Received 2004 December 22; accepted 2005 February 16
Preprint typeset using LaTeX style emulateapj v. 6/22/04

THE MURMUR OF THE SLEEPING BLACK HOLE: DETECTION OF NUCLEAR ULTRAVIOLET VARIABILITY IN LINER GALAXIES [1]

Dan Maoz,[2] Neil M. Nagar, [3,4] Heino Falcke, [5,6] and Andrew S. Wilson, [7]

Received 2004 December 22; accepted 2005 February 16

ABSTRACT

LINER nuclei, which are present in many nearby galactic bulges, may be the manifestation of low-rate or low-radiative-efficiency accretion onto supermassive central black holes. However, it has been unclear whether the compact ultraviolet (UV) nuclear sources present in many LINERs are clusters of massive stars, rather than being directly related to the accretion process. We have used the Hubble Space Telescope to monitor the UV variability of a sample of 17 galaxies with LINER nuclei and compact nuclear UV sources. Fifteen of the 17 galaxies were observed more than once, with two to five epochs per galaxy, spanning up to a year. We detect significant variability in most of the sample, with peak-to-peak amplitudes from a few percent to 50%. In most cases, correlated variations are seen in two independent bands (F250W and F330W). Comparison to previous UV measurements indicates, for many objects, long-term variations by factors of a few over decade timescales. Variability is detected in LINERs with and without detected compact radio cores, in LINERs that have broad Hα wings detected in their optical spectra ("LINER 1's"), and in those that do not ("LINER 2s"). This variability demonstrates the existence of a non-stellar component in the UV continuum of all types, and sets a lower limit to the luminosity of this component. Interestingly, all the LINERs that have detected radio cores have variable UV nuclei, as one would expect from *bona fide* AGNs. We note a trend in the UV color (F250W/F330W) with spectral type – LINER 1s tend to be bluer than LINER 2s. This trend may indicate a link between the shape of the nonstellar continuum and the presence or the visibility of a broad-line region. In one target, the post-starburst galaxy NGC 4736, we detect variability in a previously noted UV source that is offset by $2\farcs5$ ($\sim$ 60 pc in projection) from the nucleus. This may be the nearest example of a binary active nucleus, and of the process leading to black hole merging.

Subject headings: galaxies: active — galaxies: nuclei — galaxies: Seyfert – galaxies: starburst – quasars: general – Ultraviolet: galaxies –

1. INTRODUCTION

Low-ionization nuclear emission-line regions (LINERs) are detected in the nuclei of a large fraction of bright nearby galaxies (Ho, Filippenko, & Sargent 1997a; Kauffmann et al. 2003). Since their definition as a class by Heckman (1980), they have elicited debate as to their nature and relation, if any, to active galactic nuclei (AGNs). Although the luminosities of most LINERs are unimpressive compared to "classical" AGNs, a variety of observables point to similarities and continuities between AGNs and at least some LINERs. To list some of these, at least 10% of LINERs show weak, broad, Seyfert-1-like Hα wings in their spectra (Ho et al. 1997b), and Keck spectropolarimetry of several objects has revealed "hidden BLRs" (Barth, Filippenko, & Moran 1999a,b), similar to those seen in some Seyfert 2s (Antonucci & Miller 1985; Tran 1995). *Hubble Space Telescope* (HST) imaging shows that some 25% of LINERs have compact, often unresolved (i.e., $\lesssim$ few pc), bright UV sources in their nuclei (Maoz et al. 1995; Barth et al. 1998). Optical imaging with WFPC2 on HST of 14 LINERs (Pogge et al. 2000) suggests that all nearby LINERs (including the 75% that are "UV-dark", i.e., those that do not reveal a nuclear UV source at HST sensitivity, $\sim 10^{-17}$ erg cm^{-2} s^{-1} Å^{-1}) likely have such a nuclear UV source, but that it is often obscured by circumnuclear dust.

In the radio, at Very Large Array (VLA) resolution ($0\farcs1 \approx$ tens of pc), about half of LINERs display unresolved radio cores at 2 cm and 3.6 cm (Nagar et al. 2000, 2002). At 6 cm, with Very Long Baseline Interferometer (VLBI) resolution ($\sim$ 1 pc), these cores remain unresolved, strongly arguing for the presence of an AGN (Falcke & Biermann 1999; Falcke et al. 2000). The radio core fluxes have been found to be variable by factors of up to a few in about half of the $\sim$ 10 LINERs observed multiple times over 3 years (Nagar et al. 2002). A radio survey for 1.3 cm water megamaser emission, an indicator of dense circumnuclear molecular gas, detected LINER nuclei at the same rate as type-2 Seyfert nuclei (Braatz et al. 1997). Such megamaser emission is seen only in AGNs. Some LINERs have indications of a Seyfert-like ionization cone oriented along their radio axis (Pogge et al. 2000).

