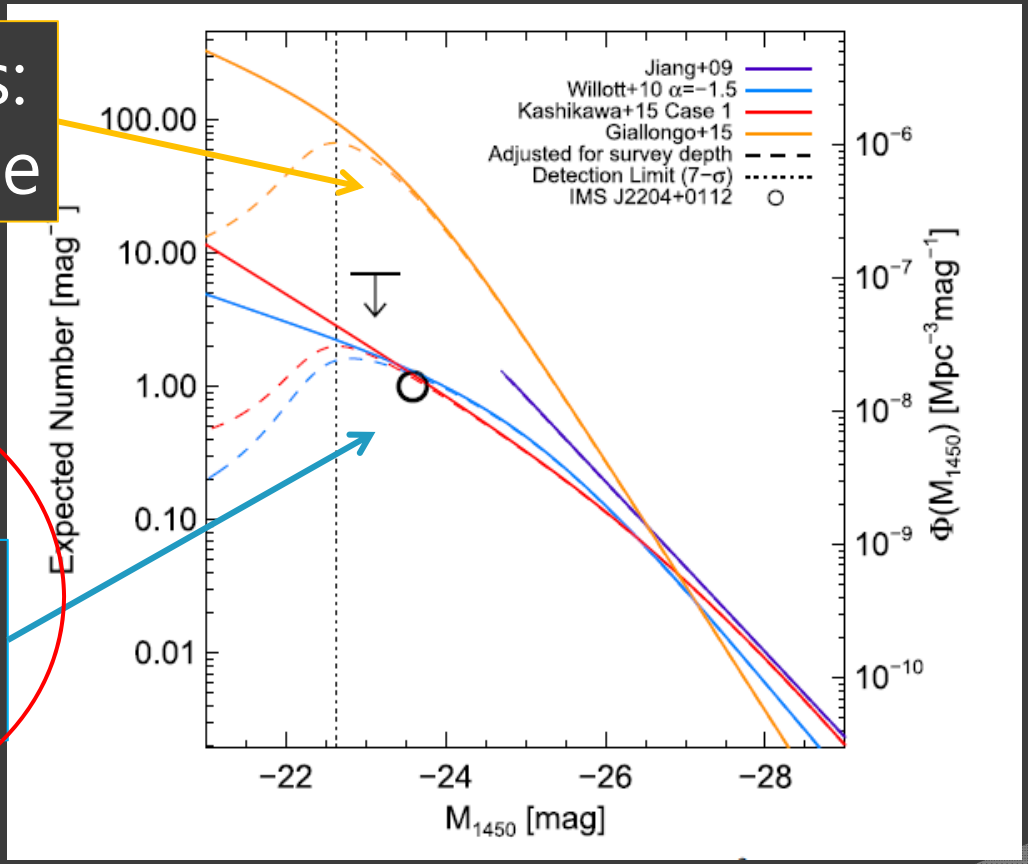


- Clear break at **~ 8443 Å** (identified as Lyα)
  - **z = 5.944 ± 0.002, M_{1450} = -23.59 ± 0.10 mag**

