LOW RADIOACTIVE EFFICIENCY ACCRETION AT WORK IN ACTIVE GALACTIC NUCLEI: THE NUCLEAR SPECTRAL ENERGY DISTRIBUTION OF NGC 4565

M. Chiaberge
Space Telescope Science Institute, 3700 San Martin Dr., Baltimore, MD 21218

R. Gilli
INAF - Osservatorio astronomico di Bologna, Via Ranzani 1, 40127 Bologna, Italy

F. D. Macchetto
Space Telescope Science Institute, 3700 San Martin Dr., Baltimore, MD 21218

AND

William B. Sparks
Space Telescope Science Institute, 3700 San Martin Dr., Baltimore, MD 21218

Submitted to ApJ

ABSTRACT

We derive the spectral energy distribution (SED) of the nucleus of the Seyfert galaxy NGC 4565. The nuclear source is substantially unabsorbed. The absorption we find from Chandra data is $N_H = 2.5 \times 10^{21}$ cm$^{-2}$ is consistent with that produced by material in the galactic disk of the host galaxy. HST images show a nuclear unresolved source in all of the available observations, from the near-IR H band to the optical U band. The SED is completely different from all other Seyfert galaxies, as it appears basically “flat” in the IR-optical region, with a small drop-off in the U-band. The extremely low Eddington ratio $L_o/L_{Edd}$ and the location of the object in diagnostic planes for low luminosity AGNs indicate that the radiation we observe is most likely produced in a radiative inefficient accretion disk. This would make NGC 4565 the first AGN in which an ADAF-like process is directly observed in the optical. We find that the relatively high [OIII] flux observed from the ground cannot be all produced in the nucleus. Therefore, an extended NLR must exist in this object. This may imply that the nuclear source has recently “turned-off”, switching from a high-efficiency accretion regime to the present low-efficiency state.

Subject headings: galaxies: active — galaxies: nuclei — accretion, accretion disks — galaxies: individual (NGC 4565)

1. INTRODUCTION

Low luminosity active galactic nuclei (LLAGN) are believed to be powered by accretion of matter onto the central supermassive black hole, similarly to powerful AGN. In a large fraction of LLAGN, the central black hole is as massive as powerful distant quasars ($M_{BH} \approx 10^6 - 10^9 M_\odot$), thus their very low nuclear luminosity implies that accretion occurs with very low radiative efficiency (or at very low rates; see e.g. Ho 2004; Chiaberge et al. 2005). If so, the physics of the accretion process may be different from the “standard” optically thick, geometrically thin accretion disks. Starting from the “ion-supported tori” of Rees et al. (1982), a number of theoretical models have been developed to describe such low-efficiency accretion processes (e.g. advection-dominated accretion flows, ADAF, advection-dominated inflow-outflow solutions, ADIOS, convection-dominated accretion flows, CDAD Narayan & Yi 1994 Quataert & Narayan 1995 Abramowicz et al. 2002). However, because of the very low radiation they emit at all wavelengths, these objects (if they at all exist) are very difficult to be observed. Such models have been applied to several sources belonging to different classes, such as low-luminosity radio galaxies, “normal” ellipticals, the Galactic center Sagittarius A (e.g. Quataert & Narayan 1995; Di Matteo et al. 2006). However, for most of these objects, the models cannot be properly constrained, mostly because the nuclear radiation is swamped by other processes. This is particularly problematic in the optical band, which appears to be crucial to fix the models, where the stellar emission from the host galaxy is substantial. Furthermore, in low luminosity radio galaxies non-thermal emission from the jet dominates the nuclear radiation (Chiaberge et al. 1999), and the Galactic center is not visible in the optical because it is hidden by a large amount of dust extinction.

