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QSONG

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QSONG

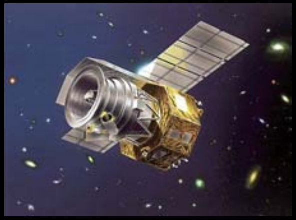
- **QSONG** = **Q**uasar **S**pectroscopic **O**bservation with **N**IR **G**rism

- NIR Spectroscopic Study of high-z and low-z AGNs at 2.5 – 5.0 μm with NIR grism of AKARI (R ~ 120, FWHM ~ 2500 km/sec)

- High-z study (HQSONG): 164 (200+) QSOs at 3.4 < z < 6.42

- Low-z study (LQSONG): 69 (102) nearby AGNs + red AGNs
  NIR Hydrogen lines and PAHs → Understand the NIR Hydrogen line characteristics, diagnostics for studying AGN/SMBHs

- Warm-mission MP observation started in June, 2008 (duration ~1.5 years; PI: H.M. Lee)
  Pilot study carried out in 2006-2007 (HZQSO: M. Im) – 12 QSO at z > 4.5
  Open time programs: DPQSO, HQSO2 (M.Im), + QSONG2 (Phase 3b)



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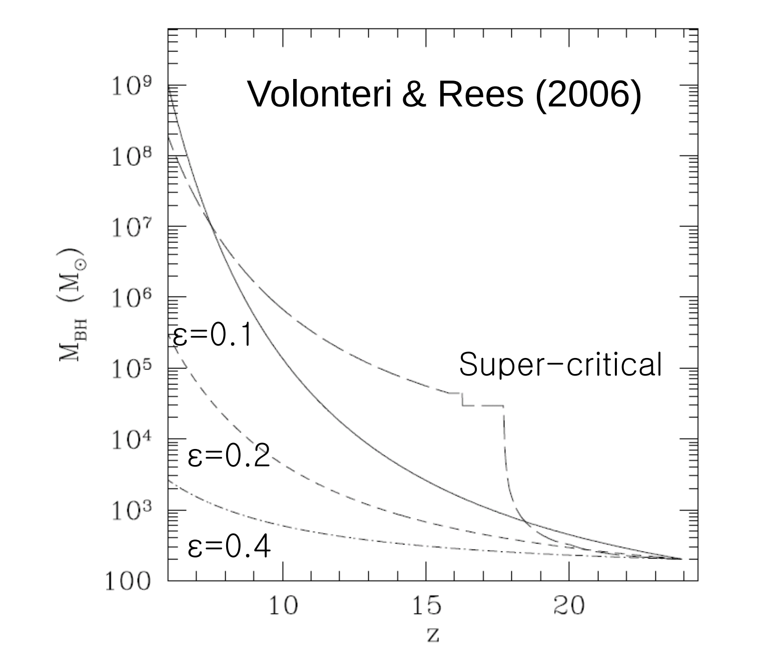
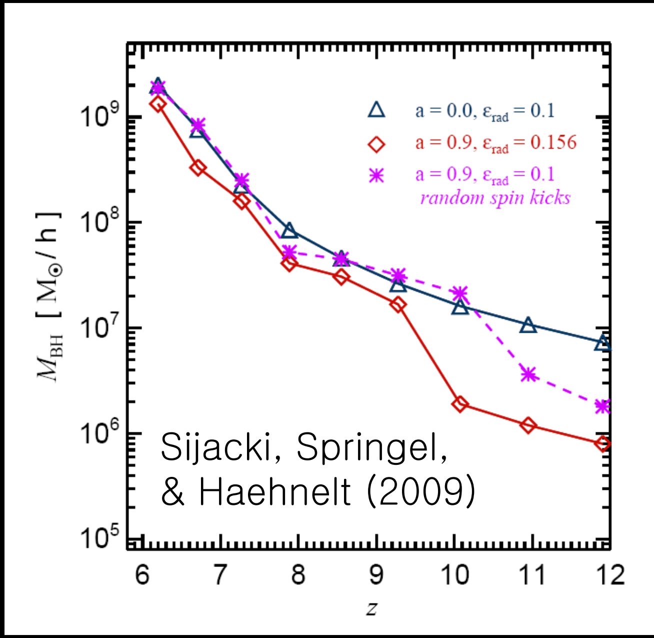
Growing SMBHs – Not an easy task -





- $M(t)=M(0)\exp[(1-\epsilon)/\epsilon\,(t/t_{Edd})]=M(0)\exp(t/\tau)$, with $\tau \sim 4.5 \times 10^7\,(\epsilon/0.1)$ yrs
- Not enough time (only ~0.64 Gyr between z= 6 and 15)
- Spinning black hole, gravitational recoil, etc