Quasar contribution is likely to be <10% of ionizing photons

Many quasars: Ionizing source

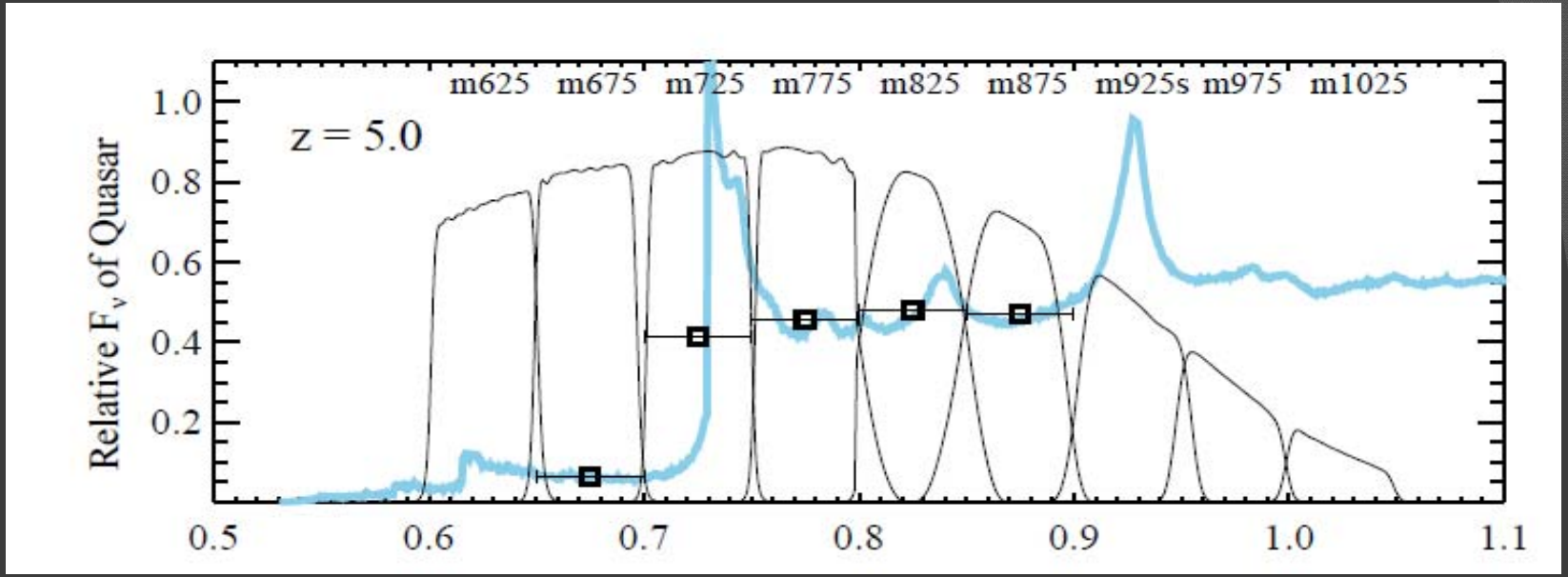
Few quasars



Quasar LF (Kim et al. 2015)

Discovery of more faint quasars is consistent with this result (e.g., Matsuoka et al. 2017)

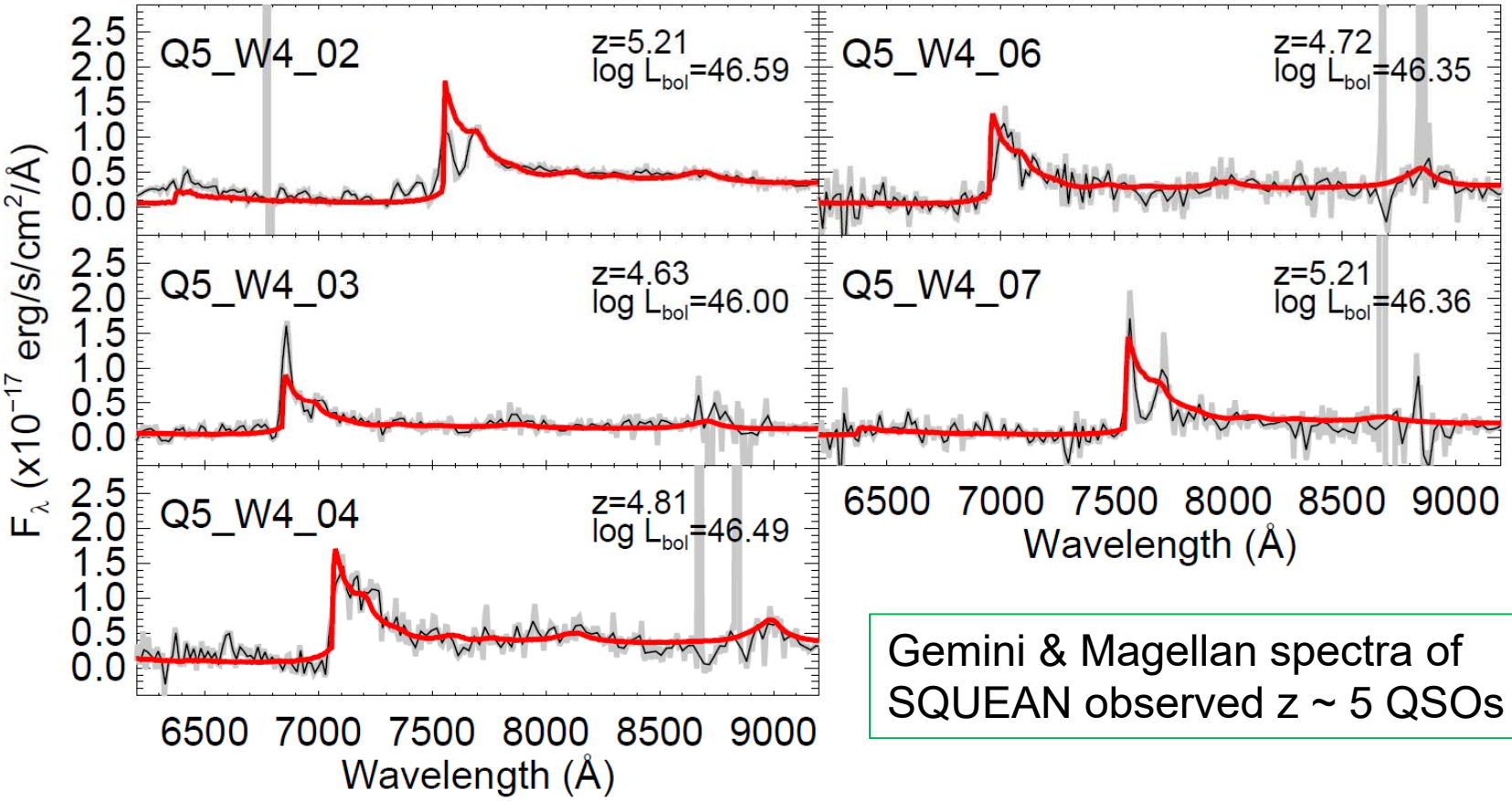
SQUEAN medium-band observation of faint quasars at z ~ 5



