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The Difference between the α-disks of Seyfert 1 Galaxies and Quasars *

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Abstract In a previous paper, it was suggested that contamination of the nuclear luminosity by the host galaxy plays an important role in determining the parameters of the standard α disk of AGNs. Using the nuclear absolute B band magnitude instead of the total absolute B band magnitude, we have recalculated the central black hole masses, accretion rates and disk inclinations for 20 Seyfert 1 galaxies and 17 Palomar-Green (PG) quasars. It is found that a small value of α is needed for the Seyfert 1 galaxies than for the PG quasars. This difference in α possibly leads to the different properties of Seyfert 1 galaxies and quasars. Furthermore, we find most of the objects in this sample are not accreting at super-Eddington rates if we adopt the nuclear optical luminosity in our calculation.

Key words: galaxies: active — galaxies: nuclei — quasars: Seyfert

1 INTRODUCTION

The standard paradigm of AGNs is an accretion disk surrounding a central super-massive black hole. The wide emission lines come from material located in regions outside the accretion disk called broad line regions (BLRs). With the reverberation mapping method, the sizes of the BLRs from the AGN centers have been obtained for 37 nearby AGNs (Ho 1998; Wandel et al. 1999; Kaspi et al. 2000). In our previous paper (Bian & Zhao 2002), we assumed that gravitational instability of standard thin disks leads to the formation of BLRs, that the B band luminosity comes from a standard thin disk and that the motion of BLRs is virial. Using the accretion disk theory, we determined some of the parameters of the AGNs, such as the central black hole mass, accretion rate, disk inclination to the line of sight and the α parameter. It was pointed out that the host contribution to the optical luminosity of AGNs had a strong effect on the determination of these parameters.

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Ho & Peng (2001) used the nuclear luminosity in optical and radio bands to discuss the radio loudness of Seyfert nuclei and found that the majority of type 1 Seyfert nuclei belongs to the category of radio-loud AGNs. They also found a strong correlation between the nuclear optical magnitude ($M_B^{\rm nuc}$) and Hβ luminosity ($L_{{\rm H}\beta}$) (see their fig. 6). Ho (2002) also used this correlation to estimate the nuclear optical luminosity to investigate the relations between radio luminosity, radio loudness, and the black hole mass.

Here we adopt the nuclear absolute B band magnitude ($M_B^{\rm nuc}$) from the literature (Schmidt & Green 1983; Ho & Peng 2001; Ho 2002) and make a recalculation of the accretion disk parameters according the method introduced in the paper of Bian & Zhao (2002). This method is briefly introduced in Section 2. The recalculated results are presented in Section 3. Section 4 is our conclusion. All the cosmological calculations in this paper assume $H_0 = 75\,{\rm km\ s^{-1}\ Mpc^{-1}}$, $\Omega = 1.0, \Lambda = 0$.

2 THE METHOD

2.1 Formulae

Here we briefly introduce the method used in Bian & Zhao (2002). First, using the standard thin disk theory, the B band luminosity (L^B) is derived from the black hole mass (M), the accretion rate ($\dot{M}$), and the inclination (i):

$$L_9^B = 13.8 \dot{M}_{26}^{2/3} M_8^{2/3} \cos i. \tag{1}$$

Here $M_8 = M/(10^8\,M_\odot)$, $L_9^B = L^B/(10^9 L_\odot)$, and $\dot{M}_{26} = \dot{M}/(10^{26}{\rm g\ s^{-1}})$.

Secondly, from the accretion disk theory, we obtain the radius of the gravitational instability ($R_{\rm ins}$) (Bian & Zhao 2002) by

$$R_{14} = 880 \alpha^{28/45} Q^{-8/9} \dot{M}_{26}^{-22/45} M_8^{1/3}, \tag{2}$$

where $R_{14} = R_{\rm ins}/(10^{14}\,{\rm cm})$, α is the parameter describing the viscosity in the standard α-disks and Q is the criterion of the gravitational instability. Under the premise that it is the gravitational instability of the accretion disk that leads to BLRs, we assume that the BLR size ($R_{\rm BLR}$) is equal to the instability radius ($R_{\rm ins}$) (see Bian & Zhao 2003).