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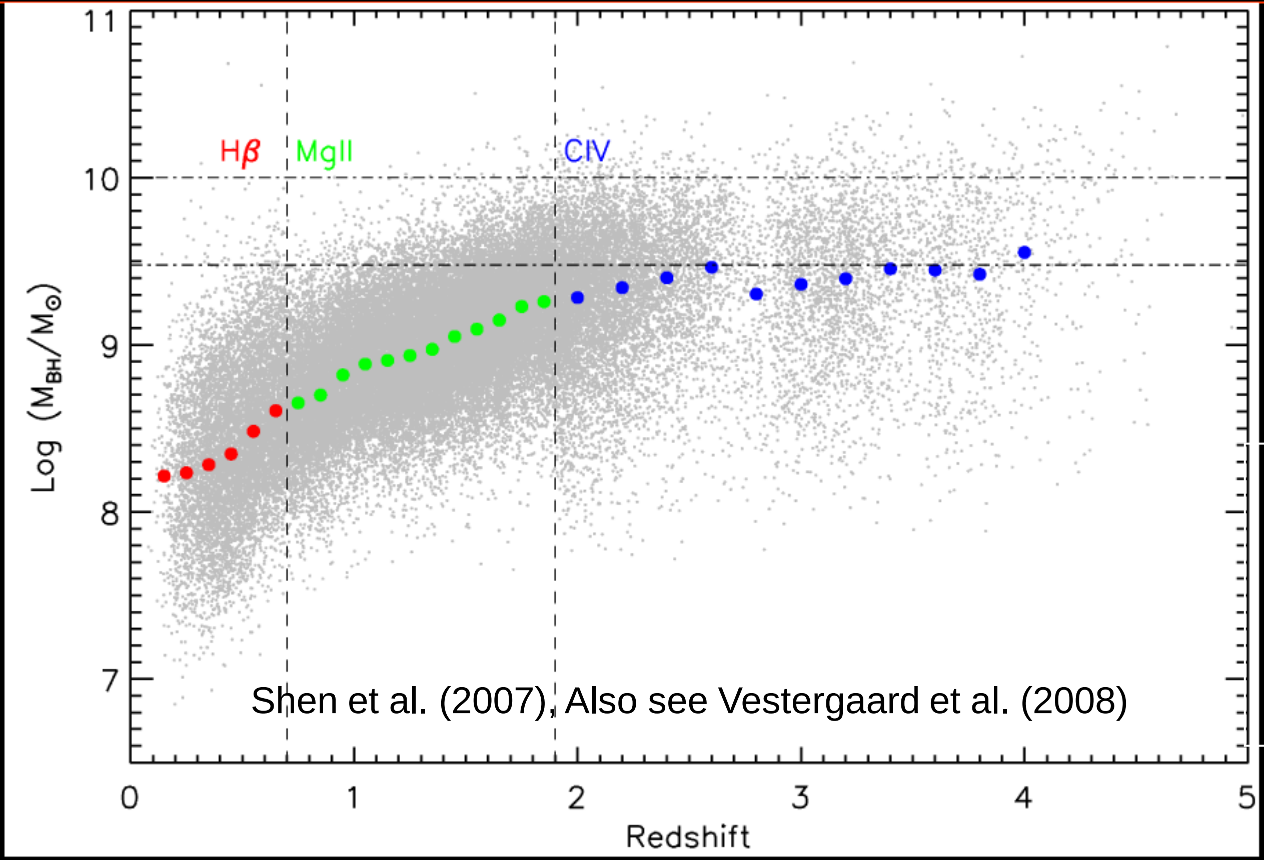
Masses of SMBHs at high redshift

- The most massive SMBHs ($M \sim 10^{10} M_{\odot}$ or more) at $2 < z < 4.5$
- M_{BH} measurements for high redshift QSOs rely on the UV-lines (CIV: 0.1549 micron, MgII: 0.2798 micon)



A few more points here from ground-based NIR spectroscopy (Jiang et al.; Kurk et al. 2007)

Why 2.5 - 5 μ*m* ?