Therefore, neither of the above mentioned classes of objects appear to be suitable laboratories to test models of low-efficiency accretion through the analysis of their overall SED. Recently, among LLAGN which show very low Eddington ratios $L_{bol}/L_{Edd} << 10^{-3}$, Chiaberge et al. 2003 have found that a class of LLAGN, mainly composed by LINERs and low-luminosity Seyfert 1 galaxies, show faint optical unre-
solved nuclei detected in HST images that may be interpreted as direct radiation from a very low efficiency accretion flow. In fact, when the radio-optical properties of LLAGN are considered, Seyfert, LINERS and low luminosity radio galaxies separate into different regions of diagnostic planes, according to the properties of their nuclei. If this interpretation is correct, the only possibility of detecting radiation from an ADAF-like process is to look in unobscured Seyferts of lowest luminosity as well as in a sub-class of LINERS. In all other objects other radiation processes dominate.

In this paper we present an objects that seems to be a perfect candidate for this kind of studies. We analyze the spectral energy distribution (SED) of NGC 4565, a nearby (d=9.7 Mpc) LLAGN classified as a Seyfert 1.9 because of the possible presence of a faint, relatively broad (FWHM = 1750 km s$^{-1}$) $\text{H}\alpha$ line. However, as Ho et al. [1997b] have pointed out, the detection of a broad component is highly uncertain. As we show in the following, although it is a Type 2 Seyfert, this object is only moderately unabsorbed, and the nuclear radiation is visible in the optical spectral region. NGC 4565 may thus represent the first clear example of low-luminosity accretion onto a supermassive black hole detected in the optical band.

In SS2 we describe the Chandra and HST observations, the data analysis procedures and flux measurements, in SS3 we present the results, we derive the spectral energy distribution and we discuss its interpretation. In SS4 we give a summary of our findings and we draw conclusions.

2. OBSERVATIONS AND DATA ANALYSIS

We use X-ray data taken with Chandra satellite, and IR through optical HST images. In the following we describe the data and the analysis procedures.

2.1. Chandra data

A 60 ksec ACIS-S observation of NGC 4565 (performed in 2003, PI D. Wang) is publicly available in the Chandra archive. We retrieve the Chandra data and analyze them using standard CIAO 3.2.2 procedures, applying the latest calibration files in the CALDB 3.1.0 database. The X-ray image reveals a wealth of pointlike sources, many of which located along the NGC 4565 disk. The two brightest sources correspond to an off-nuclear source at ~50 arcsec from the nucleus, and to the nucleus itself (see also the XMM image in Foschini et al. [2002]).

To avoid contamination from faint nearby X-ray sources, the 0.4–7 keV nuclear spectrum is extracted in a circular aperture of 6 pixel radius (~3 arcsec, corresponding to an encircled energy fraction of >97% at 1.5 keV). The background is evaluated in a large annulus around the nucleus. Faint X-ray sources are not masked out from the background region, since their presence has a negligible impact on our results (the total background flux including faint sources is less than 1% of the nuclear flux). Given the moderate nuclear count rate (0.036 counts/sec), X-ray photon pileup is under control ($\lesssim 4\%$).

Spectral analysis is carried out with XSPEC v11.3.1, with the column density of our Galaxy fixed to $1.3 \times 10^{20}$ cm$^{-2}$ [Dickey & Lockman 1990]. The spectrum is rebinned to have at least 20 photons per bin to allow use of the $\chi^2$ statistics, errors are quoted at the 90% c.l. for one interesting parameter. We find that an absorbed power law model provides a very good description of the data ($\chi^2$/dof = 51/81), the best fit photon index and column density being $\Gamma = 1.91^{+0.22}_{-0.19}$ and $N_H = 2.5 \pm 0.6 \times 10^{21}$ cm$^{-2}$, respectively. The observed source fluxes in the 0.5–2 keV and 2–10 keV band are $9.0 \times 10^{-14}$ erg cm$^{-2}$ s$^{-1}$ and $2.1 \times 10^{-13}$ erg cm$^{-2}$ s$^{-1}$, respectively. When corrected for absorption, these correspond to intrinsic nuclear luminosities of $1.9 \times 10^{39}$ erg s$^{-1}$ and $2.5 \times 10^{39}$ erg s$^{-1}$ in the soft and hard band, respectively. We note that the derived X-ray spectral parameters, fluxes and luminosities are in good agreement with those measured in a 14 ksec XMM-Newton observation performed in 2001 (Cappi et al. [2005]).