Jeon, Im, et al. (2016)

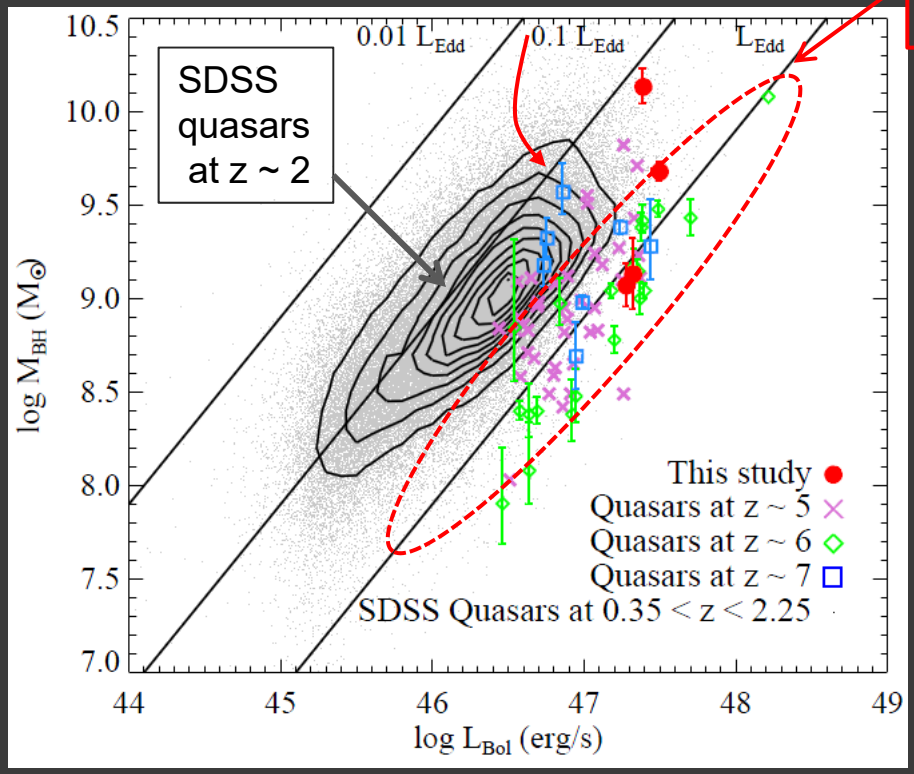
- Multi-color selection (grizJ)
- Follow-up observation with SQUEAN

Spectroscopic confirmation (60% → >90% success rate, 9 confirmed)



Gemini & Magellan spectra of SQUEAN observed z ~ 5 QSOs

Are BHs growing fast in the early universe?