At X-ray energies, Rosat HRI images showed compact ($< 5''$) soft X-ray emission in 70% of LINERs

[1] Based on observations with the *Hubble Space Telescope* which is operated by AURA, Inc., under NASA contract NAS 5-26555.

[2] School of Physics and Astronomy, Tel-Aviv University, Tel-Aviv 69978, Israel; dani@wise.tau.ac.il
[3] Kapteyn Institute, Postbus 800, 9700AV, Groningen, The Netherlands
[4] Departamento de Física, Astronomy Group, Universidad de Concepción, Casilla 160-C, Concepción, Chile
[5] ASTRON, P.O. Box 2, 7990 AA, Dwingeloo, The Netherlands
[6] Department of Astrophysics, Radboud University, Postbus 9010, 6500 GL Nijmegen, The Netherlands
[7] Astronomy Department, University of Maryland, College Park, MD 20742

and Seyferts (Roberts & Warwick 2000) which, when observed with ASCA, were found to have a nonthermal 2-10 kev spectrum (e.g., Terashima, Ho, & Ptak 2000). Arcsecond-resolution Chandra observations by Terashima & Wilson (2003) of 11 LINERs, each of which was preselected to have a radio core, revealed an X-ray nucleus in all but one case, and the nuclei were generally (but not always) unresolved.

The super-massive black holes in the nuclei of most normal galaxies (e.g., Tremaine et al. 2002; Ferrarese & Merritt 2000), many of which are also LINERs, could be the remnants of ancient quasars/Seyferts, now accreting at a low rate and/or radiating inefficiently (e.g., Reynolds et al. 1996), and producing these multiwavelength signatures. If LINERs represent the low-luminosity end of the AGN phenomenon, then they are the nearest and most common examples, and their study is germane to understanding AGN demographics and evolution, and the X-ray background.

However, an unambiguous optical/UV link between the LINER and AGN classes has remained elusive. Maoz et al. (1998) analyzed the HST UV spectra of seven "UV-bright" LINERs and showed that, in at least some of them, most or all of the compact UV continuum emission is produced by a cluster of massive stars, whose energy output may be sufficient to account for the optical recombination lines. Even in the few objects showing broad, quasar-like emission lines, one cannot say conclusively whether the UV continuum source is stellar or nonstellar, because the broad emission lines coincide in wavelength with the main expected stellar absorptions. X-ray and radio data have provided convincing evidence for the presence of AGNs in *some* of these objects. However, they cannot identify the source of the optical emission lines, which are excited by UV radiation (beyond the Lyman limit), and the entire LINER definition rests on the ratios of these emission lines. There is thus the possibility that the LINER phenomenon and central black holes are not physically connected, but simply coexist in many galaxies because both are common.

Variability is one of the defining properties of AGNs. Variability can reveal an AGN origin of an emission component, even when broad lines are not detected and much of the continuum emission is produced by a nuclear star cluster. For example, in both of the LINERs NGC 4569 and NGC 404, Maoz et al. (1998) showed that the UV spectrum has the broad absorptions in C IV λ1549 and N V λ1240 due to winds from O-type stars. However, the relative shallowness of these features in NGC 404 means the O-star light is diluted by another component. This component could be lower-mass stars (B and A dwarfs) in the same cluster, or it could be a featureless AGN component. Repeated observations could potentially detect UV variations, thereby exposing an AGN component in the UV, even when much of the continuum emission is produced by a nuclear star cluster.

Indeed, there have been several reports of UV variability in LINERs. Barth et al. (1996) compared their HST/FOS spectrum of NGC 4579 to the HST/FOC F220W measurement of Maoz et al. (1995), and found a factor of 3 decrease in the flux of the central source over the 19-month period between the observations. Cappellari et al. (1999) compared FOC observations of NGC 4552 taken in 1991, 1993, and 1996, and found a factor of 4.5 brightening between the first two epochs, followed by factor of 2 dimming between the last two epochs. While these detections of UV variability were suggestive, they were not conclusive from the technical aspect, because the observational setup was different at each epoch. In the case of NGC 4579, one is comparing a broad-band measurement to a spectroscopic one, where aperture misplacement is always a danger. In the case of NGC 4552, the three measurements were both pre- and post-HST-spherical-abberration correction, and in different FOC formats, having different dynamic and non-linearity ranges, and different fields of view. Other indications of UV variability in LINERs have been indirect, e.g., the appearance of broad (sometimes double-peaked) Balmer emission-line wings in some galaxies with LINER spectra (e.g., Storchi-Bergmann et al. 1995).