2.2. HST data

HST data are available in the MAST archive at STScI from the near IR to the optical U-band. Images were taken as part of different programs, with the following instruments and filters: NICMOS (F160W), WFPC2 (F814W, F555W, F450W), ACS/HRC (F330W). These filters approximate the H,I,V,B and U bands in the HST system. The images are processed with the standard on-the-fly reprocessing calibration pipeline (see Pavlovsky 2003).

The optical images show the bulge of the galaxy partially covered by a prominent dust lane or disk seen almost edge-on (Fig. 1). The inclination of the “disk” is such that the central region of the bulge is not covered by a large amount of dust, and a faint nuclear compact source (to which we refer as the nucleus) is visible in all images.

2.2.1. Nuclear photometry

In the U-band, the emission from the bulge stars is low, and the nucleus is the by far the brightest source in the field of view of the ACS/HRC (Fig. 3). Photometry of the nucleus is thus straightforward in the U-band, also thanks to the higher resolution, smaller projected pixel-size of the HRC. In the IR (NICMOS) and optical I,V and B band WFPC2 images (the target is always located in one of the WF cameras) the contrast with the underlying stellar background is low thus the measure the nuclear flux is more problematic. For the photometry of nuclear unresolved sources superimposed to the stellar emission of the host galaxy, we undertake two different approaches, as described in the following.

### Table 1: Nuclear fluxes from HST observations

| Instrument/Filter | $T_{exp}$ [s] | Program ID | Wavelength [Å] | $F_{\lambda}$ |
|-------------------|---------------|------------|----------------|--------------|
| ACS-HRC/F330W     | 1200          | 9379       | 3367           | 8.1          |
| WFPC2/F450W       | 600           | 6092       | 4575           | 18           |
| WFPC2/F555W       | 320           | 6685       | 5468           | 21           |
| WFPC2/F814W       | 480           | 6092       | 8023           | 11           |
| NICMOS/F160W      | 384           | 7331       | 16074          | 5.9          |

Note: Fluxes (in units of $10^{-17}$ erg cm$^{-2}$ s$^{-1}$ Å$^{-1}$) have been corrected for local extinction using $N_H = 2.5 \times 10^{20}$ cm$^{-2}$ and standard $A_V/N_H = 5 \times 10^{-22}$ ratio.
1) Aperture photometry with the IRAF task radprof, measuring the background close to the unresolved nucleus, at a distance of \( \sim 0.4'' \) from the center of the point source, and setting the aperture radius at the same distance. Note that the “background” here is the stellar emission of the galaxy in the vicinity of the nucleus. Therefore, this approach works well for nuclei in elliptical galaxies with flat radial brightness profiles, i.e. Nuker-law “core” galaxies (Faber et al. 1997) which have a flat \((\gamma < 0.3, \Sigma \propto \rho^{-\gamma})\), where \( \Sigma \) is the surface brightness) slope in the inner region (see also the discussion in Balmaverde & Capetti 2005). Clearly, this is because in this case the “background” measured at a distance of \( \sim 0.4'' \) is a good estimate of the stellar emission at the center of the nucleus. On the other hand, for both “power-law” ellipticals and spirals bulges, the profile in the innermost regions (i.e. in the central 1-2 arcsec) is significantly steeper \((\gamma \sim 0.8)\). In this latter case, the measurement and even the identification of faint nuclei is more difficult, because a “peaked” brightness profile of the bulge may hamper the detection of the central emission from the AGN. Furthermore, for the IR images, which have a lower angular resolution, the background cannot be measured close enough to the center of the nucleus, and thus may be significantly underestimated. We find that this would lead to overestimate the nuclear flux by a factor as large as \( \sim 5 \). Thus, while we used this method to measure the nuclear flux in the F330W image (aperture correction was taken into account, following the prescriptions given in Siriani et al. 2005), this method is unviable for the WFPC2 and NICMOS images.

