The Astrophysical Journal, 658:L13–L16, 2007 March 20

A NARROW-LINE SEYFERT 1–BLAZAR COMPOSITE NUCLEUS IN 2MASX J0324+3410

Hongyan Zhou,[1,2,3] Tinggui Wang,[1,2] Weimin Yuan,[4] Hongguang Shan,[4] Stefanie Komossa,[5] Honglin Lu,[1,2] Yi Liu,[6] Dawei Xu,[7] J. M. Bai,[4] and D. R. Jiang[6]
Received 2006 September 6; accepted 2007 February 7; published 2007 February 15

ABSTRACT

We report the identification of 2MASX J032441.19+341045.9 (hereafter 2MASX J0324+3410) with an appealing object that shows the dual properties of both a narrow-line Seyfert 1 galaxy (NLS1) and a blazar. Its optical spectrum, which has a Hβ line width of about 1600 km s^{-1} (FWHM), an [O III]–to–Hβ line ratio of $\simeq$0.12, and strong Fe II emission, clearly fulfills the conventional definition of NLS1s. On the other hand, 2MASX J0324+3410 also exhibits some behavior that is characteristic of blazars, including a flat radio spectrum above 1 GHz, a compact core plus a one-sided jet structure on milliarcsecond scale at 8.4 GHz, highly variable fluxes in the radio, optical, and X-ray bands, and a possible detection of TeV γ-ray emission. On its optical image, obtained with the *HST* WFPC2, the active nucleus is displaced from the center of the host galaxy, which exhibits an apparent one-armed spiral structure extended to 16 kpc. The remarkable hybrid behavior of this object presents a challenge to current models of NLS1s and γ-ray blazars.

Subject headings: galaxies: active — galaxies: individual (2MASX J0324+3410) — galaxies: jets — galaxies: peculiar — galaxies: Seyfert

Online material: color figures

1. INTRODUCTION

Since their identification as a special subgroup of broad-line active galactic nuclei (AGNs), narrow-line Seyfert 1 galaxies (NLS1s; Osterbrock & Pogge 1985) have drawn substantial attention in the AGN community over the last 20 years. The conventional definition of NLS1s consists of two criteria: (1) a narrow width of the broad Balmer emission line [FWHM(Hβ) < 2000 km s^{-1}] and (2) weak forbidden lines ([O III] λ5007/Hβ < 3). Subsequent studies revealed their other unusual properties, such as (1) strong Fe II multiplet emission (e.g., Boroson & Green 1992; Grupe et al. 1999; Véron-Cetty et al. 2001; Zhou et al. 2006), (2) steep soft X-ray spectra (Wang et al. 1996; Boller et al. 1996; Grupe et al. 1998), (3) rapid and large amplitudes of X-ray variability (e.g., Leighly 1999; Komossa & Meerschweinchen 2000), and (4) commonly blueshifted UV line profiles (e.g., Leighly & Moore 2004). These unusual properties are in fact an extension to the extremity of a set of correlations between Hβ line width and the other observables. These correlations form the so-called eigenvector 1 (E1; Boroson & Green 1992; Sulentic et al. 2000). E1 is considered as the manifestation of the variation of one or a certain combination of several fundamental parameters of AGNs, such as the black hole mass and/or accretion rate.

NLS1s are usually radio-quiet (RQ) with radio loudness $R <$ 10 (which is defined as the radio–to–B-band optical flux ratio, $R \equiv f_{5\,\mathrm{GHz}}/f_B$). The last decade has witnessed the identification of about two dozen radio-loud (RL) NLS1s (Grupe et al. 2000; Zhou & Wang 2002; Zhou et al. 2003, 2005, 2006; Komossa et al. 2006a, 2006b). Given the intriguing fact that RL AGNs and "normal" NLS1s occupy the opposite extremes of the E1 parameter space (Boroson 2002), the study of RL NLS1s may provide important clues to understanding the physical drivers of E1.

An operational definition of a blazar, which belongs to another small distinct subset of AGNs, is that it has a flat radio spectrum above 1 GHz, fast variability, high and variable polarization, superluminal motion, and high brightness temperature (Urry & Padova 1995). Blazars are believed to be radio-loud AGNs viewed (almost) along the direction of their radio jets; so that nonthermal jet emission is relativistically boosted. In our recent work, we found that the two radio loudest NLS1s, SDSS J094857.3+002225 (Zhou et al. 2003) and 0846+51W1 (Zhou et al. 2005), both show blazar-like behavior. These results suggest that relativistic beaming may play an important role in very radio-loud (VRL) NLS1s.

