JHK′ IMAGING PHOTOMETRY OF SEYFERT 1 ACTIVE GALACTIC NUCLEI AND QUASARS. I. MULTIAPERTURE PHOTOMETRY

KEIGO ENYA,1 YUZURU YOSHII,1,2 YUKIYASU KOBAYASHI,3 TAKEO MINEZAKI,1 MASAHIRO SUGANUMA,4 HIROYUKI TOMITA,4 AND BRUCE A. PETERSON5

Received 2001 October 28; accepted 2002 February 5

ABSTRACT
Near-infrared JHK′ imaging photometry was obtained of 331 AGNs consisting mainly of Seyfert 1 active galactic nuclei (AGNs) and quasars (QSOs). This sample was selected to cover a range of radio emission strength, redshift from z = 0 to 1, and absolute B magnitude from MB = −29 mag to −18 mag. Among low-z AGNs with z < 0.3, Seyfert 1–1.5 AGNs are distributed over a region from a location typical of “galaxies” to a location typical of “QSOs” in the two-color J−H to H−K′ diagram, but Seyfert 1.8–2 AGNs are distributed around the location of “galaxies.” Moreover, bright AGNs with respect to absolute B magnitude are distributed near the location of “QSOs,” while faint AGNs are near the location of “galaxies.” The distribution of such low-z AGNs in this diagram was found to have little dependence on their 6 cm radio flux. The near-infrared colors of the AGNs observed with an aperture of 7 pixels (7′′49) are more QSO-like than those observed with larger apertures up to 15 pixels (16′′1). This aperture effect may be explained by contamination from the light of host galaxies within larger apertures. This effect is more prominent for less luminous AGNs.

Subject headings: galaxies: active — galaxies: photometry — galaxies: Seyfert — infrared: galaxies — quasars: general

On-line material: machine-readable tables

1. INTRODUCTION
Near-infrared (NIR) observations are useful to study the dust distribution in active galactic nuclei (AGNs). The unified model assumes a dust torus around the central engine in which the torus viewed at different angles from the line of sight explains the difference between Seyfert 1 AGNs and Seyfert 2 AGNs (Antonucci & Miller 1985).

NIR observations are also useful to derive general features in the spectral energy distributions (SEDs) of AGNs and to examine how much these SEDs are contaminated by the light from host galaxies. Previous authors (Sanders et al. 1989; Neugebauer et al. 1979) presented the SEDs of 109 AGNs which show that the general features of a 1 μm minimum and a 3 μm bump were present in the SEDs of many AGNs. Kobayashi et al. (1993) obtained the SEDs of 14 quasars by 16 channel prism spectrophotometry between 0.95 and 2.5 μm and found that all the SEDs are characterized as having a blackbody SED with a typical temperature of 1500 K corresponding to that of dust sublimation, separated by a power-law component with a variety of power indices. Elvis et al. (1994) presented the SEDs of 47 AGNs (29 radio-quiet and 18 radio-loud AGNs) over a wide range of wavelength from the X-ray to the radio region.

Hunt et al. (1997) obtained JHK images of 26 nearby AGNs. Alonso-Herrero, Ward, & Kotilainen (1996) obtained the JHKL images of 13 Seyfert 2 AGNs and decomposed their SEDs into the stellar and nonstellar components. Because NIR imaging photometry has been limited to nearby AGNs, the sample size has also been limited. Motivated by the need to expand the sample size at least by an order of magnitude, we undertook a program of imaging a few hundred AGNs in the NIR region, carried out a statistical study AGN SEDs with the largest sample ever made. Many of them were observed on two different nights separated by a year or more, for the purpose of detecting the NIR variability of the AGNs in our sample.

In a series of three papers, we give our results from 3 years of observations. In this Paper I, we present NIR magnitudes of more than 300 AGNs derived by multicolor, multiaperture imaging photometry. Analysis and discussion of AGN variability will be presented in the forthcoming Papers II and III (Enya et al. 2002a, 2002b). We are currently conducting a project called MAGNUM (an acronym of Multicolor Active Galactic Nuclei Monitoring, Kobayashi et al. 1998a, 1998b) which monitors AGN in the 11 passbands of UBVRIJKHL and aims to determine the distances to many AGNs by measurements of the delay time between optical and NIR variabilities. Therefore, this paper is not an individual study, but also a preliminary study to select target AGNs for the MAGNUM Project.

