The AKARI 2.5–5.0μm Spectral Atlas of 83 Local Type-1 Active Galactic Nuclei

Dohyeong kim[1], Myungshin Im[1], Ji Hoon Kim[1], Jong-Hak Woo[1], Hyunsung David Jun[1], and QSONG team

[1] Seoul National University, Seoul, Korea

Abstract

We provide results of 2.5–5.0 μm near-infrared (NIR) spectroscopic observations of 83 nearby (0.002<z<0.48) and bright (K<14 mag) type-1 active galactic nuclei (AGNs). The sample is selected from bright quasar surveys of Palomar-Green (PG) and SNUQSO, and AGNs with reverberation mapped black hole (BH) masses from Peterson et al. (2004). We present the spectra of 83 AGNs and a composite spectrum for 48 PG QSOs. The 2.5–5.0 μm spectrum of AGN suffers less dust extinction than UV or optical spectrum, and contains several important emission lines (Brβ; 2.63μm, Brα; 4.05μm, and polycyclic aromatic hydrocarbon (PAH); 3.3μm). We measure the Brackett lines properties for 10 AGNs, which enables to derive BH mass estimators, and investigate circumnuclear environments based on line ratio of Balmer to Brackett lines. Moreover, we perform spectral modeling to obtain the hot and warm dust temperatures of ~1100K and ~220K, respectively. The spectral modeling shows that the hot dust component appears to dominate the flux at 2~5μm. The NIR continuum luminosity shows a correlation with the size of broad line region (BLR), which hints establishing the BH mass estimator using the NIR continuum luminosity to be possible. We derive relations for estimating BH mass based on the NIR continuum luminosity only, and combining both NIR continuum and broad line width.

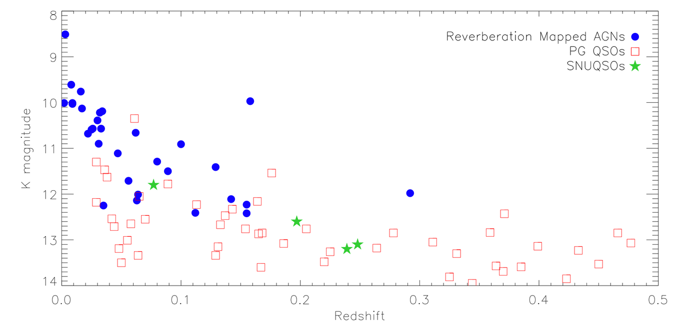
The Sample and Observation

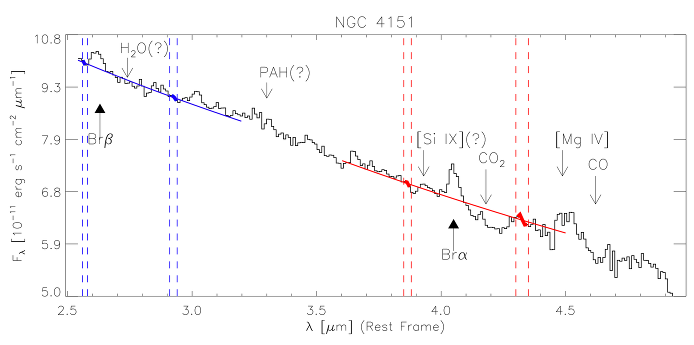
The Sample

- 83 type-1 AGNs at z=0.002–0.48, K<14, and $10^{6.3} < M_{\rm BH} < 10^{9.7} M_\odot$
  - 31 Reverberation mapped AGNs+ 48 PG QSOs+ 4 SNUQSOs

The Observation

- The 2.5–5.0μm spectra were from IRC infrared spectrograph
- R ~120 at 3.6μm
- Observed after the helium cooling over