In this Letter, we report the discovery of an appealing NLS1-blazar composite object, 2MASX J032441.19+341045.9 (hereafter 2MASX J0324+3410), an extreme example and the best example so far in the line of the NLS1-blazar connection. This object was first observed spectroscopically by Remillard et al. (1993) as an optical counterpart of an X-ray source detected in the *HEAO-1* X-ray survey, and it was classified as a Seyfert 1 galaxy. It was subsequently observed by Marchã et al. (1996) but was (mis-)classified as a narrow-line radio galaxy (NLRG). Here we present our new spectroscopic observation and classification, along with its broadband property; we defer to a future paper for detailed analyses of its full data set from both archives and our ongoing monitoring observations. Throughout this Letter, we assume a cosmology with $H_0 = 70$ km s^{-1} Mpc^{-1}, $\Omega_M = 0.3$, and $\Omega_\Lambda = 0.7$.

2. OBSERVATIONS, DATA ANALYSIS, AND BROADBAND PROPERTIES

2.1. *Optical Spectroscopy and NLS1 Classification*

We took spectra of 2MASX J0324+3410 with the Opto-Mechanics Research spectrograph attached to the Cassegrain focus of the 2.16 m telescope at Xinglong Station of National Astronomical Observatory of China on 2005 November 25. A

[1] Center for Astrophysics, University of Science and Technology of China (USTC), Hefei, Anhui 230026, China; twang@ustc.edu.cn
[2] Joint Institute of Galaxies and Cosmology, SHAO and USTC.
[3] Department of Astronomy, University of Florida, Gainesville, FL 32611.
[4] National Astronomical Observatories/Yunnan Observatory, Chinese Academy of Sciences, Kunming, Yunnan 650011, China
[5] Max-Planck-Institut für extraterrestrische Physik, 85741 Garching, Germany.
[6] Shanghai Astronomical Observatory (SHAO), Chinese Academy of Sciences, Nandan Road, Shanghai 200030, China.
[7] National Astronomical Observatories, Chinese Academy of Sciences, Chaoyang District, Beijing 100012, China.

1200 line mm^{-1} grating (50 Å mm^{-1} dispersion) and a Tek 1300 × 1024 CCD were used to cover a wavelength range of 1200 Å centered at 5100 Å. Four exposures of 60 minutes each were taken. Kitt Peak National Observatory standard stars were observed for absolute flux calibration. A slit width of 2.5″ was chosen to match the seeing disk. The spectral resolution as measured from the night-sky lines was 2.75 Å at FWHM. The CCD reduction, including bias subtraction, flat-field correction, and cosmic-ray removal, was accomplished following the standard procedures using IRAF. The spectra were extracted and combined into a one-dimensional spectrum with the Galactic extinction, $E(B-V) = 0.213$ mag, corrected.

We fit the spectrum with the following model components: (1) a power-law continuum; (2) two Gaussians for the [O III] λλ4959, 5007 doublet; (3) two Lorentzians for Hβ and Hγ, respectively; and (4) the optical Fe II multiplets of Véron-Cetty et al. (2004). The redshifts and profiles of the [O III] doublet are taken to be the same, and their flux ratio is fixed to the theoretical value. We also assume that the broad components of Hβ, Hγ, and the Fe II multiplets have the same redshifts and line profiles, and the same assumption is for the narrow component of these lines.[8] The result is displayed in Figure 1. We also tried to fit the broad components of the Balmer lines with a Gaussian and found that they cannot be fitted with a single Gaussian but that two Gaussians are needed. This latter model yields a somewhat broader FWHM but a similar line strength compared to the former Lorentzian model for both the Fe II and Balmer lines.

The redshift of 2MASX J0324+3410 as determined from [O III] is $z = 0.0629 \pm 0.0001$, consistent with that of the Balmer lines within the measurement uncertainties. The Balmer line width, FWHM = 1520 km s^{-1} for a Lorentzian model and 1650 km s^{-1} for a double Gaussian model (after correction for instrumental broadening), is narrower than that of normal Seyfert 1 galaxies and quasars, but is typical of NLS1s. The line ratio of [O III] λ5007 to Hβ is $\simeq$0.12 and is almost independent of the choice of line profiles. This value indicates that the bulk of the Balmer emission lines do not originate from the narrow-line region and hence excludes the possibility that 2MASX J0324+3410 is a type 2 AGN, e.g., a NLRG, as was claimed in Marchã et al. (1996).