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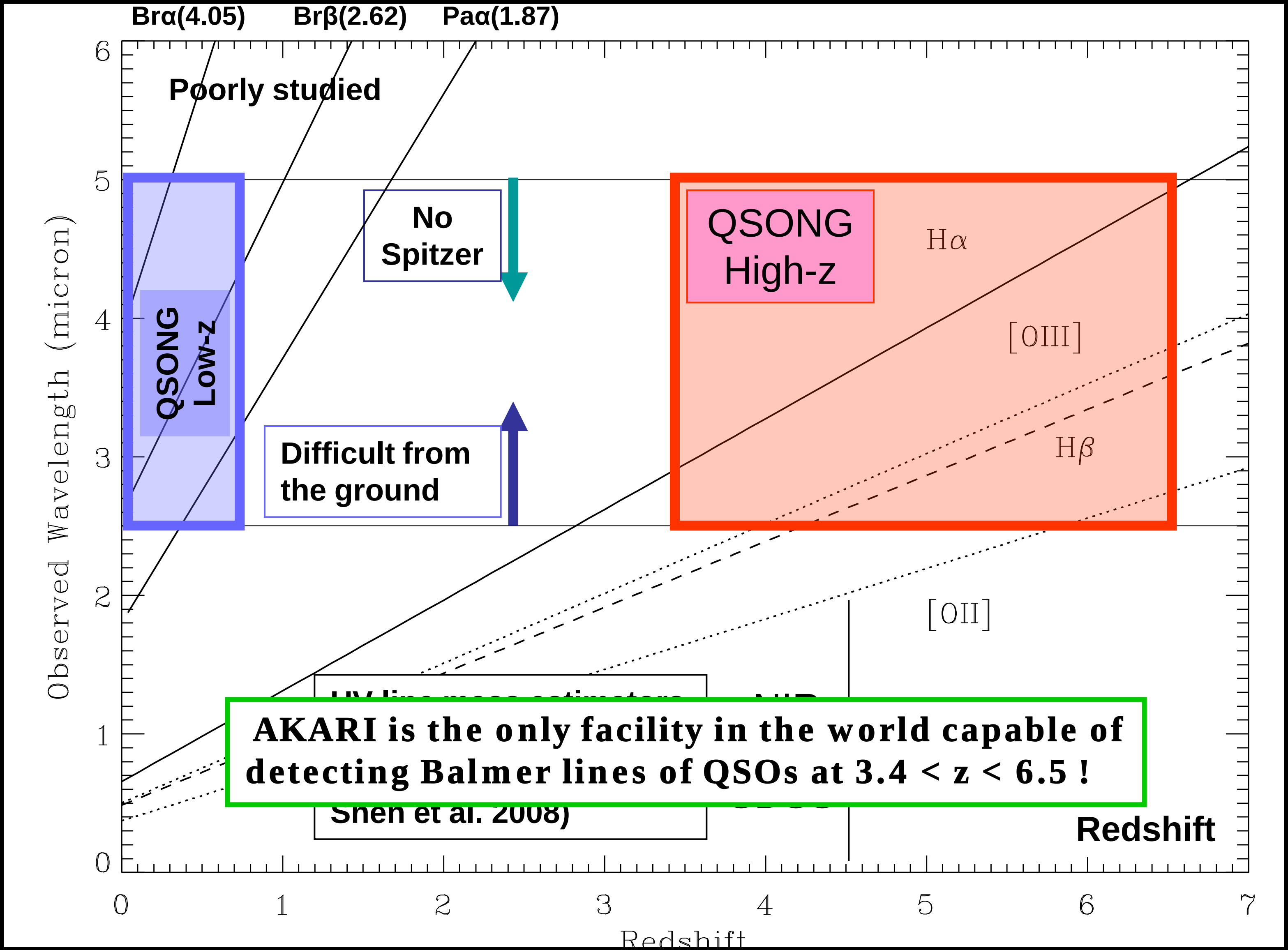

High-z QSONG Sample (HQSONG)

- 164 Type-1 QSOs at $3.4 < z < 6.4$ (mostly SDSS QSOs)

- z-band magnitude limit:
  $z_{AB} < \sim 19$ for $z < 5.5$
  $z_{AB} < \sim 20$ for $z > 5.5$

- L_{bol} limit ~ 10^{47} $ergs^{-1}$
- M_{BH} limit ~ 10^{9} $M_{\odot}$

- Several fainter QSOs were targeted for deeper observation (in NEP area)

- BH mass from well-calibrated Hα line (Greene & Ho 2005; McGill et al. 2008; versus CIV/MgII) → evolution of the most massive QSOs at high-z

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Pilot Study: Hα lines of 12 QSOs at 4.5 < z < 6.22