2. SAMPLE SELECTION AND OBSERVATIONS

2.1. Sample Selection
In the beginning of this study, all AGNs were selected from the sixth version of the Quasars and Active Galactic Nuclei catalog (hereafter referred to the VV catalog; Veron-Cetty & Veron 1993). Additional AGNs were selected from new versions that were released during this study, the seventh version (Veron-Cetty & Veron 1996) and the eighth version (Veron-Cetty & Veron 1998). We summarize the
selection criteria such as (1) coordinates, (2) AGN types, (3) absolute $B$ magnitudes, and (4) redshifts:

1. Declinations were selected from $\delta = -10$ degrees to $+50$ degrees, allowing for a wide coverage of right ascension, $\alpha$. This is necessary in order for the MAGNUM Project to observe many AGNs under good conditions during the entire year from Haleakala, on the Hawaiian Island of Maui at a latitude of $+20$ degrees where the MAGNUM Observatory is situated.

2. Seyfert 1 AGNs and quasars were selected, excluding Seyfert 2 AGNs and BL Lac objects. This is necessary in order for the MAGNUM Project to observe thermal radiation from the innermost region of the dust torus which surrounds the central engine of AGNs. We excluded Seyfert 2 AGNs, because they are aligned with the dust torus edge-on so that the inner region is obscured. We also excluded BL Lac objects, because their SEDs are known to exhibit only weak thermal radiation from hot dust.

3. Absolute $B$ magnitudes were selected to span from $M_B = -29$ to $-18$, enabling a statistical study of the $M_B$ dependence of various other spectral features of AGNs. This is necessary in order to discuss a Malmquist-type bias which affects an interpretation of any statistical study from bright, distant AGNs in a sample.

4. Redshifts were selected to span from $z = 0$ to 1, enabling a statistical study of $z$ dependence of various other spectral features of AGNs. By considering that the maximum wavelength covered by the MAGNUM camera is the $L$ band, the redshifts were limited to below unity. Otherwise the thermal radiation peaked at $2 \mu m$ corresponding to the 1500 K temperature of dust sublimation shifts to much longer wavelengths, beyond the $L$-band filter.

Table 1 tabulates the basic quantities of 331 AGNs selected in this study. For the purpose of illustration, Figure 1 shows the distribution of $\alpha$ and $\delta$ for all AGNs in the sample, and Figure 2 shows their distribution of $M_B$ and $z$.

### Table 1: Objects List

| Number | Name          | $\alpha$(2000) | $\delta$(2000) | $z$   | $M_B$ | Seyfert Type | Loud/ Quiet |
|--------|---------------|----------------|----------------|-------|-------|--------------|-------------|
| 1.......| PB 5669       | 00 00 12.0     | +0 02 24       | 0.479 | -24.6 | ...          | ...         |
| 2.......| Q2357+019A    | 00 00 23.7     | +0 12 41       | 0.81  | -26.8 | ...          | ...         |
| 3.......| PB 5677       | 00 00 42.9     | +0 55 39       | 0.949 | -25.4 | ...          | ...         |
| 4.......| PB 5723       | 00 05 47.5     | +0 03 02       | 0.234 | -24.2 | ...          | ...         |
| 5.......| PB 5853       | 00 18 22.1     | +0 19 01       | 0.16  | -22.8 | Si           | ...         |
| 6.......| Q0019+0022B   | 00 21 46.4     | +0 38 59       | 0.661 | -25.0 | ...          | ...         |
| 7.......| PB 5932       | 00 24 41.1     | +0 32 21       | 0.404 | -25.1 | ...          | ...         |
| 8.......| MS 00377–0156 | 00 40 17.9     | -0 40 15       | 0.296 | -23.6 | Si.0         | ...         |
| 9.......| Q0057+0000    | 01 00 02.3     | +0 16 42       | 0.776 | -26.3 | ...          | ...         |
| 10......| Q0058+0218    | 01 01 20.1     | +0 34 30       | 0.929 | -26.4 | ...          | ...         |