Thirdly, assuming virial motion of the BLRs, the FWHM of Hβ ($V_{\rm FWHM}$) is given by

$$V_3 = 3.89 Q^{4/9} \alpha^{-14/45} \dot{M}_{26}^{11/45} M_8^{1/3} \sin i, \tag{3}$$

where $V_3 = V_{\rm FWHM}/(1000\,{\rm km\ s^{-1}})$.

Using Eqs. (1)–(3), we can calculate the central black hole mass (M) , the accretion rate ($\dot{M}$), and the inclination (i) from known absolute B band luminosity (L^B), BLR size ($R_{\rm BLR}$) and Hβ FWHM ($V_{\rm FWHM}$).

2.2 Data

Our sample consists of all AGNs with available BLRs sizes from the reverberation mapping method: 20 Seyfert 1 galaxies (Wandel et al. 1999; Ho 1998), 17 PG quasars (Kaspi et al. 2000). $M_B^{\rm nuc}$ is available in the literature for all the quasars (Schmidt & Green 1983) of this sample and for a number of the Seyfert 1 galaxies (Ho & Peng 2001). For the other Seyfert 1 galaxies, the $M_B^{\rm nuc}$ is obtained from the $M_B^{\rm nuc} - L_{{\rm H}\beta}$ correlation (Ho 2002). We use $M_B^{\rm nuc}$ instead of the absolute B band magnitude from the Veron-Cetty & Veron (2001) to calculate absolute B band luminosity L^B. The value of $M_B^{\rm nuc}$ is listed in Column (3) in Table 1. The absolute B band magnitude (M_B) from Veron-Cetty & Veron (2001) is listed in Column (2).