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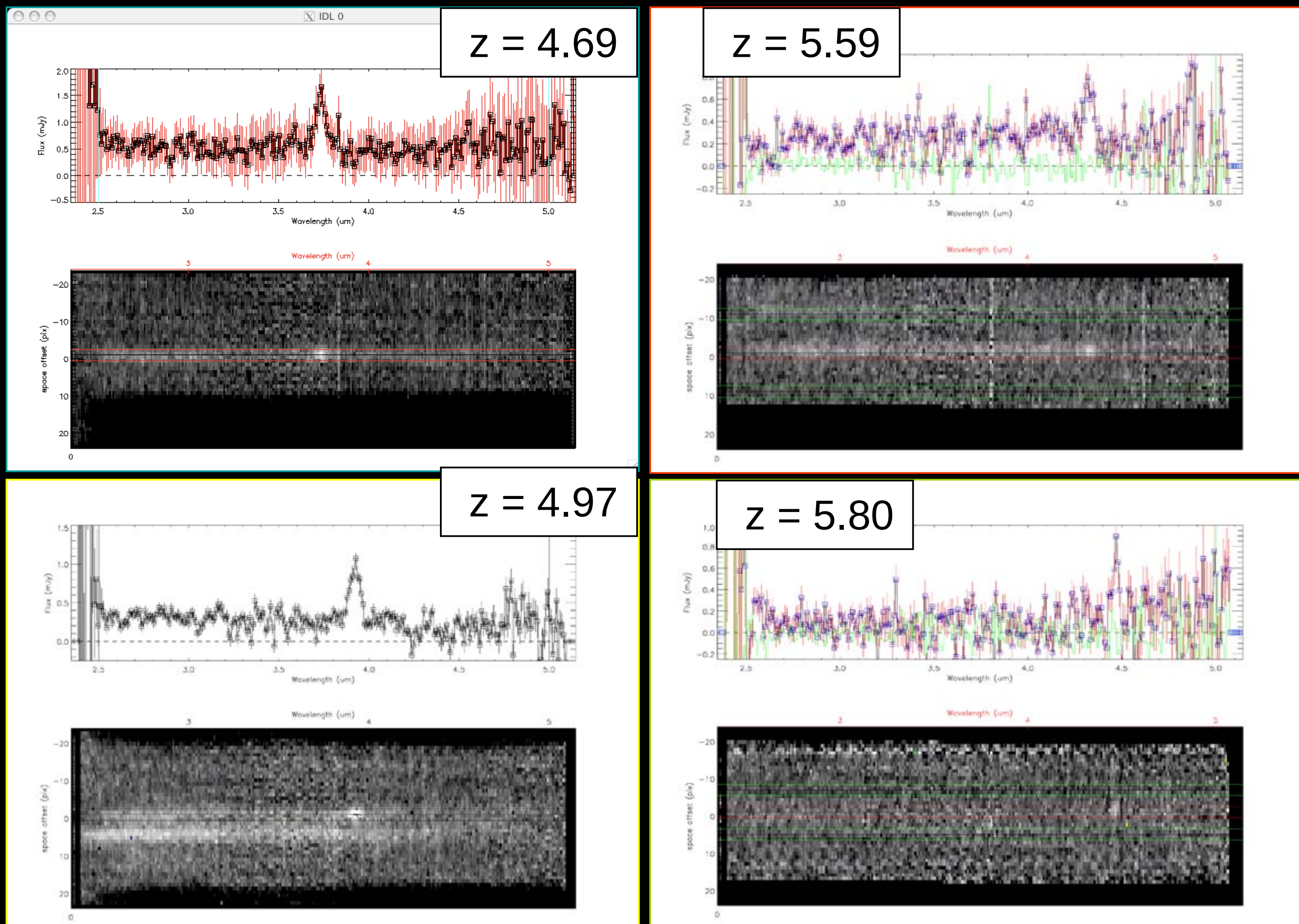