If the reported UV variations in LINERs are real, it would mean that:
1. Some of the UV emission of these LINERs is of an AGN nature;
2. LINER variations are common (since UV variations were detected in the few galaxies that were observed more than once); and
3. Large-amplitude (factor $\sim$ 3) variations on few-year timescales are the norm. This would contrast with Seyferts 1s, where typical UV variations are $\lesssim$ 2, and quasars, where variations of only tenths of a magnitude are most common (e.g., Giveon et al. 1999).

Confirming (or refuting) the above results on a carefully-selected sample could therefore provide the missing link between LINER emission and AGNs, and supply important new input to the phenomenology of AGN variability and its dependence on luminosity.

Quantifying the stellar and AGN contributions to the UV is also important for correctly comparing the continuum emission of low-luminosity AGNs with models. While in quasars and Seyferts the UV continuum in generally attributed to a standard thin accretion disk (e.g., Shakura & Sunyaev 1973), in low-luminosity AGNs the nature of the UV continuum is still a matter of debate. In models such as advection/convection dominated accretion flows (ADAFs/CDAFs; e.g., Quataert et al. 1999), the emission is from the hot accretion flow itself. Alternatively, Yuan et al. (2002) and Falcke et al. (2004) have postulated that not only the radio emission, but also the optical/UV/X-rays in low-luminosity objects could be nonthermal emission, likely from the jet itself, with the jet emission becoming dominant as the disk becomes radiatively inefficient. In the latter picture, one postulates a transition from a thermally dominated spectrum to a non-thermal (possibly jet-dominated) spectrum as one goes from black holes accreting near the Eddington limit (quasars and Seyferts) to black holes with sub-Eddington accretion. Stronger UV variability in low-luminosity AGNs could be a signature of this transition.

In the current paper, we present results from a monitoring program using HST to search for UV variability in a sample of LINERs over timescales of weeks to 10 years. Compared to previous, serendipitous, detections of variability, our program was designed to study this question systematically, using a stable observational setup and a representative sample of UV-bright LINERs.

2. SAMPLE AND OBSERVATIONS

2.1. *Sample*

Our sample includes all objects seen to have compact central UV sources in existing HST data as known by us in 2001, and classified optically as LINERs by Ho et al. (1997a) based on their optical emission line ratios.[8] The 17 LINERs in the sample include a variety of LINER subtypes: LINERs having broad Hα wings (which we will designate "LINER 1s"), and those having only narrow emission lines ("LINER 2s"); LINERs whose UV spectra show signatures of massive stars, and those that do not; and some LINERs that, in terms of optical classification, are borderline with Seyferts or with H II nuclei. We will refer to all these objects collectively as either LINER 1s or LINER 2s, depending on the presence or absence of broad Hα wings.[9] VLA imaging at 2 cm and 3.6 cm has revealed a radio core in 11 of the objects, and variability has been detected (Nagar et al. 2002) in five of those that have been monitored. Tables 1 and 2 list the objects in the sample and summarize some of their previously known properties.

2.2. *Observations*

Imaging of the sample was carried out with the HST Advanced Camera for Surveys (ACS) with its High Resolution Camera (HRC) mode. The field of view of this CCD-based instrument is about $29'' \times 25''$, with a scale of $0''.0284 \times 0''.0248$ pixel^{-1}. Each target was imaged in the F250W band ($\lambda_{\rm central} \approx 2500$ Å, FWHM≈ 550 Å) with exposure times ranging from 5 to 25 min, depending on target brightness, and in the F330W band ($\lambda_{\rm central} \approx 3300$ Å, FWHM≈ 400 Å) with an exposure time of 5 min. (The brightest target, NGC 4569, was exposed for just 1 min in each band.) The exposure time was split between two equal exposures that were used in the data reduction process to reject cosmic-ray events. Objects were repeatedly scheduled using HST's Snapshot mode, i.e., these short exposures were chosen by the HST schedulers, as dictated by convenience, in order to fill gaps left in the schedule after normal-mode observations had been scheduled. This means that both the number of epochs at which a given target was actually observed and the spacing between epochs were largely random. Between July 1, 2002 and July 2, 2003, 15 of the 17 LINERs were observed from two to five times each. Two objects, NGC 404 and NGC 1052, were observed only once. HST failed to acquire guide stars in two exposures, of NGC 3642 on December 17, 2002, and of NGC 3486 on February 13, 2003. The resulting failed data will be ignored here. We supplemented our data with archival data obtained with the same observational setup for two of the objects, using the F330W filter: one epoch for NGC 3486 from June 3, 2003, and one for NGC 4258 from December 7, 2002. Table 1 lists the exposure times and epochs of each target.