2) An alternative approach consists in deriving the radial brightness profile of the bulge, and measure any nuclear excess. Multiple component models are often used to reproduce the central regions of galaxies and measure the flux of nuclear sources (see e.g. the discussion in Quillen et al. 2001). But since here we are not interested in modeling the galaxy bulge on large scales, we only derive the radial brightness profile in the central \( \sim 2 \) arcsec. Then we produce a model galaxy with the same slope as observed in the region \( R > 0.2 \) arcsec and we assume that the profile can be extrapolated to the center of the bulge, all the way to \( R = 0 \). As shown in Fig. 5 (solid line), the effect of the finite resolution of HST \((\sim 0.1 \) arcsec) produces a flattening of the observed profile, at a distance of \( \sim 0.15 \) arcsec. The observed profile, obtained by fitting ellipses to the galaxy image using the IRAF task ellipse, shows a significant excess (filled circles). We produce synthetic PSFs using the TinyTim software (Krist 1995), which, for WFPC2, produces an accurate representation of the central region of the PSF, thus appropriate for our purpose. We align the synthetic PSF’s with the position of the nucleus, we multiply the PSF image by an appropriate constant \( K \) and we subtract the two images. We change the value of \( K \) until the profile of the nuclear regions do not produce a “hole” at the center of the galaxy. The obtained profile is shown in Fig. 3 as the empty circles. To convert the flux of the nucleus from counts to physical units, we multiply the count rate \((CR = K/t_{exp})\) by the keyword PHOTFLAM in the image header (for NICMOS \( CR = K \)).

It is not straightforward to estimate the error on the flux measurements obtained using method 2. After subtracting synthetic PSFs with different total counts and compare the resulting profiles with our model profile, we believe that our optical and IR fluxes are accurate to better than \( \sim 20\% \), while the error on the F330W flux (obtained with method 1) is 7\%. A summary of the photometry is given in Table 1.

The F450W and F555W filter pass bands include relatively strong emission lines (mainly [OIII]5007 and H\( \beta \)). However, since the pass bands are \( \sim 1000 \)\AA\ wide, the observed flux is likely to be dominated by continuum emission (see also Sect. 3).

Since the near-IR and the U-band images were not taken simultaneously to the optical data, the SED may be affected by variability. We checked for variability of the nuclear source in the optical (F814W, F555W, F450W), for which two sets of observations with the same filters, taken at a distance of \( \sim 1 \) year, are available. The nuclear fluxes are consistent within the errors, thus no variability is found between the 2 observations.

### 3. RESULTS AND DISCUSSION

#### 3.1. The nuclear SED of NGC 4565

The nuclear spectral energy distribution is shown in Fig. 6. The HST data are de-reddened using \( N_H = 2.5 \times 10^{21} \text{cm}^{-2} \), which converts to \( A_V = 1.25 \), assuming Galactic gas-to-dust ratio. Although in AGN the gas-to-dust ratio may differ from the local value, we believe that this choice is justified in the case of NGC 4565. As it is clear from the large field of view image of the galaxy (Fig. 1), this is a spiral seen almost edge on. Therefore, it is reasonable to assume that a significant amount of dust and gas in the disk of the galaxy project on our line-of-sight to the nucleus.

Assuming a circular geometry, from the observed ellipticity of the disk in the image we find that the orientation...
of the disk is likely not to exceed $\sim 10^\circ$. For comparison, we can check the absorption we find in our Galaxy for $10^\circ$ Galactic Latitude. We obtain $A_V \sim 1.0 - 1.5$, where the lower value is found for Galactic longitude $\sim 180^\circ$, the higher value is for $\sim 0^\circ$ (from NED). These values may actually increase substantially if we observe the same Galactic Latitude from the Galaxy center. This simple check shows that the absorption we measure in the X-rays is compatible with that provided by galactic dust in the disk. This supports our hypothesis that the moderate absorption observed to the nucleus of NGC 4565 is not produced locally, in the vicinity of the nucleus. In this case, Galactic dust-to-gas ratio may be used to convert $N_H$ derived from the X-rays to optical $A_V$.