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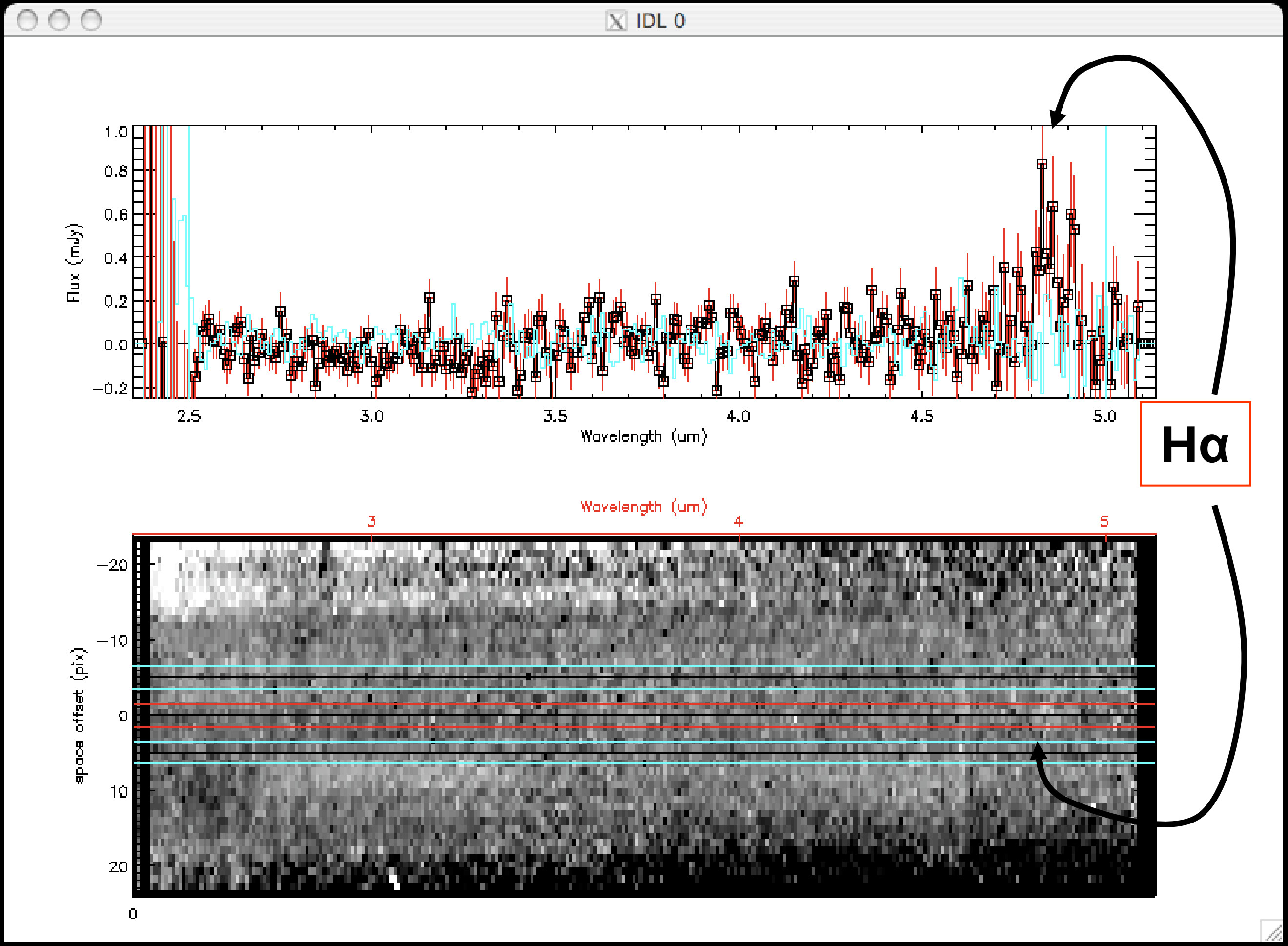
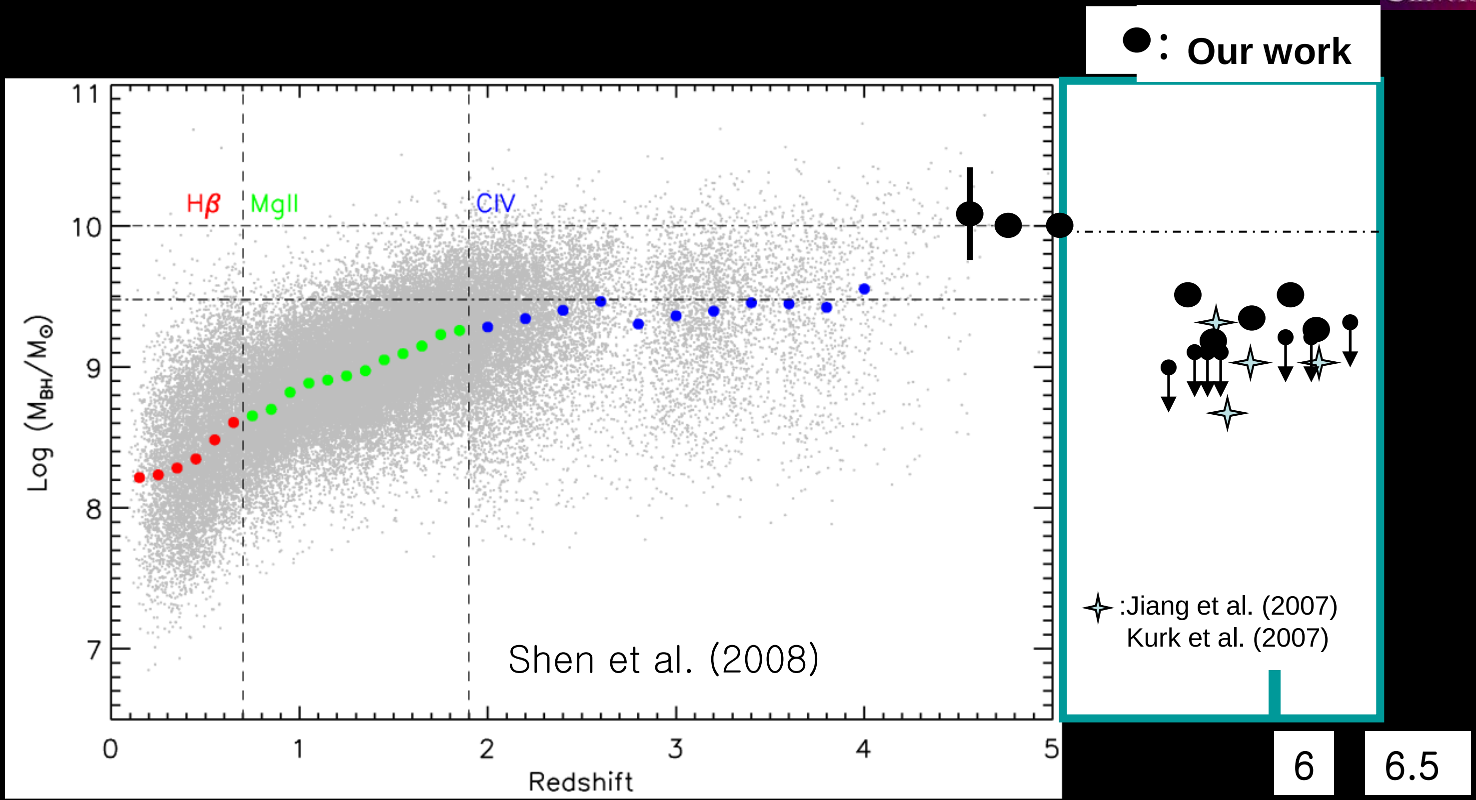
SDSS J 114816+525150 at z=6.42