Notes.—Units of right ascension are hours, minutes, and seconds, and units of declination are degrees, arcminutes, and arcseconds. Object name, $\alpha$(2000), $\delta$(2000), redshift absolute $B$ magnitude, and Seyfert type are taken from the VV catalog. AGNs with $f_v$($6 \text{ cm}$)/$f_v$($V$) $> 100$ and $f_v$($6 \text{ cm}$)/$f_v$($V$) $< 10$ are classified as radio loud and radio quiet, respectively. AGNs in between are classified as intermediate. Otherwise the radio $6 \text{ cm}$ flux is not tabulated in the VV catalog. Table 1 is available in its entirety in the electronic edition of the Astrophysical Journal Supplement. A portion is shown here for guidance regarding its form and content.
background, we used $K'$ filter which has the same transmission curve as the 2MASS $K_s$ filter (McLeod et al. 1995).

Our observational runs consist of three periods (1996 January–1996 April, 1996 November–1997 February, and 1997 December–1998 April). More than 300 AGNs were observed in the first and second periods. In the third period, however, more than 200 AGNs that had been observed in previous two periods were again observed in order to determine their variability. Analysis and discussion of the variability of AGNs will be presented elsewhere (Papers II and III).

The AGNs and quasars were imaged in the $J$, $H$, and $K'$ bands by stepping the telescope in a raster pattern. The typical exposure time of each single frame was 35 s ($J$), 17 s ($H$), and 8 s ($K'$), while a shorter exposure time was used if saturation might occur because of either a high thermal background, or a large flux from an object in the frame. The minimum number of frames for one object was four frames with $2 \times 2$ positions ($J$), four frames with $2 \times 2$ positions ($H$), and nine frames with $3 \times 3$ positions ($K'$). More frames were obtained for fainter objects. The maximum number of frames for one object was 50 frames ($J$), 200 frames ($H$), and 200 frames ($K'$), with $5 \times 5$ positions in common.

Two photometric standard stars with different elevations were observed three times in one night, that is, at the beginning of observations, midnight and at the end of observations. These standard stars were imaged with a $3 \times 3$ raster, and two frames were obtained at each position. In this way a total of 18 frames were obtained for one star, and the acquisition of all the frames in the $J$, $H$, and $K'$ bands took about 15 minutes per star. If such a schedule was impossible because of bad weather or other reasons, the standard stars were observed before and after the observations of the AGNs.

Each night after the AGNs and standard stars were observed, dome flat images were obtained by turning a calibration lamp on and off in front of white board, then the dark current was measured with a cold opaque shutter blocking all external radiation.

3. REDUCTION

3.1. Image Reduction

All the frames of AGNs and standard stars were obtained with short integration times and with dithering, which produced a large number of the frames in the end. A short integration time was used to avoid saturation during measurements with high sky background. The dithering was used to minimize the effect of bad pixels and to make a sky flat of high quality.

The software system specialized to analyze the data obtained by the PICNIC camera (hereafter PICRED) was used for the reduction. PICRED is a semiautomated system, requiring manual operations and human decisions in order to deal with various types of data, from star-forming regions to quasars. For our case of reducing an enormous amount of the data by repeating much the same procedure, the software system was made fully automated.

3.2. Photometric Calibration

Each time a pair of standard stars was observed, 18 frames were taken first for one star at high elevation for each passband, in order, from $J$ to $H$ and then to $K'$, and then similarly for another star at low elevation. This procedure was repeated three times in one night, mostly for different pairs. Abnormal data, deviating remarkably from others, would possibly occur due to major three factors, such as obscuration by thin clouds that were not detected during the observation, the effect of bad pixels, or misidentification of the target.

In the beginning of reduction process, bad frames, if any, were excluded, and only the remaining frames were used to determine the instrumental magnitudes from which the median $m$ (inst) and dispersion $\sigma_d$ were obtained for each star in each passband. The median $m$ (inst) was then transformed to the already calibrated (known) magnitude of each star, by taking a linear fit in a plot of $\Delta m = m$ (inst) $- m$ (calib) against air mass. The error $\sigma_a$ in transformation was also estimated. In this way, we determined the aperture $J$, $H$, and $K'$ magnitudes of AGNs using four different apertures of 7, 10, 12, and 15 pixels in radius. The total error in magnitude is given by $\sigma_m^2 = \sigma_a^2 + \sigma_d^2$. These aperture magnitudes and errors are tabulated in Tables 2A ($J$ band), 2B ($H$ band), and 2C ($K'$ band).