The nuclear SED appears basically flat ($\alpha \sim 1$, $F_\nu \propto \nu^{-\alpha}$) from the 1.6$\mu$m to 4500 Å, with possibly a small peak between 5000 and 4500 Å and a small drop-off in the U-band. This peak may be real, or due to a possible contamination from emission lines (mainly [OIII] and H$\beta$) that fall in the F555W and F450W filters pass bands. Unfortunately, since neither images with narrowband filter nor nuclear spectra are available to date, a certain ambiguity persists. However, all other filters are free from strong lines, thus the intrinsic SED cannot be dramatically different from what we show here. Whatever the nature of such a small peak, it is clear that neither a significant UV bump nor IR thermal emission from hot dust, which are characteristic of AGNs, are visible in NGC 4565. Furthermore, note that the luminosity in the X-ray is not higher than in the optical, even after...
are observing synchrotron emission in both bands (if \( \log(L_{\nu}/L_{\text{opt}}) \sim 3 \)), or in the optical we have some kind of excess radiation which, in the case of unabsorbed Seyferts is most likely interpreted as radiation from the accretion process. Furthermore, when the optical luminosity to Eddington luminosity ratio \( L_o/L_{Edd} \) is plotted against the nuclear radio loudness (Fig. 6 different classes of LLAGNs nicely separate into three different regions of the diagram. Seyfert nuclei with relatively high accretion efficiency objects occupy the top-left part of the diagram (\( L_o/L_{Edd} \sim 10^{-2} - 10^{-3} \) and \( \log(L_{\nu}/L_{\text{opt}}) \sim 1 \)); LINERs separate into two subclasses, which we named according to their nuclear radio-optical ratio as “radio-quiet” LINERs (bottom-left side, \( L_o/L_{Edd} < 10^{-4} \) and \( \log(L_{\nu}/L_{\text{opt}}) \sim 1 \), and “radio-loud” LINERs (bottom-right); radio galaxies (bottom-right part of the diagram) have the same Eddington ratio as for radio-quiet LINERs, but a much higher \( \log(L_{\nu}/L_{\text{opt}}) \). Note that in the plane of Fig. 6 the objects in which we observe an extra-component in the optical, in excess of synchrotron emission, are those that lie on the left side. Therefore, those are the objects in which emission from the accretion process can be detected.

Let us explore how this applies to NGC 4565. First of all, we calculate the ratio between the nuclear radio flux and the optical flux. Nagar et al. (2005) measured a radio core flux of 3.2 mJy, which implies that \( \log(L_{\nu}/L_{\text{opt}}) = 1.6 \). Therefore, NGC 4565 has an excess in the optical of at least 2 dex with respect to the expected synchrotron emission (i.e. the optical counterpart of the radio core should be \( > 2 \) dex fainter than the measured optical flux, unless the radio-to-optical spectral index has unreasonable values for synchrotron radiation). Thus it is reasonable to interpret the optical nucleus as radiation from the accretion process. In this case, assuming a central black hole mass of \( 2.8 \times 10^7 M_\odot \), as derived from the M-\( \sigma \) relation of Tremaine et al. (2002) and using \( \sigma \) value from the LEDA database, the resulting Eddington ratio \( L_o/L_{Edd} \) is extremely low, \( 2 \times 10^{-6} \). It is important to note that in the case of “typical” Seyferts, which show a blue bump, a significant bolometric correction is needed (however, this should not exceed a factor of \( \sim 15 \)). For NGC 4565 a big blue bump is clearly not present, thus our value of \( L_{\text{opt}} \) is a good estimate of \( L_{bol} \).