SMBH Mass Evolution



- $10^{9.3} – 10^{10.1}$ $M_\odot$ ➔ A few x 10^9 $M_\odot$ SMBHs existed at z ~ 6 (0.95 Gyr)
- L_{bol}/L_{Edd} ~ 0.4 – 1.8 [0.8]
- 10^{10} $M_\odot$ SMBHs existed at z ~ 5 (1.2 Gyr)
- No M ~ 10^{10} $M_\odot$ SMBHs at z > ~6 (t_{univ} ~ 0.9 Gyr) - they are growing!

Current Status

- All targets were observed (and QSONG2 targets are being observed)
- First pass reduction is done, tweaking with the data to improve the spectra
- Scientific analysis – BH measurements, comparison with CIV, MgII measurements

*Presentation by Hyunsung Jun

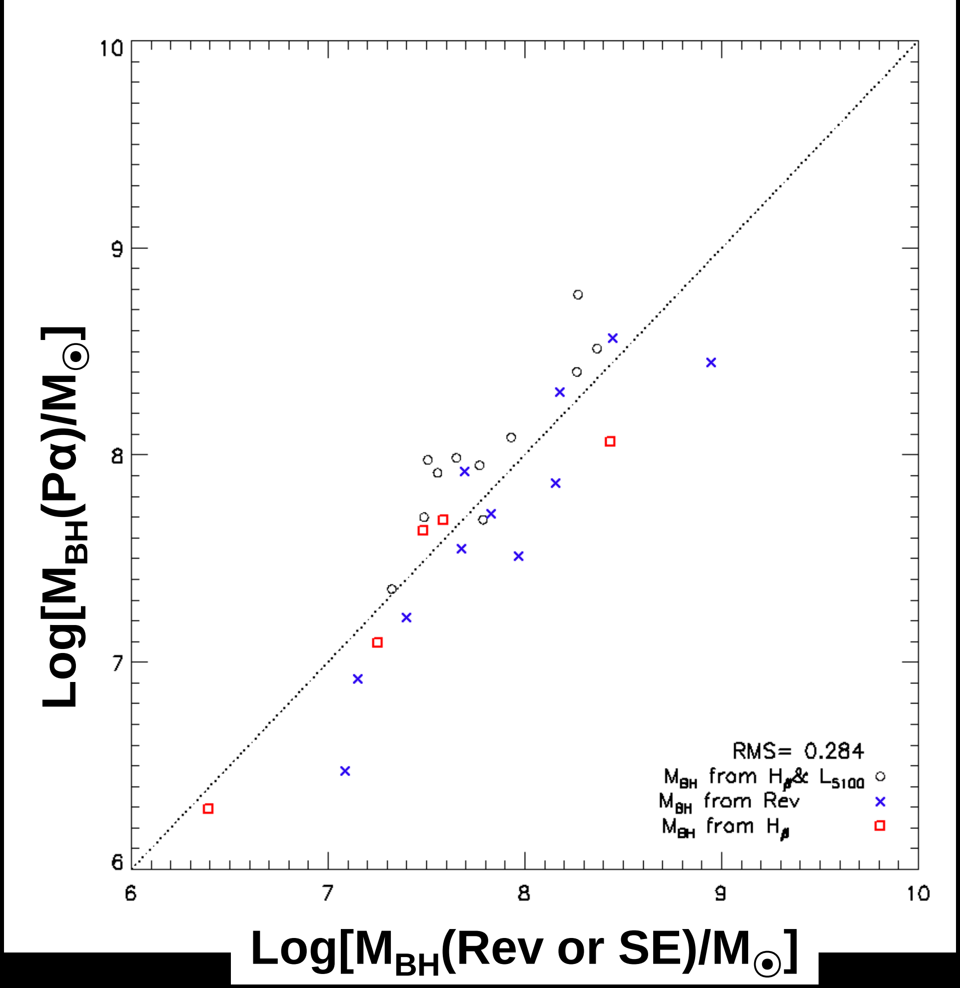
Low Redshift QSONG (LQSONG)

- NIR Hydrogen lines as diagnostics for AGN and SMBHs
  - BH mass estimator from NIR H lines
  - Line ratios