Table 1 Properties of the 37 AGNs

Name (1)	M_B (mag) (2)	$M_B^{\rm nuc}$ (mag) (3)	$\log_{10} M_{\rm rm}$ ($M_\odot$) (4)	$\log_{10} M_{\rm cal}$ ($M_\odot$) (5)	$\log_{10} \dot{M}$ ($M_\odot$/yr) (6)	$\dot{m}$ (7)	i (deg) (8)
3C 120	–20.8	–20.79	7.36	9.00 ±0.38	–1.22 ±0.38	0.0045 ±0.0043	5.4 ±2.2
3C 390.3	–21.6	–21.22	8.53	8.88 ±0.35	–0.76 ±0.40	0.017 ±0.016	24.9 ±10.0
Akn 120	–22.2	–22.62	8.26	9.60 ±0.38	–0.71 ±0.38	0.0037 ±0.0035	7.8 ±3.2
F9	–23.0	–23.13	7.90	9.34 ±0.38	–0.15 ±0.38	0.025 ±0.023	6.94 ±2.8
IC 4329A	–20.1	–19.25	6.70	6.76 ±0.30	0.28 ±0.43	23.63 ±22.07	36.9 ±14.2
Mrk 79	–20.9	–19.93	7.72	8.27 ±0.36	–0.95 ±0.39	0.045 ±0.043	19.6 ±7.9
Mrk 110	–20.6	–19.40	6.75	8.09 ±0.38	–1.13 ±0.38	0.046 ±0.044	7.8 ±3.2
Mrk 279[a]	–21.2	–20.55	7.62	8.18 ±0.36	–0.50 ±0.39	0.16 ±0.15	19.4 ±7.9
Mrk 335[a]	–21.7	–18.18	6.80	7.59 ±0.37	–1.35 ±0.39	0.09 ±0.08	14.8 ±6.0
Mrk 509	–23.3	–22.48	7.76	9.92 ±0.38	–1.12 ±0.38	6.8E–4 ±6.4E–4	3.00 ±1.2
Mrk 590[a]	–21.6	–16.46	7.25	7.20 ±0.28	–1.78 ±0.45	0.07 ±0.067	41.7 ±15.5
Mrk 817[a]	–22.3	–17.81	7.64	7.56 ±0.27	–1.29 ±0.45	0.1 ±0.09	44.3 ±16.2
NGC 3227[a]	–18.7	–16.01	7.59	7.17 ±0.06	–1.27 ±0.60	0.22 ±0.20	72.4 ±12.2
NGC 3516[a]	–20.5	–17.21	7.36	7.09 ±0.17	–0.93 ±0.52	0.63 ±0.58	57.7 ±17.2
NGC 3783	–19.7	–19.01	6.97	7.24 ±0.34	–0.43 ±0.41	1.56 ±1.46	27.8 ±11.1
NGC 4051[a]	–16.8	–14.97	6.11	6.07 ±0.28	–1.56 ±0.44	1.67 ±1.55	41.2 ±15.4
NGC 4151[a]	–18.7	–19.18	7.18	7.13 ±0.31	–0.15 ±0.43	3.79 ±3.54	36.4 ±14.0
NGC 4593	–19.7	–17.80	6.91	6.84 ±0.27	–0.60 ±0.45	2.55 ±2.37	42.8 ±15.8
NGC 5548[a]	–20.7	–17.29	8.09	7.77 ±0.14	–1.45 ±0.54	0.039 ±0.036	61.9 ±16.4
NGC 7469[a]	–21.6	–17.78	6.81	6.89 ±0.31	–0.75 ±0.42	1.669 ±1.559	35.3 ±13.7
PG 0026	–24.0	–24.35	7.73	9.645 ±0.74	0.277 ±0.74	0.17027 ±0.16991	4.24 ±0.64
PG 0052	–24.5	–23.99	8.34	9.631 ±0.75	0.082 ±0.76	0.11803 ±0.11781	9.12 ±1.40
PG 0804	–23.9	–23.17	8.28	9.415 ±0.70	–0.194±0.70	0.07901 ±0.07876	9.39 ±1.33
PG 0844	–23.1	–23.30	7.33	8.443 ±0.86	0.857 ±0.87	18.06383 ±18.05147	10.09 ±1.77
PG 0953	–25.6	–25.24	8.26	10.114 ±0.74	0.341 ±0.74	0.06530 ±0.06515	3.91 ±0.59
PG 1211	–24.0	–23.31	7.61	9.195 ±0.79	0.104 ±0.80	0.40511 ±0.40458	5.77 ±0.93
PG 1226	–26.9	–26.47	8.74	11.066 ±0.72	0.126 ±0.72	0.00416 ±0.00415	2.51 ±0.37
PG 1229	–22.4	–22.61	7.88	8.564 ±0.91	0.338 ±0.92	5.21516 ±5.21290	15.66 ±2.88
PG 1307	–24.6	–24.07	8.45	9.422 ±1.00	0.340 ±1.01	1.09526 ±1.09505	9.82 ±1.99
PG 1351	–24.1	–22.52	7.66	9.408 ±0.88	–0.584±0.89	0.07716 ±0.07711	4.62 ±0.83
PG 1411	–24.7	–22.95	7.90	9.075 ±0.85	0.013 ±0.86	0.56902 ±0.56858	8.97 ±1.55
PG 1426	–23.4	–22.91	8.67	9.023 ±0.85	0.091 ±0.87	0.80285 ±0.80228	23.31 ±4.00
PG 1613	–23.5	–23.43	8.38	8.794 ±0.87	0.630 ±0.89	4.98799 ±4.98486	22.96 ±4.00
PG 1617	–23.4	–23.06	8.44	9.030 ±0.79	0.150 ±0.80	0.66211 ±0.66124	18.12 ±2.89
PG 1700	–25.8	–25.46	7.78	9.045 ±2.14	1.542 ±2.14	10.52923 ±10.52919	3.67 ±1.49
PG 1704	–25.6	–25.50	7.57	10.146 ±1.36	0.464 ±1.36	1.41944 ±1.41943	1.13 ±0.32
PG 2130	–22.9	–22.61	8.16	9.396 ±0.75	–0.512±0.75	0.05085 ±0.05075	9.21 ±1.40

Col.1: name, Col.2: absolute B band magnitude from Veron-Cetty et al. (2001), Col.3: nuclear absolute B band magnitude, Col.4: log of the reverberation mapping BH mass in $M_\odot$ from Kaspi et al. (2000), Col.5: log of our calculated BH mass in $M_\odot$, Col.6: log of accretion rates in $M_\odot$/yr, Col.7: the accretion rate in units of Eddington accretion rate, Col.8: calculated inclinations (in deg) to our sight.The nuclear absolute B band magnitude of Seyfert 1 galaxies labelled with [a] are from Ho & Peng (2001), the rest of Seyfert 1 galaxies are from Ho (2002). The nuclear absolute B band magnitude of Quasars are from Schmidt & Green 1983.