The optical Fe II complexes are rather strong with EW(Fe II λ4570) ~ 130 Å and $R_{4570} \equiv$ Fe II λ4570/Hβ ~ 2.0, where the Fe II blend is integrated from 4434 to 4684 Å for both broad and narrow components with larger EW(Fe II) and R_{4570} for the Lorentzian model. Remillard et al. (1993) reported a $R_{4570} = 1.54$. In summary, our optical spectrum clearly shows that 2MASX J0324+3410 is a classic NLS1.

2.2. *Broadband Properties and SED*

Radiation from 2MASX J0324+3410 was detected in a wide wavelength range across almost the whole electromagnetic spectrum. It is a strong radio source with a flux density of 304–581 mJy at 5 GHz, and it shows a flat radio spectrum up to at least 10 GHz and significant flux variations. Using simultaneous observations at 2.695, 4.75, and 10.55 GHz, Neumann et al. (1994) found a flat spectral index, $\alpha_r \simeq 0.1$ ($S_\nu \propto \nu^{\alpha}$), and detected polarization at the 3%, 5%, and 4% level, respectively. A factor of 1.3 variation (4 σ level) in its 1.4 GHz flux on timescales of 10 years was found by comparing the Green Bank 1.4 GHz Northern Sky Survey (White & Becker 1992) with the NRAO VLA Sky Survey (Condon et al. 1998).

[8] The Véron-Cetty et al. (2004) Fe II model includes forbidden Fe II lines.

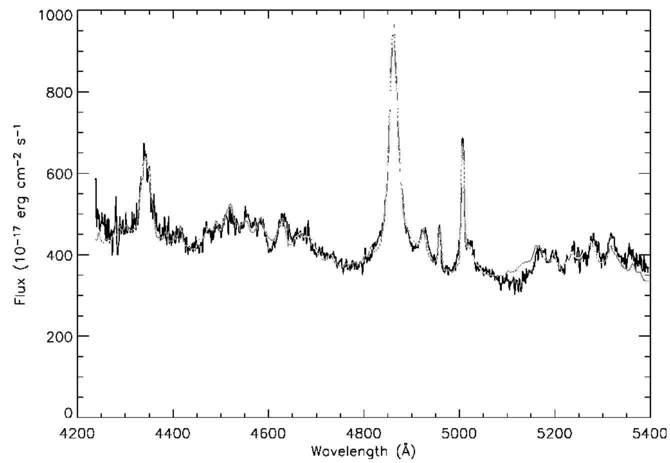

FIG. 1.—Observed spectrum of 2MASX J0324+3410 and the best-fit model (*solid line*). [*See the electronic edition of the Journal for a color version of this figure.*]

Even larger amplitude variations (a factor of 1.6 and 1.9) on shorter timescales (3.5 and 3.3 yr) were observed at 5 GHz (Neumann et al. 1994; Griffith et al. 1991; Laurent-Muehleisen et al. 1997). These variations are significant at the 3–6 σ level and cannot be attributed to source contamination as the beam sizes for observations at the higher flux states are (fortunately) smaller than those at the lower states. Assuming the flux variability is intrinsic, we can derive a lower limit on the brightness temperature of 5×10^{11} K (see Wang et al. 2006). This value is an order of magnitude higher than the equipartition value of $\sim 5 \times 10^{10}$ K (e.g., Readhead 1994) but close to the inverse Compton limit of 10^{12} K (Kellermann & Pauliny-Toth 1969).

The source was also observed by the Very Long Baseline Array (VLBA) in the VLBA calibrator survey. High-resolution images at 2.2 and 8.4 GHz reveal a core and a weak extended southwest component 6.8 mas (8.2 pc) away from the core (Beasley et al. 2002). We have reprocessed the VLBA data. The core is further resolved into the brightest component in the northeast and an extension toward the southwest, reminiscent of a core–jet structure. The brightest compact component has a deconvolved size of about 0.1 mas (0.12 pc) and a flux of 0.165 Jy at 8.4 GHz, leading to a brightness temperature of about 4×10^{11} K, consistent with the estimate from the variability analysis above. The southwest component has a steep radio spectrum and seems to have no proper motion (<0.05c; W. Yuan et al. 2007, in preparation), and therefore it is possibly a weak radio lobe.