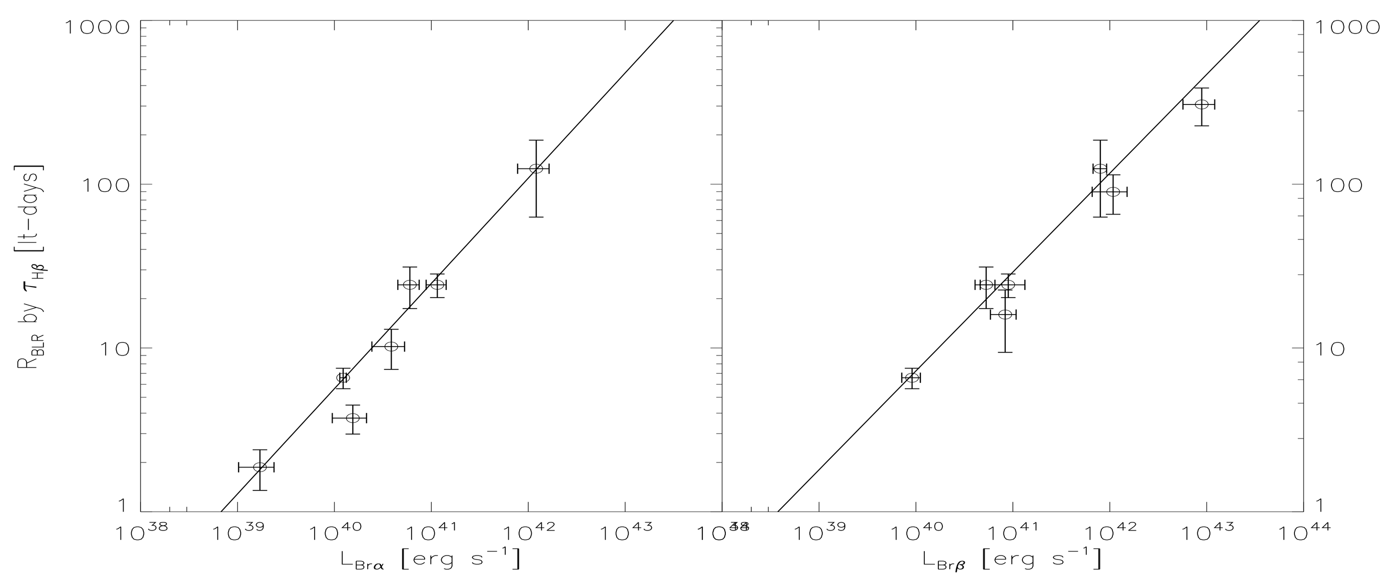


Brackett line luminosities and the BLR radii

The time lags in the variability between the Hβ and the 5100Å continuum luminosities from Bentz et al. (2013) versus Brackett line luminosities

$$\frac{R_{\rm BLR}}{lt-days} = (-0.53 \pm 0.13) + (0.64 \pm 0.05)\log(\frac{L_{\rm Br\alpha}}{10^{38}\ {\rm erg\ s^{-1}}})$$

$$\frac{R_{\rm BLR}}{lt-days} = (-0.34 \pm 0.15) + (0.60 \pm 0.04)\log(\frac{L_{\rm Br\beta}}{10^{38}\ {\rm erg\ s^{-1}}})$$