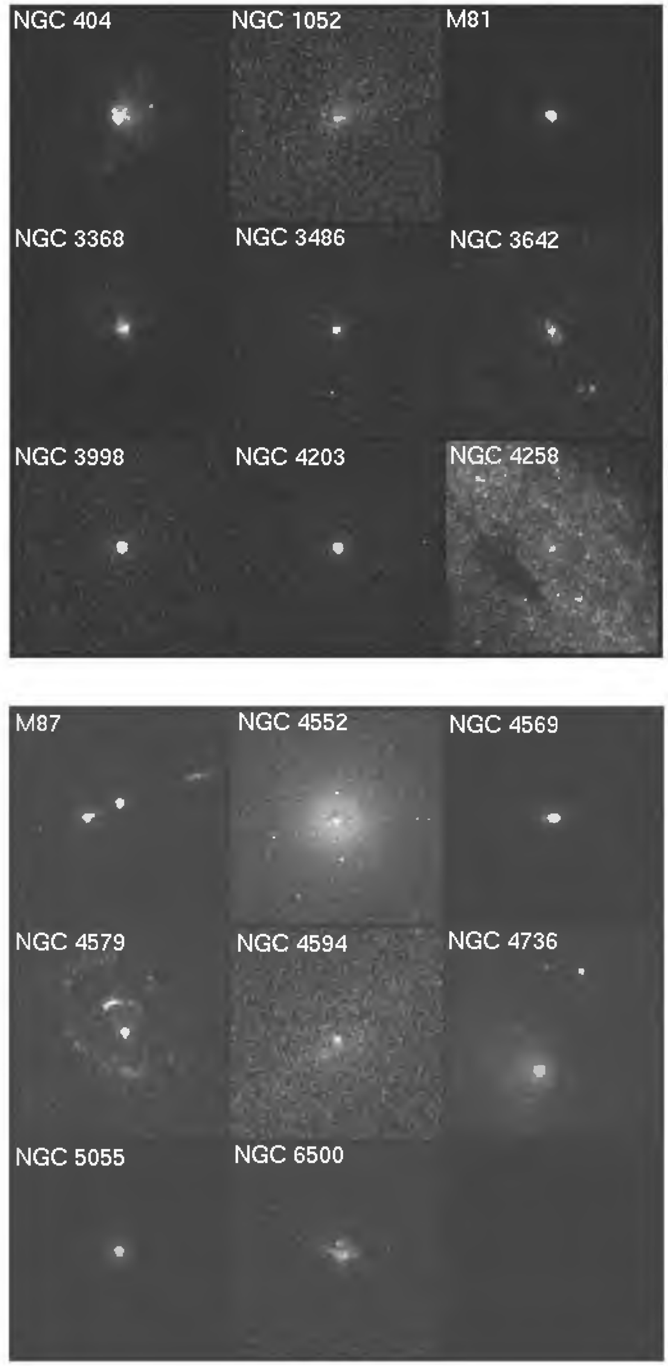

FIG. 1.— Sections of the ACS/HRC F250W images, 5″ on a side, of each of the galaxies in the sample. The nuclei are at the center of each image, except in the case of M87 and NGC 4736, in which the nuclei are slightly offset to the lower left so as to include in the image the jet and the off-nuclear UV source, respectively. Note that an unresolved object is the only significant UV source in the central regions of most of these bright, nearby, galaxies.

[8] Our sample inadvertently excluded NGC 4303, a UV-bright nucleus (Colina et al. 1997, 2002), classified by Ho et al. (1997a) as an H II nucleus, but which higher spatial resolution spectroscopy by Colina & Arribas (1999) identified as a LINER

[9] Ho et al. (1997a) designated LINERs with broad Hα wings as LINER 1.9 objects. Since this is the only kind of type-1 LINER in the sample of Ho et al. (i.e., there are no known examples of LINER 1.2, 1.5, etc.), we will simply refer to LINER 1.9s as LINER 1s. Three of the objects in our sample are classified by Ho et al. as Seyferts, since their narrow emission line ratios [OIII] $\lambda 5007$/Hβ are above the defining border between LINERs and Seyferts by $\sim 30-40\%$ (for M81 and NGC 3486) and by a factor ~ 3 (for NGC 4258). The border is somewhat arbitrary (see, e.g., the distribution of emission-line nuclei from the Sloan Digital Sky Survey on the diagnostic diagrams shown by Kauffmann et al. 2003), so we consider the former two objects also as borderline LINER/Seyfert cases, and the latter as a low-luminosity Seyfert.