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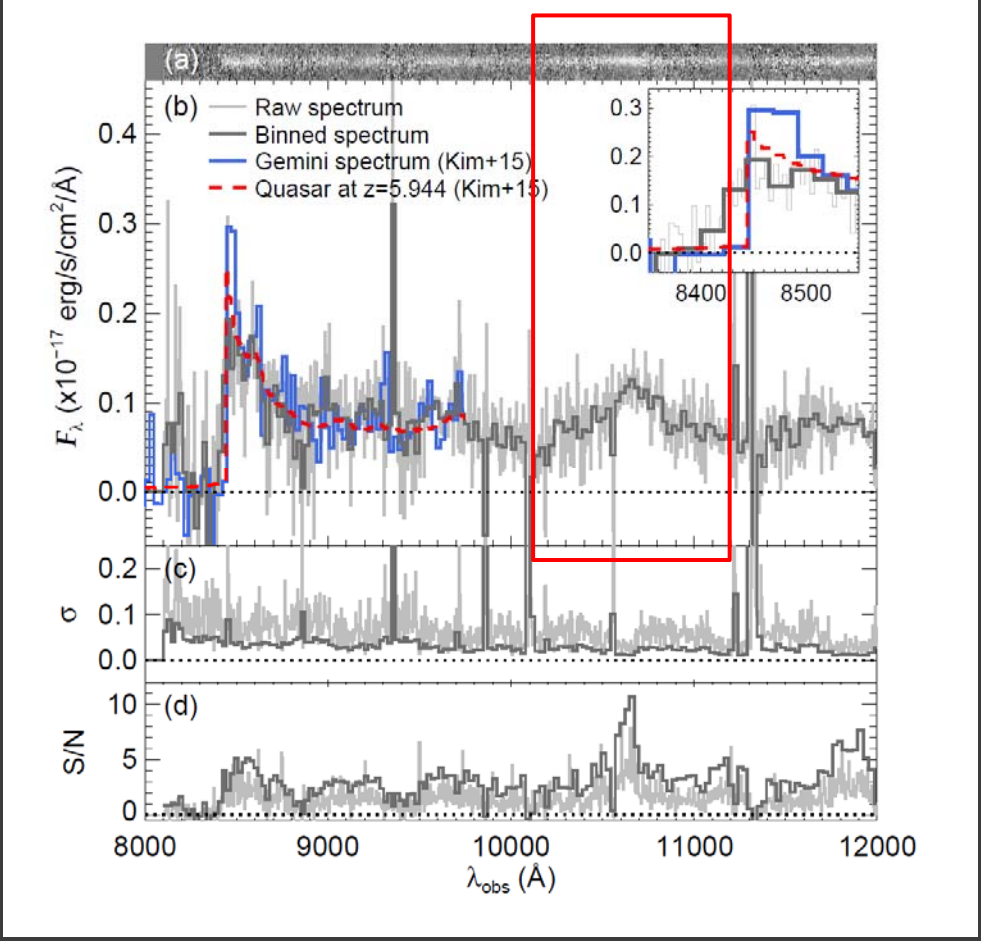
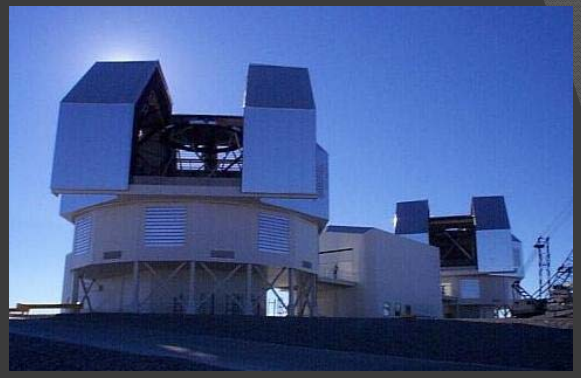
Magellan FIRE spectra: CIV detection