The radio loudness of 2MASX J0324+3410 is estimated to be $R = f_{5\,\mathrm{GHz}}/f_B = 38$–71 using the *Hubble Space Telescope* (*HST*) magnitude and assuming $\alpha_{\rm opt} = 0.5$ for the nucleus. If we adopt the *Swift* UV/Optical Telescope B magnitude of 16.11, we obtain $R \simeq 89$–151, after correction for Galactic extinction. Note that the *Swift B* magnitude may include some contamination of the galactic light (see last section), so there can be a significant variation between the *Swift* and *HST* observations. Since the 5 GHz radio emission is likely subject to substantial enhancement due to the Doppler-beaming effect, we try to estimate its "intrinsic radio loudness" using a low-frequency flux, which is thought to be less affected by Doppler boosting. Assuming typical spectral indices $\alpha_r = 0.7$–1.0 for the extended radio components, we find an intrinsic radio loudness of 4–25 from a radio flux of 1.02 Jy at 151 MHz (Hales et al. 1993). This puts 2MASX J0324+3410 in the class of radio intermediate quasars. Its radio power at 178 MHz, $P_{178\,\mathrm{MHz}} \lesssim 8 \times 10^{24}$ W Hz^{-1}, as interpolated from the one at 151 MHz, is below the dividing line separating the FR II and FR I galaxy types.

X-ray emission as well as hard X-ray (and perhaps even γ-ray) flares have been detected from 2MASX J0324+3410 by various instruments. Hard X-ray emission was detected with the High Energy Detectors (2.6–60 keV) on board *HEAO-1* at three epochs over a time span of 1 year, when it showed decreasing averaged count rates from 1.25 $\pm$ 0.39 to 0.01 $\pm$ 0.26 counts s^{-1}. It was also detected in the *ROSAT* All-Sky Survey (RASS), with a 0.1–2.4 keV flux of (3.1 $\pm$ 0.5) $\times$ 10^{-12} ergs cm^{-2} s^{-1} in the observed frame and corrected for the Galactic absorption ($N_H^G = 1.45 \times 10^{21}$ cm^{-2} (Dickey & Lockman 1990). 2MASX J0324+3410 has been monitored by the All-Sky Monitor (ASM) on board the *Rossi X-Ray Timing Explorer* since 1996 June. The average ASM count rate over the last 10 years is 0.0343 $\pm$ 0.0065 counts s^{-1}, converting to a 2–10 keV flux of $F_X = 9.0 \times 10^{-12}$ ergs cm^{-2} s^{-1}. The most recent X-ray observation was done by the *Swift* X-Ray Telescope in July of 2006. The spectrum in the 0.3–10 keV band can be well fitted with a power law of a photon index 2.02 $\pm$ 0.06 with Galactic absorption. X-ray flux variations of up to a factor of 2 on timescales of less than 1 ks have been detected in the *Swift* data. The average flux in the 0.2–2.4 keV band was 3 times brighter than that measured in the RASS. Of particular interest, a TeV flare was claimed to be marginally detected at a significance level of ~2.5–3.3 σ on 2001 October 10 with a peak rate of 0.62 $\pm$ 0.19 crab (Falcone et al. 2004).

The broadband spectral energy distribution (SED) for the nucleus of 2MASX J0324+3410 is plotted in Figure 2, using the results of our own data as well as data collected through the HEASARC Web browser. For comparison, the SED for I Zw 1 and Mrk 421—a well-known NLS1 and blazar, respectively—are overplotted. It can be seen that 2MASX J0324+3410 resembles Mrk 421 in terms of the broadband, nonthermal continuum in the radio and possibly X-ray bands, whereas it resembles I Zw 1 in the infrared-optical regime where thermal emission is dominant.