Figure 1 shows ACS image sections around each of the LINER nuclei. Compared with previous UV images of these objects with the FOC, WFPC1, and WFPC2 instruments, the improvement in resolution, sensitivity, and linearity reveals, in some cases, fine structures and details that were not clearly seen before. However, the morphologies characterized by isolated, compact or unresolved, nuclear UV sources are consistent with the previous images by Maoz et al. (1995) and Barth et al. (1998). This simple morphology also facilitates the photometric measurements described below.

3. ANALYSIS AND RESULTS

3.1. *Data reduction*

Data were reduced automatically by the Space Telescope Science Institute (STScI) pipeline. This includes bias and overscan subtraction, cosmic-ray rejection and combination of the two split exposures, dark subtraction, flat-fielding, and geometric distortion correction. To assure uniform reduction using the latest available flats and distortion-correction algorithms, the entire dataset was re-retrieved from the HST archive and processed on-the-fly on May 4, 2004.

3.2. *ACS UV photometric stability*

Of great concern in a program such as this is the photometric stability of the camera. This concern is heightened by the fact that, given the small field of view, the short exposures, and the old stellar population of the galaxy bulges in which LINERS are preferentially found, the compact nucleus is generally the only bright feature in the image, and relative photometry is not possible. Indeed, WFPC2, the ACS's predecessor CCD imager on HST, suffers from severe and variable molecular contamination on its front window, which causes large variations with time in UV sensitivity. ACS was expected not to be afflicted by such a problem, since it does not have a cold window on which contaminants can condense. However, as our program was executed on the first observing cycle after the installation of ACS, the actual in-flight UV sensitivity stability was not known, and must be addressed when assessing the reality of any detected UV variations.

Fortunately, STScI staff carried out a program to monitor the UV photometric stability of ACS/HRC, including the two filters we used, contemporaneously with our program. As reported by Boffi, Bohlin, & de Marchi (2004), the open star cluster NGC 6681 was observed 19 times from May 2002 to July 2003. Observations were roughly bi-weekly until mid-November 2002, then paused, and resumed in mid-February 2003, roughly once a month. Not only was the observational setup identical to ours, but the total exposure time per filter (140 s split into two exposures) was comparable to the one we used (300 s for most targets), and the brightnesses of the stars (20,000-30,000 total counts per star within an 8.5-pixel radius) in this test field were similar to those of the compact nuclei in our program. Boffi et al. show light curves for eight of the stars in the field, and report that the UV sensitivities in both F250W and F330W are stable "to 1%".

To obtain a more quantitative estimate of the photometric stability, we used the plots of Boffi et al. (2004) to calculate the actual rms scatter of each star's light curve in each filter. We also measured the brightness of each of these stars in several of the reduced images of NGC 6681 that we retrieved from the HST archive. We then subtracted, in quadrature from the rms scatter of each light curve, the readout noise due to the pixels within an 8.5-pixel radius in two exposures, and the Poisson noise due to the total counts, to obtain the remaining scatter due to other sources of noise. We designate this remaining noise as the "photometric scatter". We find that, among the 16 stellar light curves (8 stars in two bands each), the photometric scatter ranges from zero (i.e., the rms of a light curve is at the level expected from Poisson noise and readout noise alone) up to 1.1%. Four of the light curves have photometric scatter near zero, eight have scatter from 0.4% to 0.7%, and four have scatter of about 1%. We do not find a correspondence between the photometric scatter of a light curve and any obvious parameter, such as the identity of a star, its position on the chip, its brightness, or its color. In fact, some of the stars with the highest scatter in one band have the lowest scatter in the other band, even though at each epoch the two bands were obtained consecutively, with shifts of only a few pixels between exposures. Since a sizeable fraction (25%) of the stellar light curves show photometric scatter of about 1%, and since the first purpose of the present study is to test the null hypothesis that LINERs do not vary, we will conservatively assume that the ACS/HRC has a photometric rms scatter of 1% in both the F250W and the F330W bands. We will adopt this figure as the photometric calibration uncertainty of our measurements, to be combined with the other, statistical, sources of error.