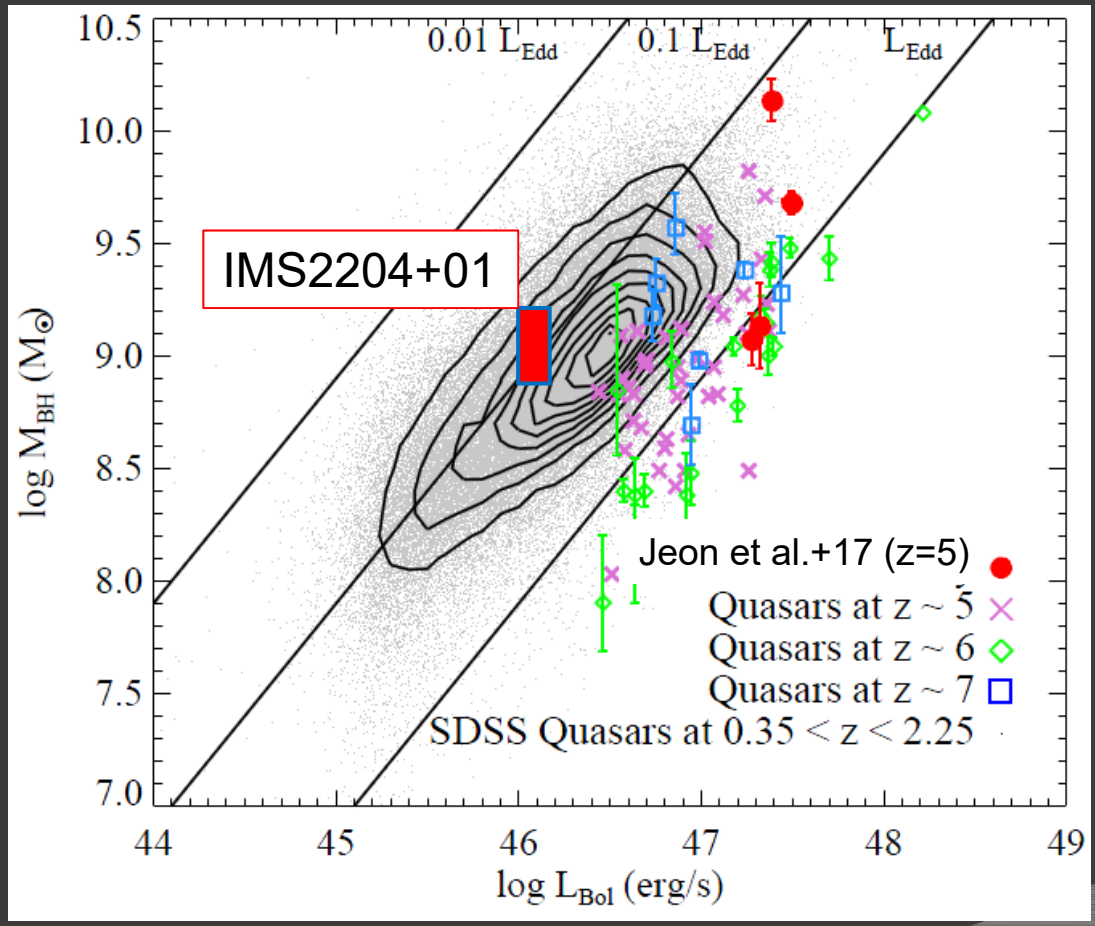




Magellan/FIRE – 2017/09

- Log ($M_{BH}/M_\odot$) = 8.7 to 9.3
- Log(Lbol/erg/s) = 46.1
- L/L_{Edd} ~ 0.1

Low accretion rate for IMS J2204+0112



Jeon, Im, et al. (2017)
Kim, Im, et al. (2017, submitted)

Summary

- Faint quasars: IGM ionization source/SMBH growth probe
- We discovered one z ~6 quasar and ~10 of z ~ 5 (J~23 AB mag) + BH measurement
- **Faint quasar are probably too few to fully account for the IGM ionization at z ~ 6**
- **Not all quasars are accreting materials at maximal rate**