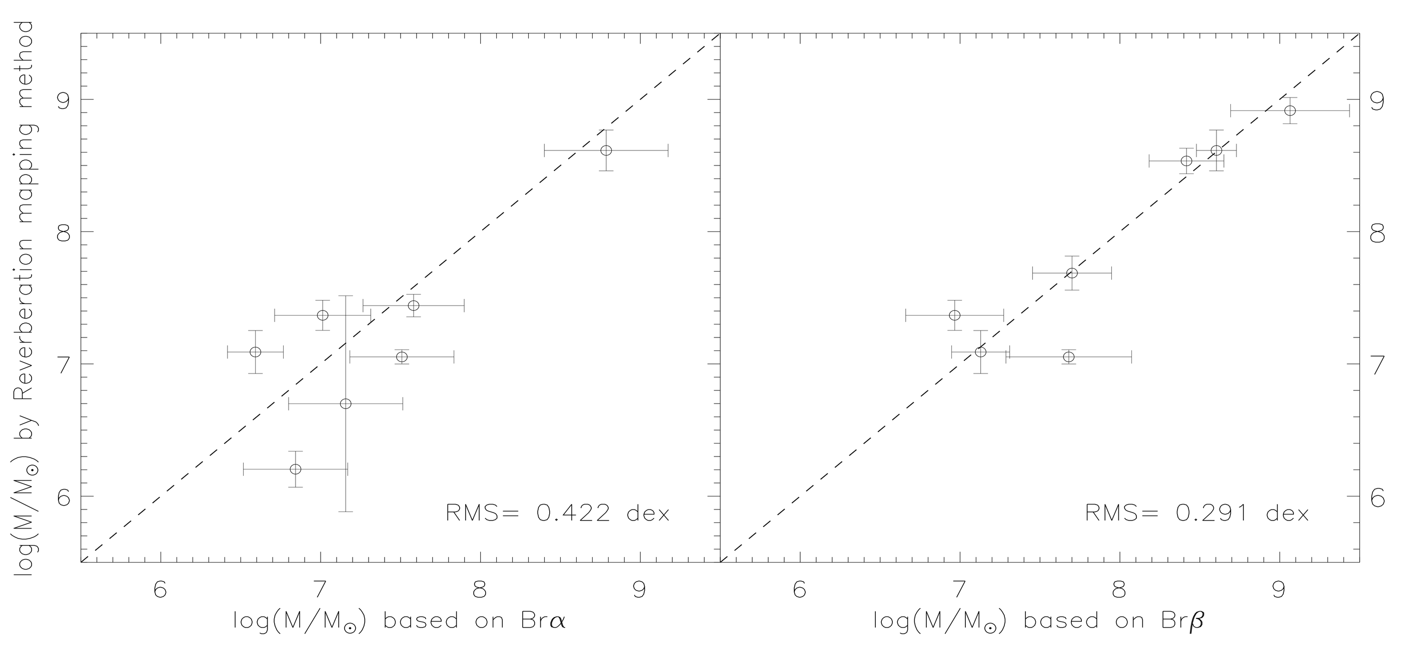


BH Mass Estimators with Brackett Lines

The $M_{\rm BH}$s from the reverberation mapping method (based on updated virial factor of 5.1; Woo et al. 2013) and the $M_{\rm BH}$s from the Brackett line based estimators. For the Brackett line $M_{\rm BH}$ estimators, the radius and velocity of the BLRs are inferred from the luminosity and FWHM of the Brackett lines.

$$\frac{M}{M_\odot} = 10^{5.51\pm0.28}\,(\frac{L_{\rm Br\alpha}}{10^{42}\ {\rm erg\ s^{-1}}})^{0.56\pm0.17}\,(\frac{\rm FWHM_{Br\alpha}}{10^{3}\ {\rm km\ s^{-1}}})^{2}$$

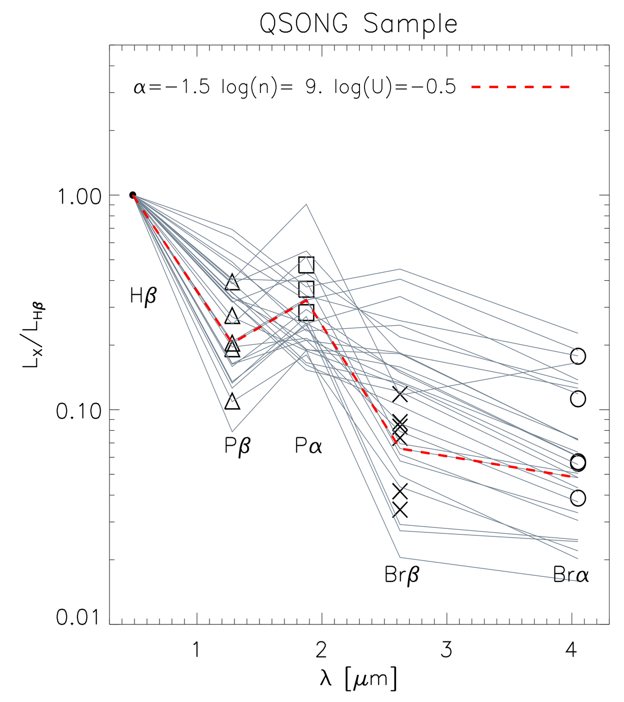
$$\frac{M}{M_\odot} = 10^{5.13\pm0.29}\,(\frac{L_{\rm Br\beta}}{10^{42}\ {\rm erg\ s^{-1}}})^{0.67\pm0.11}\,(\frac{\rm FWHM_{Br\beta}}{10^{3}\ {\rm km\ s^{-1}}})^{2}$$