3.3. *Photometry*

We used IRAF[10] to perform aperture photometry of the nuclear source in each image. Counts were summed within a 10-pixel-radius (0.27″) aperture centered on the source. The background level was determined from the median counts in an annulus at radii of 14 to 18 pixels. Experimenting with the more constant among the nuclear sources (e.g., NGC 4569), we found that an aperture radius of > 8 pixels is required in order to obtain photometric stability of better than 1% between epochs. This is consistent with the use of 8.5-pixel-radius apertures by Boffi et al. (2004) in the photometric stability tests described above. Errors were calculated by combining in quadrature the Poisson errors of the counts, the readout-noise errors from the pixels within the aperture in the two split exposures (assuming a readout noise of 4.71 e pixel^{-1}), and the adopted photometric scatter of 1%. Counts and their errors were multiplied by 1.25 (for F250W) and by 1.18 (for F330W) to correct for the finite aperture radii, based on the point-source encircled energy curves in the ACS Data Handbook (Pavlovsky et al. 2004). Finally, count rates were converted to flux densities using the conversion given by the PHOTFLAM keyword in the image headers, 1 e s^{-1} = 4.781×10^{-18} erg cm^{-2} s^{-1} Å^{-1} (F250W), and 1 e s^{-1} = 2.237×10^{-18} erg cm^{-2} s^{-1} Å^{-1} (F330W). This conversion assumes a spectral shape that is flat in f_λ, which is a reasonable approximation for these objects

[10] IRAF (Image Reduction and Analysis Facility) is distributed by the National Optical Astronomy Observatories, which are operated by AURA, Inc., under cooperative agreement with the National Science Foundation.

– their UV colors (see below) imply a spectral slope in the range $-0.4 < \alpha < 0.4$, for an assumed spectral shape $f_\lambda \propto \lambda^\alpha$.

Three galaxies, NGC 4736, NGC 5055, and NGC 6500, merit separate mention. NGC 4736, apart from its nuclear UV source (which is clearly centered on a diffuse, centrally peaked stellar light distribution) displays a second UV point source, 2.″5 north of the nuclear UV source. The flux from the off-nuclear source, which we designate NGC 4736b, was measured exactly as for the other nuclear sources. The off-nuclear source will be further discussed below. NGC 5055, has a central source which is resolved, with an observed full-width-half-maximum (FWHM) of about 5.5 pixels (0.15″), as opposed to the 2-3 pixel FWHM typical of point sources. In its second epoch, on March 12, 2003, it is significantly *more* extended in both bands, with a FWHM of 7 pixels, perhaps due to spacecraft jitter. To prevent both the normal large width and the anomalous epoch from adversely affecting the photometry, we used a 13-pixel aperture in this case, which increases the flux by 20% but eliminates a spurious 3% decline at this epoch. NGC 6500 does not have a clearly defined nuclear source. Instead, it has a diffuse central light distribution, on which are superposed a number of faint sources, some compact and some extended. Although this structure was already known from previous imaging with WFPC2 by Barth et al. (1998), we included this galaxy in the sample since it has various known AGN properties (a radio core – Nagar et al. 2000; a possibly nonstellar UV spectrum – Barth et al. 1997), keeping in mind the possibility that one of the faint sources in the WFPC2 image could have been the active nucleus, perhaps temporarily in a low state. To encompass within the aperture the diffuse nuclear light from this galaxy, we used an aperture radius of 20, rather than 10, pixels.

3.4. *Light curves*

The fluxes at every epoch are included in Table 1. Figure 2 shows the light curves in F250W (filled circles) and F330W (empty circles) for each object. Every object is designated as L1, for type-1 objects (including transition LINER/Seyfert objects), or L2, for type-2 objects (including transition LINER/Seyfert objects and transition LINER/H II objects), and is marked with an "R" if it has a detected compact flat-spectrum radio core. The Seyfert nucleus NGC 4258 and the LINER NGC 4552, unusual objects that have broad components in both the permitted and the forbidden transitions (see below, and in Notes on Individual Objects), are labeled S1/2 and L1/2, respectively. The horizontal dotted lines are plotted at the time-averaged mean flux value in each band. The solid lines show one of the flux levels measured previously (1993-2000) for these objects at bandpasses similar to the F250W band, usually at 2200 Å. While straightforward comparison to the currently measured levels is difficult (see §1), very large variations, of a factor of a few, between these "historical" measurements and the current ones are probably real. Such a comparison is discussed in each case in §4, "Notes on Individual Objects".