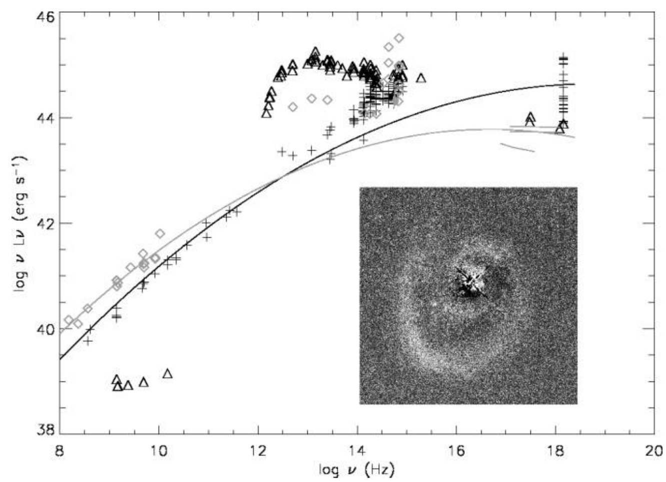

FIG. 2.—Broadband SED of 2MASX J0324+3410 (*diamonds*). A typical NLS1, I Zw 1 (*black triangles*), and a typical TeV blazar, Mrk 421 (*crosses*), are also plotted for comparison. The second-order polynomial (parabolic) fit of the radio and X-ray data of 2MASX J0324+3410 and that of the radio, IR, and X-ray data of Mrk 421 are shown as dashed and dotted lines, respectively. Data apart from those described in the text were retrieved from the HEASARC browser server (http://heasarc.gsfc.nasa.gov/db-perl/W3Browse/w3browse.pl). *Inset*: Residual image after subtraction of the best-fit model of a point source plus a Sérsic component from the *HST* WFPC image. The similarity to a one-armed spiral-like structure can be clearly seen. [*See the electronic edition of the Journal for a color version of this figure.*]

2.3. *The Host Galaxy: A One-armed Spiral?*

Two snapshot images of 2MASX J0324+3410, each of 200 s exposure, were taken with the Wide Field Planetary Camera 2 (WFPC2) on the *HST* with the F702W filter ($\lambda_{eff} = 6919$ Å). The data were retrieved from the *HST* archive. The two exposures were combined to create a single image with a better signal-to-noise ratio. A ringlike structure of ~15″ diameter can be clearly seen, which corresponds to ~15.6 kpc at redshift 0.0629. A nuclear source with high surface brightness is apparently displaced from the symmetric center of the host galaxy. The surface brightness profile of the galaxy can be decomposed into two components: an unresolved pointlike source as the NLS1 nucleus, and a Sérsic model for the host galaxy (detailed analysis is to be presented in a later paper). We find $m_{NLS1,\,F702} = 15.15$ mag for the active nucleus and $m_{bulge,\,F702} = 15.22$ mag for the host galaxy. After correcting for the Galactic extinction, $E(B-V) = 0.213$ mag, we get $m_{NLS1,\,F702} \approx 14.70$ mag. The residual looks like a one-armed spiral (see Fig. 1).

3. DISCUSSION: A NLS1-BLAZER COMPOSITE

The spectral and temporal properties of 2MASX J0324+3410 in the radio and X-ray bands, as presented in § 2.2, are characteristic of blazars: a flat radio spectrum and flux variability, a compact and bright radio core on a milliarcsecond scale, hard X-ray emission and flares, short timescale variations in X-rays, and a broadband, nonthermal continuum. In particular, its SED and possible TeV γ-ray emission resemble those of a high-energy–peaked blazar (HBL). On the other hand, its optical properties fulfill all criteria for classification as a NLS1. These observational facts thus make 2MASX J0324+3410 a composite of a NLS1 and a blazar. We note that the rest-frame Hβ equivalent width EW(Hβ) = 58 $\pm$ 4 Å is only slightly below the median value ($\simeq$80 Å) for a large sample of NLS1s (Zhou et al. 2006); i.e., the contribution from a potential nonthermal continuum is small in the optical. If the X-ray–to–optical spectral slope is similar to that of I Zw 1 for the NLS1 component, the NLS1 accounts for only $\sim\frac{1}{3}$ of the observed X-ray emission, which also has a flat spectrum compared with other NLS1s. Its radio and, most likely, X-ray radiation can be naturally explained as being from a jet (via synchrotron emission), while the infrared and optical light is dominated by thermal emission from a Seyfert nucleus.

We estimate the central black hole (BH) mass using a few methods. Using the width and luminosity of the Hβ line and the empirical scaling relations as in Greene & Ho (2005), we find a BH mass of $10^7\ M_\odot$. While the empirical relations of Vestergaard & Peterson (2006) give BH masses of $3 \times 10^7\ M_\odot$ using the continuum luminosity at 5100 Å and $1.8 \times 10^7\ M_\odot$ using the Hβ luminosity. These BH mass estimates are consistent within their uncertainties, giving $M_{BH} \sim 10^7\ M_\odot$. Interestingly, this value falls into the overlapping region in the BH mass distributions for NLS1s and blazars, which have the bulk lying within 10^6–$10^7\ M_\odot$ (e.g., Wang & Lu 2001; Grupe & Mathur 2004; Zhou et al. 2006) and 10^7–$10^9\ M_\odot$ (e.g., Woo et al. 2005; Falomo et al. 2002), respectively.