Line Luminosity Ratios

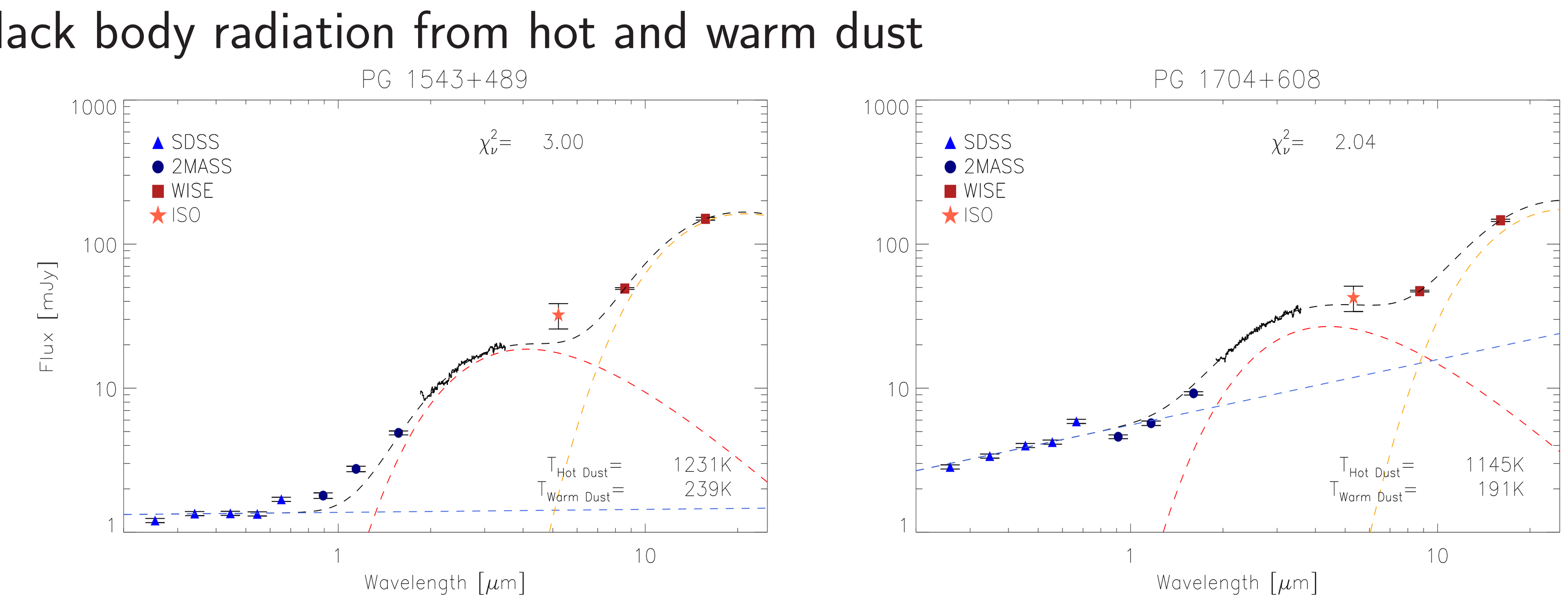
To find physical conditions of AGNs by comparing CLOUDY model prediction and observed line ratios

- CLOUDY model (Ferland et al. 1998)
  - α = -1.0, -1.5
  - n= $10^9 \sim 10^{13}$ cm^{-3}
  - U= $10^{-1.5} \sim 10^{0.5}$
- Line ratios and best-fit
  - $\frac{\rm Br\beta}{\rm H\beta} = 0.076 \pm 0.010$ and $\frac{\rm Br\alpha}{\rm H\beta} = 0.093 \pm 0.010$
  - α=-1.5, n=10^9 cm^{-3}, and U=$10^{-0.5}$



Dust Components

The AGN spectrum from optical to MIR is composed by power-law and black body radiation from hot and warm dust



Model

$$F_\nu = C_0\nu^\alpha + C_1 B_\nu(T_{\rm Hot\ Dust}) + C_2 B_\nu(T_{\rm Warm\ Dust})$$

SED fitting

- Spectrum: *AKARI*
- Photometry: SDSS, 2MASS, *WISE* (*W*3 and *W*4), and ISO (7.3μm)
- $\chi^2_\nu < 5$