- PAH emission of AGN

- Red AGN properties
  - BH masses
  - Dust extinction properties

NIR Hydrogen Line BH Mass Estimator



E(B-V)	A(Hα)	A(Pα)	A(Brα)
0.5	1.27	0.23	0.13
1.2	3.04	0.54	0.32

Lower extinction at longer λ

- ✓ **Good BH mass estimator**
- ✓ **Extinction curve pivot point**

$$\frac{M}{M_\odot} = 10^{6.81}\left(\frac{L_{P\beta}}{10^{42} erg/s}\right)^{0.545}\left(\frac{FWHM_{P\beta}}{1000 km/s}\right)^2$$

$$\frac{M}{M_\odot} = 10^{6.83}\left(\frac{L_{P\alpha}}{10^{42} erg/s}\right)^{0.430}\left(\frac{FWHM_{P\alpha}}{1000 km/s}\right)^2$$

(Kim, D., Im, M., & Kim, M., in preparation)

LQSONG Sample

- 69 bright, low redshift AGN

- 59 (+33) Type-1 AGN
  - 29 Reverberation mapping sample (Kaspi et al. 2000; Peterson et al. 2004)
  - 26 (+33) PG Quasars ($z < 0.5$)
  - 4 SNUQSO Quasars (Lee, Im, et al. 2008; $z < 0.3$)

- 10 Red AGN
  - Glikman et al. (2007)

Sample Characteristics 1 (Mass-Eddington Ratio)

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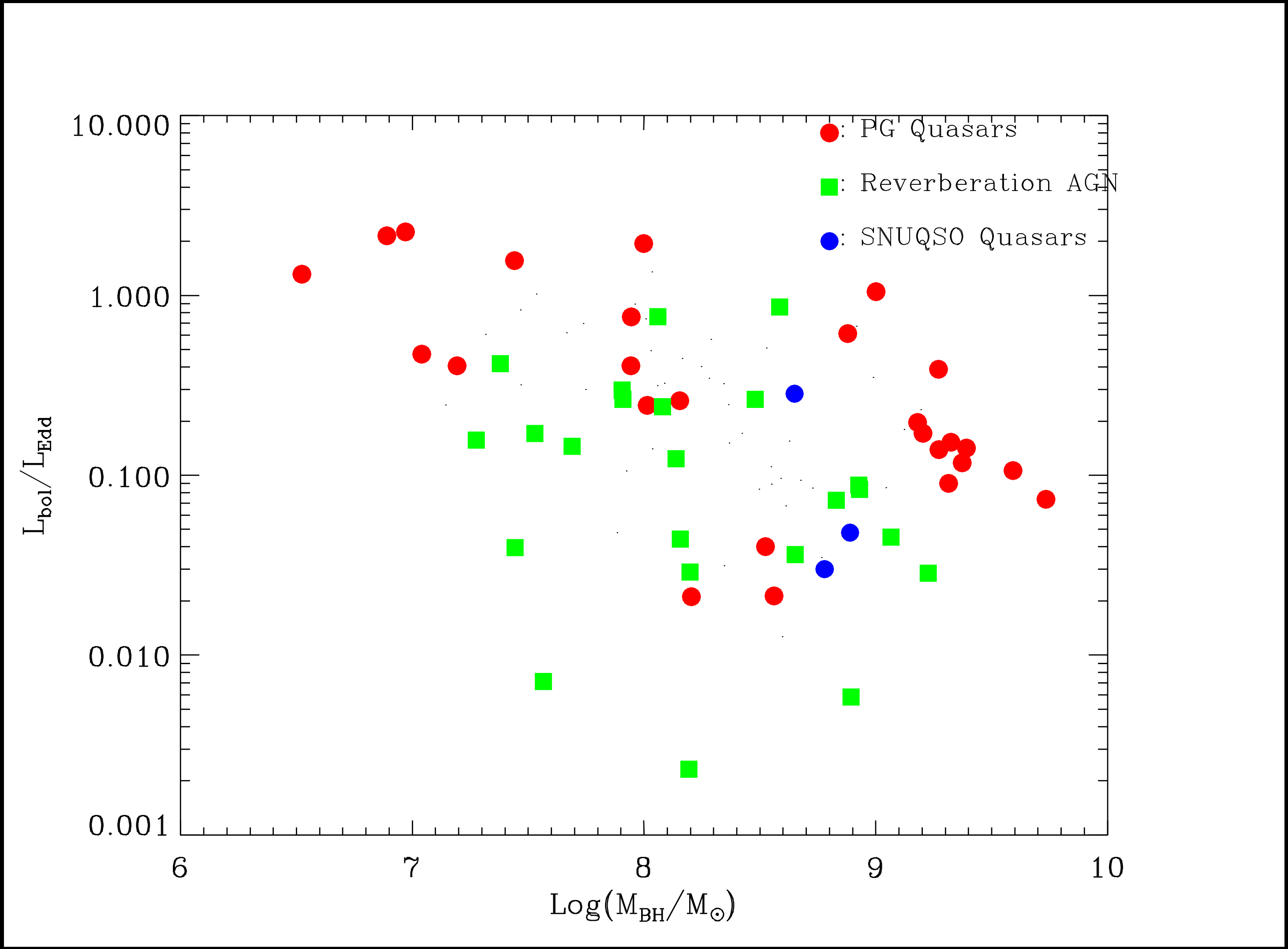