In Table 2 we list some statistics derived from the light curve of each object. These include: the number of epochs; the time-averaged mean flux in each band; the χ^2 per degree of freedom of the data in each band, relative to a model with a constant (non-variable) flux at the mean level – this number appears in boldface for the cases that are variable at > 95% confidence; the peak-to-peak variation, with the typical error subtracted in quadrature (if negative, the peak-to-peak variation is set to zero); the time-averaged mean UV color f_λ(F250W)/f_λ(F330W), after correction for Galactic reddening, assuming the B-band extinction values of Schlegel et al. (1998) and the Galactic extinction curve of Cardelli et al. (1995) with the parameter $R_V = 3.1$; the color change between the two epochs with extreme fluxes – $[f_{\rm max}({\rm F250W})/f_{max}({\rm F330W})]/$

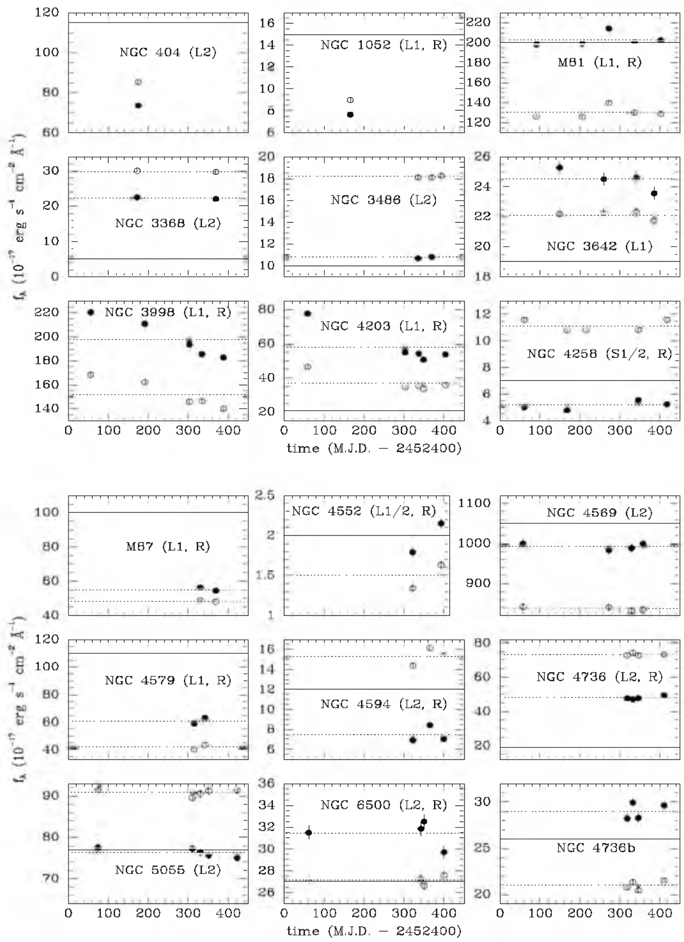

FIG. 2.— UV light curves in F250W (filled circles) and F330W (empty circles) for each of the 17 nuclei in the sample, plus the off-nuclear source NGC 4736b. The period shown corresponds to May 7, 2002 through July 30, 2003. Objects are labeled in parentheses as L1 for type-1 objects (including transition LINER/Seyfert objects), L2 for type-2 objects (including transition LINER/Seyfert objects and transition LINER/H II objects), and R for objects with a detected radio core. The Seyfert nucleus NGC 4258 and the LINER NGC 4552, have broad components in both the permitted and the forbidden lines, and are labeled S1/2 and L1/2, respectively. Dotted lines show the time-averaged mean flux in each band, and solid lines show one of the "historical" (1991-1997) flux levels measured previously for these objects at bandpasses similar to the F250W band, usually at 2200 Å . See §4, Notes on Individual Objects, for details. A historical level is not shown for NGC 3998, as it is ∼ 5 times higher than the 2003 level. Many of the objects display significant short-term ($\lesssim$ 1 yr) variations, correlated between both UV bands, and large-amplitude long-term variations.

$[f_{min}(\mathrm{F250W})/f_{min}(\mathrm{F330W})]$; and its uncertainty.