Figure 3 shows the frequency distribution of $\sigma_d$ for the aperture of 15 pixels in the $J$, $H$, and $K'$ bands. For this large aperture of 15 pixels, the error $\sigma_d$ would originate from the variation of atmospheric transmissivity rather than the variation in the seeing during the night. The passband of longer wavelength has the smaller $\sigma_d$ distribution. This feature indicates that detected photon
### TABLE 2A

**Photometry Data in the J Band**

| Number | Name     | $J_1$ | $\sigma_{J_1}$ | $J_{10}$ | $\sigma_{J_{10}}$ | $J_{12}$ | $\sigma_{J_{12}}$ | $J_{15}$ | $\sigma_{J_{15}}$ | Date     | FWHM (arcsec) |
|--------|----------|-------|-----------------|----------|-------------------|----------|-------------------|----------|-----------------|----------|---------------|
| 1............ | PB 5669  | 16.24 | 0.09            | 16.09    | 0.10              | 15.96    | 0.12              | 15.78    | 0.14            | 96/12/03 | 3.3           |
| 6............ | Q0019+0022B | 16.62 | 0.12            | 16.59    | 0.17              | 16.67    | 0.24              | 16.62    | 0.31            | 96/12/02 | 3.5           |
| 8............ | MS 00377–0156 | 15.90 | 0.08            | 15.83    | 0.11              | 15.98    | 0.16              | 16.13    | 0.26            | 96/12/22 | 3.5           |
| 9............ | Q0057+0000 | 16.08 | 0.09            | 16.04    | 0.12              | 16.05    | 0.15              | 16.07    | 0.20            | 96/12/03 | 3.3           |
| 10............ | Q0058+0218 | 15.90 | 0.08            | 15.92    | 0.11              | 15.92    | 0.14              | 15.94    | 0.19            | 98/01/21 | 4.1           |

**Notes.**—The number in the subscript corresponds to the aperture radius in unit of pixel. The pixel scale in this study is 1.07 pixel$^{-1}$. Table 2A is available in its entirety in the electronic edition of the Astrophysical Journal Supplement. A portion is shown here for guidance regarding its form and content.

### TABLE 2B

**Photometry Data in the H Band**

| Number | Name     | $H_7$ | $\sigma_{H_7}$ | $H_{10}$ | $\sigma_{H_{10}}$ | $H_{12}$ | $\sigma_{H_{12}}$ | $H_{15}$ | $\sigma_{H_{15}}$ | Date     | FWHM (arcsec) |
|--------|----------|-------|-----------------|----------|-------------------|----------|-------------------|----------|-----------------|----------|---------------|
| 1............ | PB 5669  | 15.45 | 0.10            | 15.29    | 0.13              | 15.26    | 0.16              | 15.13    | 0.20            | 96/12/03 | 3.2           |
| 2............ | Q2357+019A | 15.81 | 0.23            | 15.15    | 0.19              | 14.87    | 0.19              | 14.63    | 0.21            | 98/01/05 | 4.1           |
| 3............ | PB 5677  | 16.16 | 0.12            | 16.27    | 0.20              | 16.10    | 0.22              | 15.87    | 0.25            | 97/01/06 | 4.1           |
| 4............ | PB 5723  | 15.03 | 0.10            | 15.13    | 0.17              | 15.22    | 0.24              | 14.99    | 0.27            | 96/12/22 | 3.4           |
| 5............ | PB 5853  | 15.31 | 0.11            | 15.18    | 0.14              | 15.11    | 0.17              | 15.06    | 0.23            | 96/12/03 | 3.2           |
| 6............ | Q0019+0022B | 15.16 | 0.09            | 15.26    | 0.14              | 15.35    | 0.20              | 15.30    | 0.27            | 96/12/01 | 4.3           |
| 7............ | PB 5932  | 15.34 | 0.10            | 15.43    | 0.16              | 15.31    | 0.18              | 15.39    | 0.28            | 96/12/03 | 3.2           |
| 8............ | MS 00377–0156 | 15.32 | 0.08            | 15.18    | 0.11              | 14.93    | 0.12              | 14.66    | 0.13            | 98/01/06 | 3.6           |
| 9............ | Q0057+0000 | 15.63 | 0.16            | 15.67    | 0.24              | 15.85    | 0.36              | 15.77    | 0.47            | 96/12/02 | 3.3           |
| 10............ | Q0058+0218 | 15.83 | 0.14            | 15.27    | 0.13              | 15.17    | 0.15              | 15.05    | 0.18            | 96/12/02 | 3.3           |