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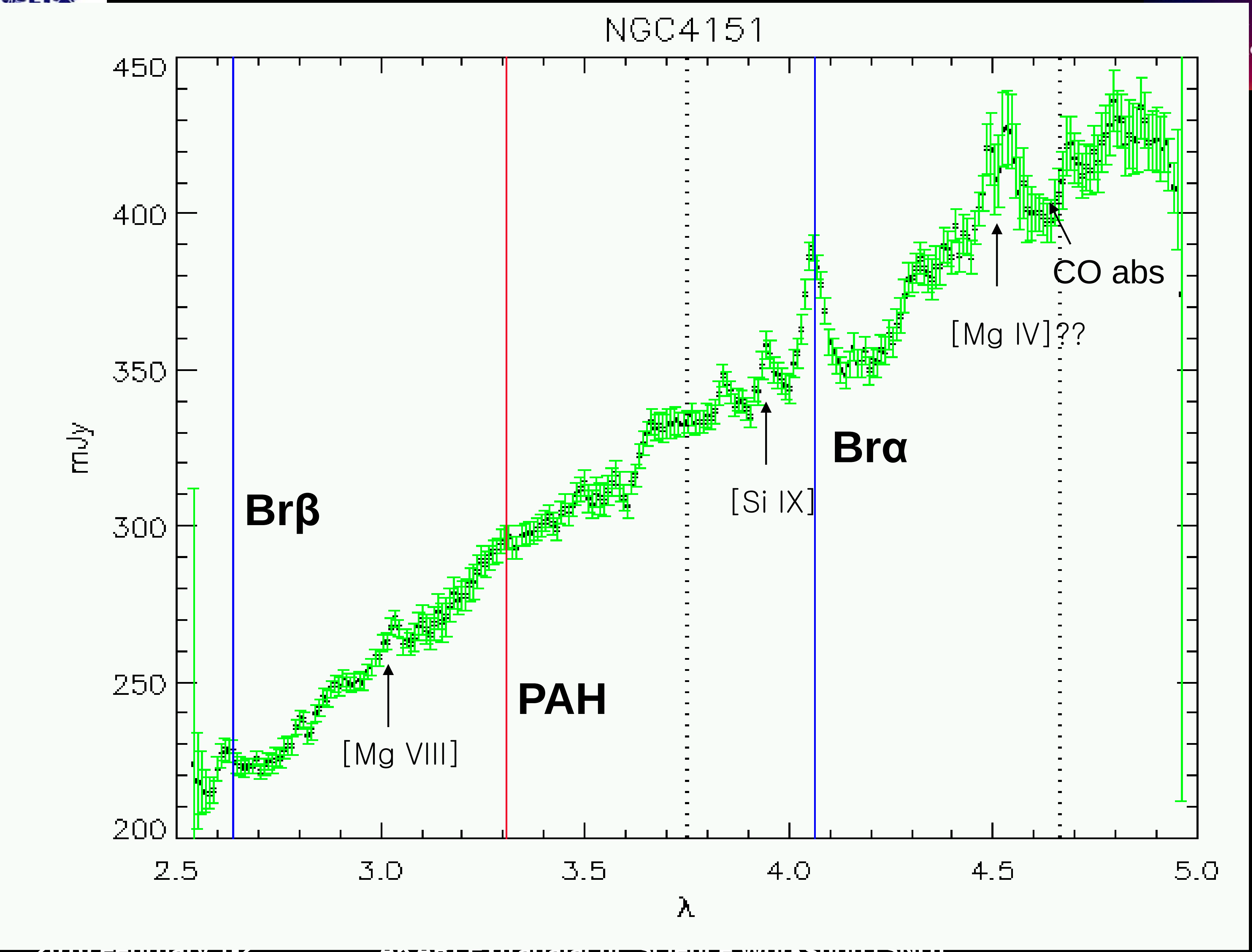

Ongoing Works

- Reduction of the data in progress

- BH mass estimator from Brα, Brβ, and Pα using normal type-1 AGN
- Line ratio study with type-1 AGN (physical environment, NIR template)
- BH mass of red AGN
- Extinction properties of dusty AGN

*Presentation by Dohyeong Kim

Summary

- QSONG: AKARI NIR (2.5-5 micron) Spectroscopy Study of 164 high redshit QSOs (3.4 < z < 6.4) and 69 low redshfit AGNs
- Rest-frame optical spectra for high redshift QSOs – Evolution of mass of SMBHs at high redshift – first detection of Hα lines at QSOs z > 4.5 (before JWST)
- NIR Hydrogen lines + PAHs for low redshift QSOs, ongoing
- Preliminary study based on Hα suggests there are ~10^9 $M_\odot$ SMBHs out to z ~ 6, but the most massive QSOs (10^{10} $M_\odot$) *may* be disappearing beyond z ~ 6
- QSONG2 will cover expand the sample at low-z and high-z