We estimate the bolometric luminosity from the 5100 Å luminosity using the correction factor for quasars given by Elvis et al. (1994). This gives $L_{bol} \approx 1.2 \times 10^{45}$ ergs s^{-1}. We thus obtain a rough estimate of the Eddington ratio $\dot{m} \equiv L_{bol}/L_{Edd} \approx 0.1$ for 2MASX J0324+3410. The Eddington ratio is typical of NLS1s and resembles that for flat-spectrum radio quasars as far as its blazar property is concerned; however, the SED of its jet emission is more like HBLs, which have, on the contrary, generally low accretion rates. The one-armed spiral may provide such fueling to the active nucleus, although it cannot be completely ruled out that the *HST* image we see is a structure made up by dust lanes or even a ring galaxy.

2MASX J0324+3410 is not unique but is the most representative object of its kind, which seems to be rare. The optical spectrum of the BL Lac object 0846+51W1 showed typical NLS1 characteristics at low states (Zhou et al. 2005). The radio-to-optical SED of the radio-loud NLS1 J094857.3+002225, for which beaming is required to explain the high brightness temperature, is also similar to that of 2MASX J0324+3410 (Zhou et al. 2003; also Doi et al. 2006). A third example is RX J16290+4007 (Zhou & Wang 2002; see also Komossa et al. 2006b), a flat-spectrum radio quasar with NLS1 characteristics in the optical. Furthermore, eight out of the nine VRL ($R_{1.4} \equiv f_{1.4\,\mathrm{GHz}}/f_B \gtrsim 250$) NLS1s currently under study (H.-Y. Zhou et al. 2007, in preparation) show flat radio spectra, $\alpha_{1.4\text{–}5\,\mathrm{GHz}} \lesssim 0.5, f_\nu \propto \nu^{-\alpha}$, which is remarkable. Thus, it is probably true that most VRL NLS1s are actually radio intermediate (RI) NLS1s with boosted jet emission. If so, they are similar to a population of boosted RI quasars recently identified by Wang et al. (2006) from their high radio brightness temperature, but with more extreme optical properties. They may be an analog to the radio-bright, very high soft states in black hole binaries (e.g., Fender et al. 2004).

The hybrid state of 2MASX J0324+3410 raises questions concerning our current understanding of TeV/high-energy–peaked blazars. It is widely accepted that this type of blazar has a very low accretion rate, but 2MASX J0324+3410 is doubtlessly an exception. A common notion is that the intensive radiation field of the accretion disk prevents electrons from gaining the high energies that are required for TeV γ-ray production or for the formation of high-frequency synchrotron peaks in the SED. This is certainly not the case for 2MASX J0324+3410.

We thank Jianyan Wei and Jing Wang for help in our spectroscopic observations and Dirk Grupe and Binbin Zhang for help in the analysis of the *Swift* data. This work was supported by the Chinese NSF through grants NSF10233030, NSF10533050, and NSF10473013 and by the Bairen Project of the Chinese Academy of Sciences. D. Xu acknowledges the Chinese NSF support through grant NSFC10503005. This Letter has made use of data from the NASA/IPAC Extragalactic Database.