In the diagnostic diagram of Fig. 6, NGC 4565 lies in the lower-right quadrant, among “radio-quiet” LINERs (the other two Seyferts in the same region of the plot are M 81 and NGC 4639, as discussed in Chiaberge et al. 2003). In order to reconcile NGC 4565 with other Seyferts, which are confined in the top-left quadrant, the central black hole mass would have to be at least a factor of \( \sim 100 \) lower. This would substantially violate the \( M_{BH} - \sigma \) relation. We conclude that the nucleus of NGC 4565 is a very low-efficiency accretion object and that we are observing the accretion process directly in the optical. This is extremely important since models of advection-dominated accretion flows are particularly sensitive to the optical-UV spectral region. For example, as shown by Quataert & Narayan (1999) the presence of winds in the disk can dramatically change the shape of the observed SED in the range of frequencies between \( \nu \sim 10^{13} \) Hz and \( \nu \sim 10^{15} \) Hz.

\[ \text{http://leda.univ-lyon1.fr/} \]
A similar study of the nuclear emission has been performed by Moran et al. (1999) for NGC 4395, “the least luminous Seyfert 1”. In that case, the nuclear luminosity is even lower than in NGC 4565, but the central black hole mass in NGC 4395 is dramatically lower. A recent estimate based on reverberation mapping gives a value of $M_{BH} = 3.6 \times 10^5 M_{\odot}$ (Peterson et al. 2003). Such a low black hole mass implies $L_{bol}/L_{Edd} \sim 10^{-3}$ or higher if, as Moran et al. (1999) point out, intrinsic nuclear absorption is present. This seems in fact to be the case since $M_{BH} = 3.6 \times 10^5 M_{\odot}$ (Peterson et al. 2003) obtain $N_H \sim 10^{22}$ cm$^{-2}$ analyzing Chandra data, although most of the absorption might be produced by ionized gas. Therefore, although it is clear that even if NGC 4395 displays peculiar characteristics, its Eddington ratio is not different from the average of low luminosity Seyferts in the Palomar and CFA samples (Chiaberge et al. 2003). Instead, NGC 4565 has completely different physical properties, as appears from its extremely low value of the Eddington ratio, and it is a perfect candidate for hosting a radiative inefficient accretion process.

3.3. Where is the narrow line region in NGC 4565?

One further implication of the observations we present here is worth mentioning. The flux of the [OIII] emissi
tion line, as measured from the ground with a 2" beam size (Ho et al. 1997a), and the diagnostic line ratios are typical of Seyfert galaxies. However, if we assume that all of the [OIII] flux is produced in the unresolved nucleus, this would result in a count rate higher by factor of 5 and 20 than we measure in the nucleus in the F555W and F450W, respectively. This implies that the narrow emission line region (NLR) must be extended. It is particularly interesting to investigate the properties of the NLR relatively to the nuclear properties, since it is usually assumed that radiative inefficient accretion cannot provide a sufficient photon field to ionize the surrounding medium and create the NLR. If this is true, it is possible that NGC 4565 may have recently transitioned from a relatively high-efficiency accretion state (as in “normal” Seyferts) to a very low-efficiency accretion process. This might also reconcile its classification as Seyfert with the fact that its nucleus is located among LINERs in the plane of Fig. 4. The spectral classification is in fact based on the large-scale properties of the emission-line gas, that may still be powered by a higher radiation field (possibly having also a different spectral shape), because of light travel time effects. Clearly, high spatial-resolution images with narrow band filters, and nuclear spectra, can provide further information to understand the recent history of the nucleus of NGC 4565.

4. SUMMARY AND CONCLUSIONS

We have derived the spectral energy distribution of a peculiar low-luminosity Seyfert 2 galaxy which basically shows no local nuclear absorption. The SED is peculiar, as it is almost flat in a $\log \nu - \log (\nu \lambda F_{\nu})$ representation, with no sign of both a UV bump and thermally reprocessed IR emission. The very low luminosity of the source associated with a relatively high central black hole mass imply an extremely small value of the Eddington ratio ($L_{bol}/L_{Edd} \sim 10^{-6}$). This, together with the position occupied by this object on diagnostic planes for low luminosity AGN, represents clear evidence for a low radiative efficiency accretion process at work in the innermost regions of NGC 4565. The direct detection of optical emission from such radiative inefficient processes is particularly important for providing constraints to ADAF models or similar. The fact that the [OIII] emission line flux is substantial in this object implies that an extended narrow line region, similar to other Seyfert galaxies, is still present in NGC 4565. A possible intriguing scenario is that the active nucleus has recently “turned-off”, switching from a high efficiency, standard, accretion disk, to a radiative inefficient accretion process.

