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Medium resolution near-infrared spectra of the host galaxies of nearby quasars

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Abstract

We present medium resolution near-infrared host galaxy spectra of low redshift quasars, PG 0844 + 349 ($z = 0.064$), PG 1226 + 023 ($z = 0.158$), and PG 1426 + 015 ($z = 0.086$). The observations were done by using the Infrared Camera and Spectrograph (IRCS) at the Subaru 8.2 m telescope. The full width at half maximum of the point spread function was about 0.3 arcsec by operations of an adaptive optics system, which can effectively resolve the quasar spectra from the host galaxy spectra. We spent up to several hours per target and developed data reduction methods to reduce the systematic noises of the telluric emissions and absorptions. From the obtained spectra, we identified absorption features of Mg I (1.503 μm), Si I (1.589 μm) and CO (6-3) (1.619 μm), and measured the velocity dispersions of PG 0844 + 349 to be 132 ± 110 km s^{-1} and PG 1426 + 015 to be 264 ± 215 km s^{-1}. By using an $M_{\rm BH}$–σ relation of elliptical galaxies, we derived the black hole (BH) mass of PG 0844 + 349, $\log(M_{\rm BH}/M_{\odot}) = 7.7 \pm 5.5$ and PG 1426 + 015, $\log(M_{\rm BH}/M_{\odot}) = 9.0 \pm 7.5$. These values are consistent with the BH mass values from broad emission lines with an assumption of a virial factor of 5.5.

Keywords: Galaxies; Active-galaxies; Kinematics and dynamics

1. Introduction

Nearby galaxies have bulge with supermassive black holes (Richstone et al., 1998). Understanding the link between the supermassive black holes and their host galaxies is important in studying the formation and evolution of the galaxies. The relation of $M_{\rm BH}$–σ has been discovered, in which $M_{\rm BH}$ is the mass of supermassive black hole and σ is the stellar velocity dispersion of the bugle (e.g., Ferrarese et al., 2001; Gebhardt et al., 2000a; Gebhardt et al., 2000b).

Nevertheless, the measurements of stellar velocity dispersion of host galaxy are difficult in optical bands because of the presence of young stars in the host galaxy. Absorption lines in optical bands such as Mg b at 517 nm and Ca triplet at 850 nm are diluted by continuum. Therefore, it is necessary to use stellar lines in other wavebands in measuring velocity dispersion. CO bandheads in near-infrared (NIR) have been suggested to be the best in studying the velocity dispersion of nearby galaxies (McConnell et al., 2011). In addition, NIR stellar lines have the potential of

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Table 1
Observation log.

Date (UT)	Quasars	z	R	Echelle setting	Slit width (arcsec)	Total exposure (sec)
2003 Feb 11	PG 0844 + 349	0.064	10,000	$H+$	0.3	37 × 180
2004 April 3	PG 0844 + 349	0.064	5000	$H-$	0.6	10 × 300
2004 April 3	PG 1226 + 023	0.158	5000	$H-$	0.6	8 × 300
2004 April 3	PG 1226 + 023	0.158	5000	$H+$	0.6	8 × 300
2004 April 3	PG 1426 + 015	0.086	5000	$H-$	0.6	5 × 300
2004 April 3	PG 1426 + 015	0.086	5000	$H+$	0.6	5 × 300
2004 April 4	PG 0844 + 349	0.064	5000	$H+$	0.6	8 × 300
2004 April 4	PG 1426 + 015	0.086	5000	$H-$	0.6	12 × 300
2004 April 4	PG 1426 + 015	0.086	5000	$H+$	0.6	15 × 300

explaining for the relation between supermassive back holes and their host galaxies.

In this paper, we present the medium resolution host galaxy spectra of nearby quasars in H-band obtained at the Subaru telescope. Thanks to the advantages of using adaptive optics technology, we can isolate the quasar spectra from the host galaxy spectra. The obtained spectra with medium resolution can be used to determine the stellar velocity dispersions in the bulge of the host galaxies, and to estimate the supermassive black hole masses.

Section 2 of this paper shows the observation processes. The detailed data reduction processes of NIR quasar spectra are presented in Section 3. Results and discussions are shown in Section 4. Section 5 is the conclusion.

2. Observations

The observations were performed at the Subaru 8.2 m telescope using the IRCS (Kobayashi, 2000) operated with the Adaptive Optics (AO), AO36 (Hayano et al., 2008), on 2003 February 11 and 2004 April 3 and 4. The average AO-assisted point spread function was 0.3 arcsec.

2.1. Observation of quasars

We observed three nearby quasars, PG 0844 + 349, PG 1226 + 023, and PG 1426 + 015. Table 1 shows the log of the observations. In 2003, we observed PG 0844 + 349 only. The slit width was 0.3 arcsec with $R = 10^4$, and the position angle of the slit was 0 deg. The echelle setting of the spectrograph was in $H+$ setting (1.47–1.82 μm), and the total integration time was about two hours with each exposure of 180 s. The observations were done in an *Nod-off-slit* mode. We first observed the target and then moved the telescope to the nearby background sky. The sequences of the observations were *object* → *sky* → *sky* → *object*.

In 2004, we observed three targets: PG 0844 + 349, PG 1226 + 023, and PG 1426 + 015. The slit width was 0.6 arcsec with $R = 5 \times 10^3$. The echelle settings of the spectrograph were in $H-$ setting (1.46–1.83 μm) and $H+$ setting, and the total integration time was one hour for each target. Other instrument settings and the observation modes were the same as in 2003.

2.2. Standard stars and template stars

We observed A0 V type standard stars to correct the telluric absorption lines in the target spectra. In addition, bright template stars ($H < 5$ mag) in spectral classes of G, K, and M with the luminosity class of III are used to measure the velocity dispersions of the host galaxies.

3. Data reduction

Data reduction was done by using *IRAF*[1] tasks following the methods described in Pyo (2002). The details of the data reduction for standard stars and template stars can be found in Le et al. (2011). The host galaxy spectra were reduced by using similar procedures as that of the template stars. Fig. 1 shows the detailed data reduction processes.

The host galaxy spectra within the radius from 0.24 to 1.89 arcsec are extracted for PG 0844 + 039, and from 0.24 to 2.34 arcsec for PG 1226 + 023 and PG 1426 + 015. We chose the minimum radius to be 0.24 arcsec to ensure that the extracted host galaxy spectra are not affected by emission from QSOs. We confined the maximum radius to extract the host galaxy spectra within the effective radii (Peng et al., 2002) of the targets. In the case of PG 0844 + 349, the maximum radius is equal to the effective radius, $R_e = 1.89$ arcsec. The slit length[2] of Subaru/IRCS, $L = 5.17$ arcsec, however, is shorter than the diameters of PG 1226 + 023 ($D = 12.56$ arcsec) and of PG 1426 + 015 ($D = 8.22$ arcsec). Therefore, the maximum radius to be extracted should be smaller than half of the slit length, $L = 2.59$ arcsec.

The effects of the residual OH sky-lines could cause one of the problems of our obtained spectra. The emission lines of OH cannot be completely corrected by the sky-background subtraction processes. We masked out the data points which contain noises from the OH sky-lines.

[1] *IRAF* (Image Reduction and Analysis Facility) is distributed by the National Optical Astronomy Observatories (NOAO).

[2] http://www.naoj.org/Observing/Instruments.