REFERENCES

Beasley, A. J., Gordon, D., Peck, A. B., Petrov, L., MacMillan, D. S., Fomalont, E. B., & Ma, C. 2002, ApJS, 141, 13
Boller, T., Brandt, W. N., & Fink, H. 1996, A&A, 305, 53
Boroson, T. A. 2002, ApJ, 565, 78
Boroson, T. A., & Green, R. F. 1992, ApJS, 80, 109
Condon, J. J., Cotton, W. D., Greisen, E. W., Yin, Q. F., Perley, R. A., Taylor, G. B., & Broderick, J. J. 1998, AJ, 115, 1693
Dickey, J. M., & Lockman, F. J. 1990, ARA&A, 28, 215
Doi, A., Nagai, H., Asada, K., Kameno, S., Wajima, K., & Inoue, M. 2006, PASJ, 58, 829
Elvis, M., et al. 1994, ApJS, 95, 1
Falcone, A. D., et al. 2004, ApJ, 613, 710
Falomo, R., Kotilainen, J. K., & Treves, A. 2002, ApJ, 569, L35
Fender, R. P., Belloni, T. M., & Gallo, E. 2004, MNRAS, 355, 1105
Greene, J. E., & Ho, L. C. 2005, ApJ, 630, 122
Griffith, M., Heflin, M., Conner, S., Burke, B., & Langston, G. 1991, ApJS, 75, 801
Grupe, D., Beuermann, K., Mannheim, K., & Thomas, H.-C. 1999, A&A, 350, 805
Grupe, D., Beuermann, K., Thomas, H.-C., Mannheim, K., & Fink, H. H. 1998, A&A, 330, 25
Grupe, D., Leighly, K. M., Thomas, H.-C., & Laurent-Muehleisen, S. A. 2000, A&A, 356, 11
Grupe, D., & Mathur, S. 2004, ApJ, 606, L41
Hales, S. E. G., Baldwin, J. E., & Warner, P. J. 1993, MNRAS, 263, 25
Kellermann, K. I., & Pauliny-Toth, I. I. K. 1969, ApJ, 155, L71
Komossa, S., & Meerschweinchen, J. 2000, A&A, 354, 411
Komossa, S., Voges, W., Adorf, H.-M., Xu, D., Mathur, S., & Anderson, S. F. 2006a, ApJ, 639, 710
Komossa, S., Voges, W., Xu, D., Mathur, S., Adorf, H.-M., Lemson, G., Duschl, W. J., & Grupe, D. 2006b, AJ, 132, 531
Laurent-Muehleisen, S. A., Kollgaard, R. I., Ryan, P. J., Feigelson, E. D., Brinkmann, W., & Siebert, J. 1997, A&AS, 122, 235
Leighly, K. M. 1999, ApJS, 125, 297
Leighly, K. M., & Moore, J. R. 2004, ApJ, 611, 107
Marchã, M. J. M., Browne, I. W. A., Impey, C. D., & Smith, P. S. 1996, MNRAS, 281, 425
Neumann, M., Reich, W., Fuerst, E., Brinkmann, W., Reich, P., Siebert, J., Wielebinski, R., & Trümper, J. 1994, A&AS, 106, 303
Osterbrock, D. E., & Pogge, R. W. 1985, ApJ, 297, 166
Readhead, A. C. S. 1994, ApJ, 426, 51
Remillard, R. A., Bradt, H. V. D., Brissenden, R. J. V., Buckley, D. A. H., Roberts, W., Schwartz, D. A., Stroozas, B. A., & Tuohy, I. R. 1993, AJ, 105, 2079
Sulentic, J. W., Zwitter, T., Marziani, P., & Dultzin-Hacyan, D. 2000, ApJ, 536, L5
Urry, C. M., & Padovani, P. 1995, PASP, 107, 803
Véron-Cetty, M.-P., Joly, M., & Véron, P. 2004, A&A, 417, 515
Véron-Cetty, M.-P., Véron, P., & Gonçalves, A. C. 2001, A&A, 372, 730
Vestergaard, M., & Peterson, B. M. 2006, ApJ, 641, 689
Wang, T., Brinkmann, W., & Bergeron, J. 1996, A&A, 309, 81
Wang, T., & Lu, Y. 2001, A&A, 377, 52
Wang, T.-G., Zhou, H.-Y., Wang, J.-X., Lu, Y.-J., & Lu, Y. 2006, ApJ, 645, 856
White, R. L., & Becker, R. H. 1992, ApJS, 79, 331
Woo, J.-H., Urry, C. M., van der Marel, R. P., Lira, P., & Maza, J. 2005, ApJ, 631, 762
Zhou, H.-Y., & Wang, T.-G. 2002, Chinese J. Astron. Astrophys., 2, 501
Zhou, H.-Y., Wang, T.-G., Dong, X.-B., Li, C., & Zhang, X.-G. 2005, Chinese J. Astron. Astrophys., 5, 41
Zhou, H.-Y., Wang, T.-G., Dong, X.-B., Zhou, Y.-Y., & Li, C. 2003, ApJ, 584, 147
Zhou, H.-Y., Wang, T.-G., Yuan, W., Lu, H.-L., Dong, X.-B., Wang, J.-X., & Lu, Y.-J. 2006, ApJS, 166, 128