**Notes.**—The number in the subscript corresponds to the aperture radius in unit of pixel. The pixel scale in this study is 1.07 pixel$^{-1}$. Table 2B is available in its entirety in the electronic edition of the Astrophysical Journal Supplement. A portion is shown here for guidance regarding its form and content.

### TABLE 2C

**Photometry Data in the K' Band**

| Number | Name     | $K'_7$ | $\sigma_{K'_7}$ | $K'_{10}$ | $\sigma_{K'_{10}}$ | $K'_{12}$ | $\sigma_{K'_{12}}$ | $K'_{15}$ | $\sigma_{K'_{15}}$ | Date     | FWHM (arcsec) |
|--------|----------|-------|-----------------|----------|-------------------|----------|-------------------|----------|-----------------|----------|---------------|
| 1............ | PB 5669  | 14.60 | 0.08            | 14.43    | 0.10              | 14.28    | 0.12              | 14.16    | 0.14            | 96/12/03 | 3.0           |
| 2............ | Q2357+019A | 14.75 | 0.10            | 15.19    | 0.22              | 15.67    | 0.44              | ...      | ...             | ...      | ...           |
| 3............ | PB 5677  | 14.07 | 0.08            | 14.34    | 0.16              | 14.57    | 0.25              | 14.87    | 0.45            | 96/12/22 | 3.1           |
| 4............ | PB 5723  | 14.53 | 0.10            | 14.29    | 0.13              | 14.26    | 0.16              | 14.27    | 0.22            | 96/12/03 | 3.0           |
| 5............ | PB 5853  | 14.21 | 0.04            | 14.10    | 0.06              | 14.06    | 0.07              | 13.99    | 0.09            | 98/01/21 | 3.9           |
| 6............ | Q0019+0022B | 16.01 | 0.26            | 15.80    | 0.32              | 15.55    | 0.33              | 15.27    | 0.35            | 96/12/30 | 2.9           |
| 7............ | PB 5932  | 14.21 | 0.04            | 14.12    | 0.06              | 14.00    | 0.07              | 13.85    | 0.08            | 98/01/26 | 3.4           |
| 8............ | MS 00377–0156 | 14.21 | 0.06            | 14.20    | 0.09              | 14.18    | 0.11              | 14.17    | 0.15            | 96/12/03 | 3.0           |
| 9............ | Q0057+0000 | 15.30 | 0.21            | 15.29    | 0.32              | 15.04    | 0.33              | 14.80    | 0.36            | 96/12/02 | 3.4           |
| 10............ | Q0058+0218 | 14.94 | 0.10            | 14.65    | 0.12              | 14.61    | 0.14              | 14.50    | 0.18            | 96/12/02 | 3.4           |

**Notes.**—The number in the subscript corresponds to the aperture radius in unit of pixel. The pixel scale in this study is 1.07 pixel$^{-1}$. Table 2C is available in its entirety in the electronic edition of the Astrophysical Journal Supplement. A portion is shown here for guidance regarding its form and content.
counts in the $J$ band as compared to the $H$ and $K'$ bands is more sensitive to the variation of atmospheric transmissivity.

Figure 4 shows the frequency distribution of $\sigma_d$ for the aperture of 15 pixels in the $J$, $H$, and $K'$ bands. In each panel, the distributions shown are based on our observations in the first and third periods (solid line; 1996 January–1996 April, 1997 December–1998 April) and in the second period (dashed line; 1996 November–1997 February). These distributions are similar to each other, except that the peak for the first and third periods occurs at larger $\sigma_d$ than that for the second period.