3 RESULTS

Figure 1 shows that for the PG quasars $M_B^{\rm nuc}$ is almost equal to M_B , while for the Seyfert 1 galaxies $M_B^{\rm nuc}$ is almost always larger than M_B, implying that there is much contamination of the luminosity of the nucleus from the host galaxy in Seyfert 1 galaxies.

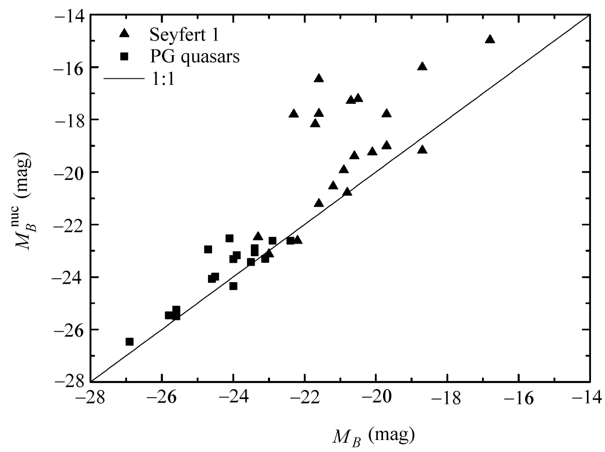

Fig. 1 Absolute nuclear B magnitude ($M_B^{\rm nuc}$) vs. the absolute B magnitude (M_B) ($\alpha = 1$). The triangle denotes Seyfert 1 galaxy and the square denotes PG quasar. The straight line represents $M_B^{\rm nuc} = M_B$.

From Table 2, we suggest that a reasonable value of α for Seyfert 1 galaxies is about $0.1 \sim 0.01$ if the mean inclination of Seyfert 1 galaxies is about 30 (deg) (Nandra et al. 1997; Wu & Han 2001). Because the uncertainties in our results come mainly from the uncertainties in α and little from the uncertainties in Q or in the BLR size, we determine our results uncertainties from the uncertainties in α alone. We use $\alpha = 0.1$ and $\alpha = 0.01$ to calculate the accretion disk parameters for Seyfert 1 galaxies. The mean values of these three parameters are listed in Table 1. The mean inclination of Seyfert 1 galaxies is 30.4 ± 4.5 (deg), which is consistent with AGNs unification schemes (Urry & Padovani 1995). However, for the PG quasars, a reasonable value of α is 1, since using a smaller value will lead to a too small mean inclination. We fix $\alpha = 1$ and use the method in Bian & Zhao (2002) to calculate these three parameters. Their uncertainties are from the uncertainties in the values of Q and BLRs sizes. The values of the black hole mass, accretion rates and accretion rates in units of the Eddington accretion rate, and inclinations are listed in Column (5)–(8) in Table 1, respectively.

From Table 1 and Table 2, we find that for most Seyfert 1 galaxies the accretion rates are less than one solar mass per year and the accretion rates in units of the Eddington accretion rates are less than one. The higher accretion rates for Seyfert 1 galaxies given in Bian & Zhao (2002) is due to the overestimated absolute B band magnitude, which can explain the question on super-Eddington rates found by Collin & Hure (2001). Collin & Hure (2001) also suggested that half of the objects in the sample of Kaspi et al. (2000) are accreting close to the Eddington rate or at super-Eddington rates unless the BLRs are a flat thin rotating structure with the same axis as the accretion disk, close to the line of sight. Here we show that the almost face-on

BLRs, namely, small inclination, indeed lead to the sub-Eddington rates in the sub-sample of PG quasars.

Table 2 Statistics of Inclinations and Absolute and Relative Accretion Rates for $Q = 1$ and Different Values of α

α	1	0.1	0.05	0.01	0.001
i (Seyfert 1)	62.8±27.3	40.7±25.1	35.9±23.9	20.1±15.4	8.7±7.0
i (PG quasar)	9.3±6.7	3.9±2.8	3.2±2.3	1.6±1.2	0.7±0.5
$\log_{10} \dot{M}$ (Seyfert 1)	0.6±0.5	−0.5± 0.5	−0.3±0.9	−1.3± 0.5	−2.1±0.6
$\log_{10} \dot{M}$ (PG quasars)	0.1±0.4	−0.6±0.4	−0.5±0.8	−1.4± 0.4	−2.1±0.4
$\dot{m}$ (Seyfert 1)	76.7±221	3.5±10.1	3.1±5.6	0.1±0.4	0.004±0.01
$\dot{m}$ (PG quasars)	0.06±0.1	0.002±0.004	0.5±2.0	5.6E–5±1.3E–4	1.7E–6±4.1E–6