We acknowledge Dave Axon, Alessandro Capetti and Alice Quillen for stimulating conversations and useful comments. RG acknowledges support from the STScI Visitor Program.

This research has made use of the NASA/IPAC Extragalactic Database (NED) which is operated by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

Facilities: HST, Chandra.

REFERENCES

Abramowicz, M. A., Igumenshchev, I. V., Quataert, E., & Narayan, R. 2002, ApJ, 565, 1101
Balmain, B., & Capetti, A. 2005, A&A Submitted
Campi, M., et al., 2005, ArXiv Astrophysics e-prints astro-ph/0505584
Chiaberge, M., Capetti, A., & Celotti, A. 1999, A&A, 349, 77
Chiaberge, M., Capetti, A., & Macchetto, F. D. 2005, ApJ, 625, 716
Di Matteo, T., Allen, S. W., Fabian, A. C., Wilson, A. S., & Young, A. J. 2003, ApJ, 582, 133
Di Matteo, T., Quataert, E., Allen, S. W., Narayan, R., & Fabian, A. C. 2000, MNRAS, 311, 507
Dickey, J. M., & Lockman, F. J. 1990, ARA&A, 28, 215
Faber, S. M., et al. 1997, AJ, 114, 1771
Foschini, L., et al. 2002, A&A, 392, 817
Granato, G. L., Danese, L., & Franceschini, A. 1997, ApJ, 486, 147
Ho, L. C. 2004, in Multimwavelength AGN Surveys, 153
Ho, L. C., Filippenko, A. V., & Sargent, W. L. W. 1997a, ApJS, 112, 315
Ho, L. C., Filippenko, A. V., Sargent, W. L. W., & Peng, C. Y. 1997b, ApJS, 112, 391
Iwasawa, K., Lee, J. C., Young, A. J., Reynolds, C. S., & Fabian, A. C. 2004, MNRAS, 347, 411
Krist, J. 1995, in ASP Conf. Ser. 77: Astronomical Data Analysis Software and Systems IV, 349+
Maiolino, R., Marconi, A., & Oliva, E. 2001, A&A, 365, 37
Moran, E. C., Eracleous, M., Leighly, K. M., Chartas, G., Filippenko, A. V., Ho, L. C., & Blanco, P. R. 2005, AJ, 129, 2108
Moran, E. C., Filippenko, A. V., Ho, L. C., Shields, J. C., Belloni, T., Comastri, A., Snowden, S. L., & Sramek, R. A. 1999, PASP, 111, 801
Nagar, N. M., Falcke, H., & Wilson, A. S. 2005, A&A, 435, 521
Narayan, R., & Yi, I. 1994, ApJ, 428, L13
Pavlovsky, C. e. a. 2005, ACD Data Handbook, Version 4.0, (Baltimore: STScI)
Peterson, B. M., et al. 2005, ApJ, 632, 799
Quataert, E., & Narayan, R. 1999, ApJ, 520, 298
Quillen, A. C., McDonald, C., Alonso-Herrero, A., Lee, A., Shaked, S., Rieke, M. J., & Rieke, G. H. 2001, ApJ, 547, 129
Rees, M. J., Phinney, E. S., Begelman, M. C., & Blandford, R. D. 1982, Nature, 295, 17
Reyes, J. M., Rieke, M. J., & Rieke, G. H. 2001, ApJ, 547, 129
Sirianni, M., et al. 2005, PASP, 117, 1049
Tremaine, S., et al. 2002, ApJ, 574, 740