Dust temperatures of 14 PG QSOs

- Hot dust: ~1100K
- Warm dust: ~215K

BH Mass Estimators with $L_{\rm NIR}$

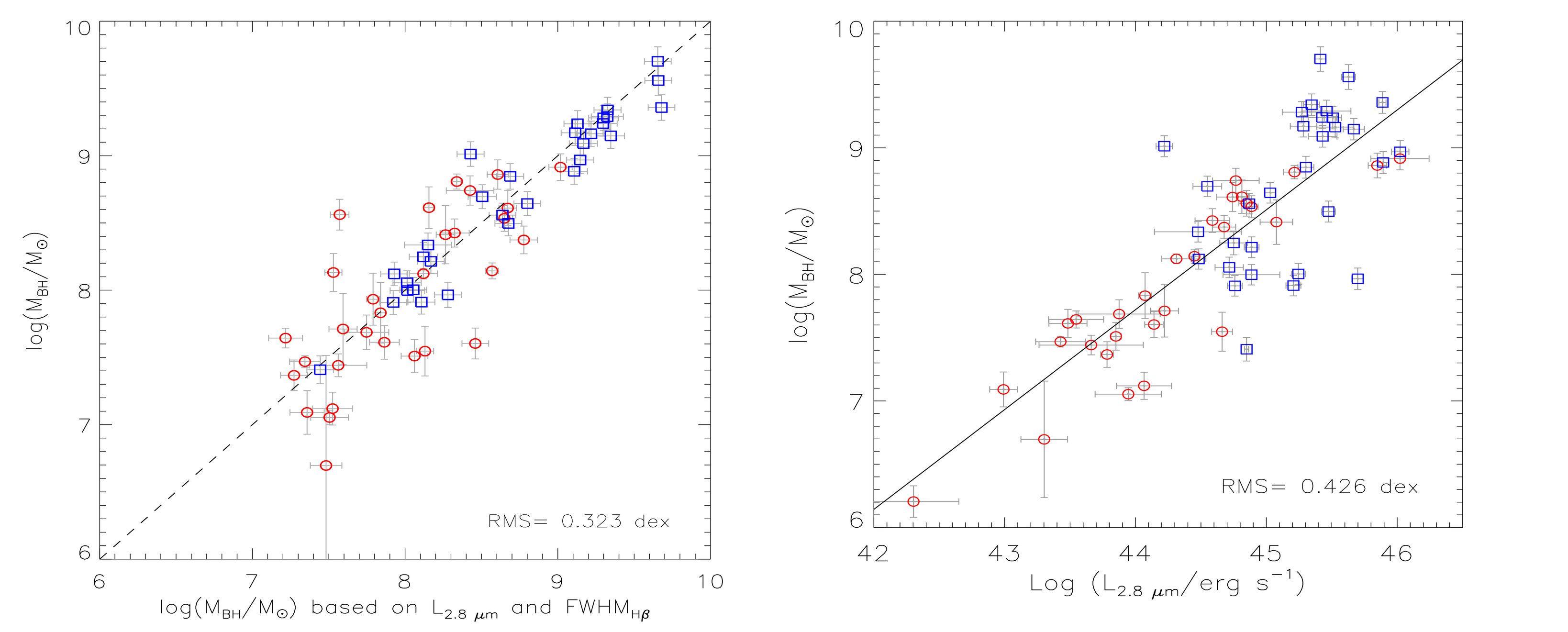
The $M_{\rm BH}$s estimated from reverberation mapping method and optical single epoch method versus the $M_{\rm BH}$s from $L_{\rm NIR}$ and $\rm FWHM_{H\beta}$ or only $L_{\rm NIR}$

$L_{\rm NIR}$ at 2.4 and 2.8μm

- Representing blackbody radiation from dust torus
- $L_{\rm NIR} \propto R_{\rm BLR}$ (Landt et al. 2011)

$$\frac{M}{M_\odot} = 10^{5.27\pm0.07}\,(\frac{L_{2.8\mu m}}{10^{42}\ {\rm erg\ s^{-1}}})^{0.71\pm0.03}\,(\frac{\rm FWHM_{H\beta}}{10^{3}\ {\rm km\ s^{-1}}})^{2}$$

$$\frac{M}{M_\odot} = 10^{6.14\pm0.20}\,(\frac{L_{2.8\mu m}}{10^{42}\ {\rm erg\ s^{-1}}})^{0.78\pm0.07}$$



Acknowledgment

This work was supported by the Creative Initiative Program of the National Research Foundation of Korea (NRF), No. 2008-0060544, funded by the Korea Government (MSIP)

D.K. is supported by NRF (National Research Foundation of Korea) Grant funded by the Korean Government (NRF-2013-Fostering Core Leaders of the Future Basic Science Program, No. 2013-004286)

This research is based on observations with *AKARI*, a *JAXA* project with the participation of ESA

dohyeong@astro.snu.ac.kr