In Equation (2) we assumed that gravitational instability of the accretion disk leads to BLRs, and that the BLR size ($R_{\rm BLR}$) is equal to the gravitational instability radius ($R_{\rm ins}$). It is possible that $R_{\rm ins} \ll R_{\rm BLR}$. Here we re-calculate Eqs. (1)–(3) assuming $R_{\rm ins} = 0.1R_{\rm BLR}$. The results are listed in Table 3. Compared to the previous calculation assuming $R_{\rm ins} = R_{\rm BLR}$, the inclinations are about the same, while the accretion rates are larger. Equation (2) is not directly related to the inclination. The relation between $R_{\rm ins}$ and $R_{\rm BLR}$ would affect mainly the accretion rates, not the inclinations. We should note that we use the BLRs sizes based on the Hβ emission line from the reverberation mapping method. Peterson & Wandel (2000) found various emission lines spanning an order of magnitude in distance from the central source follow the expected $V \propto r^{-1/2}$ relation between the emission line size and the emission line width, and they also suggested that it is the gravity that controls the broad emission line region clouds, not the radiation pressure. Based on our calculation, we find the gravitational instability would lead to the BLRs clouds and $R_{\rm ins} \approx R_{\rm BLR}$. In Equation (3), we omit the random isotropic velocity and adopt the assumption of randomly-orientated BLR orbits (Bian & Zhao 2002). McLure & Dunlop (2001, 2002) modelled the Hβ FWHM distribution and suggested the disk-like BLRs model is suitable for AGNs with FWHM larger than 2800 km s^{-1}. At the same time, the smaller observed Hβ line width in AGNs is possibly from the isotropic velocity (Zhang & Wu 2002). The disk and isotropic figuration of the BLRs should be considered in this case. We should be cautious of our results for AGNs with small FWHM.

Table 3 Statistics of Inclinations and Absolute and Relative Accretion Rates for $R_{\rm ins} = 0.1R_{\rm BLR}$

α	1	0.1	0.05	0.01	0.001
i (Seyfert 1)	67.6±26.0	47.6±26.8	40.5±25.0	20.1±15.4	11.1±8.9
i (PG quasar)	11.9±8.5	5.0±3.6	3.9±2.8	1.6±2.1	0.9±0.6
$\log_{10} \dot{M}$ (Seyfert 1)	1.9±0.6	0.8±0.5	0.5±0.5	−0.1 ± 0.5	–0.9±0.6
$\log_{10} \dot{M}$ (PG quasars)	1.4±0.35	0.6±0.4	0.4±0.4	–0.2±0.4	–0.9±0.4
$\dot{m}$ (Seyfert 1)	1.7E+4±5.1E+4	876±2537	333±962	32.2±92.3	1.1±2.9
$\dot{m}$ (PG quasars)	16.0±37.8	0.5±1.2	0.4±0.4	–0.2±0.4	4.66E–4±1.1E–3

4 CONCLUSIONS

Using the nuclear absolute B band magnitude instead of the total absolute B band magnitude, we recalculated the central black hole masses, the accretion rates, and the disk inclinations to the line of sight according the method of Bian & Zhao (2002). The main conclusions can be summarized as follows:

1. Using smaller nuclear absolute B band luminosities in Seyfert 1 galaxies than in Veron-cetty & Veron (2001) has yielded results different from Bian & Zhao (2002).
2. The value of α is different for Seyfert 1 galaxies and quasars if the mean inclination of Seyfert 1 galaxies is about 30 (deg). The value of α is about $0.1 \sim 0.01$ for Seyfert 1 galaxies and is about 1 for PG Quasars. The difference in α may lead to the different properties between Seyfert 1 galaxies and Quasars.
3. Choosing a smaller value of α than in Bian & Zhao (2002), we find that most Seyfert 1 galaxies are not accreting at super-Eddington rates. The higher accretion rates given in Bian & Zhao (2002) is due to the adopting of overestimated absolute B band magnitudes.

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