Irrespective of the observational period, however, the dispersion $\sigma_d$ is larger than that expected from the high S/N ratio ($\lesssim 0.01$ mag), or from small changes of atmospheric transmissivity and air mass during the short exposure time of about 15 minutes. Therefore, the dispersion $\sigma_d$ may originate from systematic errors in flat-fielding.

Our observations in the second period were made by avoiding use of the fourth quadrant of the detector because it was out of order. The dithering shifts in the second period were at most about 3000, only half of those for normal observations in the first and third periods. The resulting difference in dithering patterns gives a measure of the flat-fielding error over some tens of arcsec that is comparable to $\sigma_d$.

The average and median of $\sigma_d$ for the first and third periods are 0.033 mag and 0.027 mag, respectively. Corresponding values for the second period are smaller. This result is almost independent of passband, in contrast to that for $\sigma_a$.

Thus, $\sigma_a$ is larger than $\sigma_d$ in the $J$ band, while the converse is true in the $K'$ band.

4. RESULTS

The ratio of radio flux $f_r(6 \, \text{cm})$ relative to optical $V$-band flux $f_r(\text{V})$ is used as a measure of radio strength of the AGNs in our sample. Figure 5 shows the distribution of this ratio based on the data taken from the VV catalog. The values of this ratio range over several orders but are localized around 1 and 1000. Here, in this paper, the AGNs with $f_r(6 \, \text{cm})/f_r(\text{V}) < 10$ and no radio detection are classified as radio quiet, and those with $f_r(6 \, \text{cm})/f_r(\text{V}) > 100$ as radio loud.

It is known that there are two typical locations in the two-color $J-H$ to $H-K'$ diagram, such as $(J-H, H-K')=(0.8, 1)$ for the “QSOs” (Hyland & Allen 1982), and $(0.7, 0.3)$ for “galaxies” (Willner et al. 1982). AGNs in our sample are found to be distributed in a wide region from “QSOs” to “galaxies.” In fact, brighter AGNs tend to populate the diagram near the “QSOs,” while fainter AGNs or Syfert 1.8–2 AGNs near the “galaxies.” No such localization, however, occurs if the sample is divided into the radio-quiet and radio-loud AGNs.

All these features are more clearly seen in Figure 6, where averages of $J-H$ and $H-K'$ colors and their errors for low-$z$
AGNs with $0 < z < 0.3$ are plotted as a function of $M_B$, Seyfert type, and $f_\nu(6\text{ cm})/f_\nu(V)$. Shown are the results for the four different apertures of 7, 10, 12, and 15 pixels. Here, averages are taken with no weights, and error bars are the standard deviations of the colors for an aperture of 7 pixels.

The $H-K'$ color becomes monotonically bluer from $M_B = -27$ to $-21$, irrespective of aperture. AGNs with $M_B < -25$ have $H-K'\sim 1$ and are QSO-like, while those with $M_B > -22$ have $H-K' \sim 0.5$ and are galaxy-like. On the other hand, the $J-H$ color stays at about 0.8, and its $M_B$ dependence is much weaker than that for $H-K'$.

Furthermore, for AGNs with $M_B > -24$, the $H-K'$ color determined with larger aperture is more galaxy-like. This feature originates from the color gradient in the central region where the AGN dominates to the outer region where the host galaxy dominates. It should be noticed that the blueward color shift with the use of larger aperture is more significant for fainter AGNs with $M_B > -24$ and for the $H-K'$ color rather than for $J-H$. This feature can be explained naturally by considering that the host galaxy becomes more visible within larger aperture and its SED is enhanced over the AGN at NIR wavelengths in rest frame.

The monotonical trend in the average colors is also seen by changing Seyfert type from 1 to 2. Although Seyfert 1–1.5 AGNs are in between “QSOs” and “galaxies,” Seyfert 1.8–2 AGNs are galaxy-like. This partly reflects the tendency that Seyfert 1.8–2 AGNs are, on the whole, faint in $M_B$, because of obscuration of the central AGN component by the dust torus. On the contrary, no such trend is seen with changing radio strength. The $H-K'$ color for radio-quiet AGNs is much the same as that for radio-loud AGNs and is in between “QSOs” and “galaxies.” This indicates that the radio strength has no significant correlation with $M_B$ in its range considered here.
In order to see the $z$ dependence, we show the $J-H$ and $H-K$ colors of intermediate-$z$ AGNs with $0.3 < z < 0.6$ by dashed lines in Figure 6 only for the case of an aperture of 10 pixels. It is apparent that the QSO-like colors of brighter AGNs with $M_B < -25$ shift blueward for larger $z$, while galaxies-like colors of Seyfert 1.8 shift redward. This opposite color trend is consistent with the opposite of $k$-corrections between AGNs and galaxies, and calculations based on the typical SEDs have confirmed that the values of the $k$-corrections for AGNs and galaxies indeed agree with their respective color shifts as seen in Figure 6. Thus, a criterion of $M_B < -27$ is regarded as a discriminator of QSOs, and a criterion of Seyfert type later than 1.8 as a discriminator of AGNs dominated the galaxy SED component. Otherwise, the intermediate colors, as a result of being contributed equally from QSO and galaxy components, do not show any significant $z$ dependence, because the $k$-corrections of the different components cancel any $z$ dependence.

We are grateful to H. Okuda, M. Narita, and other staff of the infrared astronomy group of the Institute of Space and Astronautical Science (ISAS) for their support in using their 1.3 m telescope. We thank the staff of the Advanced Technology Center of the National Astronomical Observatory of Japan (NAOJ) for their new coating on the mirror of the 1.3 m telescope at the ISAS. Gratitude is also extended to the Computer Data Analysis Center of the NAOJ. This work has made use of the NASA/IPAC Extragalactic Database (NED) and has been supported partly by the Grant-in-Aid (07CE2002, 10304014) of the Ministry of Education, Science, Culture, and Sports of Japan and by the Torey Science Foundation.

REFERENCES

Alonso-Herrero, A., Ward, M. J., & Kotilainen, J. K. 1996, MNRAS, 278, 902
Antonucci, R. R. J., & Miller, J. S. 1985, ApJ, 297, 621
Elvis, M., et al. 1994, ApJS, 95, 1
Enya, K., Yoshii, Y., Kobayashi, Y., Minezaki, T., Suganuma, M., Tomita, H., & Peterson, B. A. 2002a, ApJS, 141, 31 (Paper II)
Enya, K., Yoshii, Y., Kobayashi, Y., Minezaki, T., Suganuma, M., Tomita, H., & Peterson, B. A. 2002b, ApJS, 141, 45 (Paper III)
Hunt, L. K., Malkan, M. A., Salvati, M., Mandolesi, N., Palazzi, E., & Wade, R. 1997, ApJS, 108, 229
Hyland, A. R., & Allen, D. A. 1982, MNRAS, 199, 943
Kobayashi, Y., et al. 1998a, Proc. SPIE, 3352, 120
Kobayashi, Y., Fang, G., Minezaki, T., Waseda, K., Nakamura, K., & Sato, S. 1994, Proc. SPIE, 2198, 603
Kobayashi, Y., Sato, S., Yamashita, T., Shiba, H., & Takami, H. 1993, ApJ, 404, 94
Kobayashi, Y., Yoshii, Y., Peterson, B. A., Minezaki, T., Enya, K., Suganuma, M., & Yamamuro, T. 1998b, Proc. SPIE, 3354, 769
McLeod, B. A., Bernstein, G. M., Rieke, M. J., Tolststrup, E. V., & Fazio, G. G. 1995, ApJS, 96, 117
Neugebauer, G., Oke, J. B., Becklin, E. E., & Matthews, K. 1979, ApJ, 30, 79
Sanders, D. B., Phinney, E. S., Neugebauer, G., Soifer, B. T., & Matthews, K. 1989, ApJ, 347, 29
Veron-Cetty, M.-P., & Veron, P. 1993, A Catalogue of Quasars and Active Nuclei (6th ed.; Garching: ESO)
———. 1996, A Catalogue of Quasars and Active Nuclei (7th ed.; Garching: ESO)
———. 1998, A Catalogue of Quasars and Active Nuclei (8th ed.; Garching: ESO)
Willner, S. P., Fabbiano, G., Elvis, M., Ward, M., Longmore, A., & Lawrence, A. 1982, PASP, 96, 143