3.5. *Distances*

We have compiled from the literature recent distance estimates to all the galaxies in the sample. In 11/17 cases, the distances are based on "modern" methods – Cepheids, surface-brightness fluctuations, tip of the red giant branch, Tully Fisher, and maser proper motion. Several of the galaxies have distances from several different methods, which always agree to better than 10%, in which cases we have used the averages. Our adopted distances are listed in Table 2, along with the literature sources on which they are based. We have used these distances, and Galactic extinction corrections as described above, to compute monochromatic luminosities at 2500 Å, which are also given in Table 2.

3.6. *UV Variability*

Inspection of Figure 2 and Table 2 reveals a number of new results. First, in the F250W band, among the 16 objects with multiple epochs (the 15 galaxies with multiple epochs, including the double nucleus in NGC 4736), significant variability at greater than the 95% confidence level, based on χ^2, is detected in all but four cases: NGC 3368, NGC 3486, NGC 4569, and NGC 5055 (plus M87, that varied at 94% confidence. The apparently significant variations in NGC 6500 are uncertain – see below). In the F330W band, eight objects reveal significant changes, and all of these vary in F250W as well. Whenever significant variations are detected in both bands (in eight objects), the variations are correlated. Significant variations range in peak-to-peak amplitude (expressed as a fraction of the mean flux) from 3% to 46%, with a median of 7%, in F250W, and from 5% to 34%, with a median of 11%, in F330W. (Note that these statistics are affected by the different number of epochs and time intervals for each object.)

As summarized in §1, UV variability in some of these LINERs has been reported before. However, this is the first time such variability is seen on relatively short timescales, and it is detected using an unchanging, and photometrically very stable, observational setup (§3.2). The variable flux provides a firm lower limit on the AGN contribution to the UV flux at each band. We see that variability, and hence an AGN contribution, exists in some members of both LINER classes, 1 and 2. This situation is distinct from the one in Seyfert galaxies. In Seyferts, the AGN continuum that is visible in type-1 objects is obscured in type 2s, in which the observed UV continuum is sometimes scattered AGN light and sometimes produced by young stars in the circumnuclear region (e.g., González-Delgado et al. 1998), and, in either case, is not expected to be variable on ≈ 1 year or shorter timescales. Our finding that variability is seen in at least some LINER 2s suggests that the "unified scheme", believed to apply to Seyferts, may not always apply to LINERs.

In terms of longer timescale variability, comparison of the UV flux levels we measure to the "historical" ones shown with a solid line in Figure 2 reveals likely large-amplitude variations even in some objects that were not seen to vary during the present campaign, either because they were sampled too closely or too infrequently, or because they were temporarily inactive. These include NGC 404, NGC 1052, NGC 3368, and M87 (see §4, for details). Indeed, the nucleus of M87 was recently monitored by Perlman et al. (2003) using the ACS/HRC with the F220W filter, and was shown to vary in flux, consistent with previous reports of optical variability by Tsvetanov et al. (1998). This leaves only three out of the 17 LINER nuclei that appear to be constant on both short (months) and long (up to 10 years) timescales. These constant objects are NGC 3486, NGC 4569, and NGC 5055. We can conclude, therefore, that UV variability is a common property of the majority of LINERs.

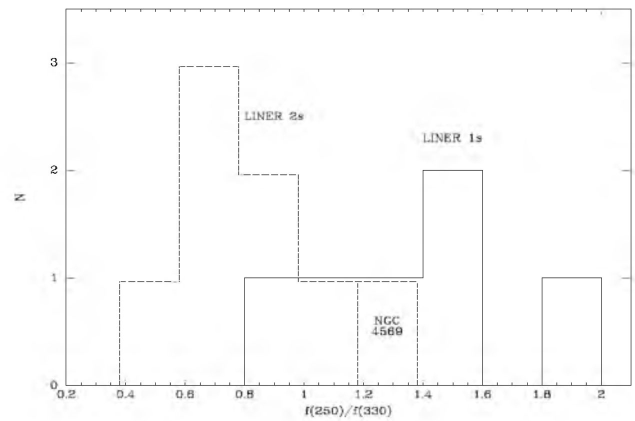

FIG. 3.— Histograms of Galactic-reddening-corrected UV color, $f_\lambda(\mathrm{F250W})/f_\lambda(\mathrm{F330W})$, for type-1 objects (solid line) and type 2 objects (dashed line). Type-1 objects appear to be generally bluer than type-2's. NGC 4569, the bluest type-2 object (see text), is labeled.

The nuclear UV source in NGC 4736 appears variable in F250W, but only at the 95% confidence level, and is constant in F330W. However, a surprising result is that the off-nuclear source, NGC 4736b, is clearly variable in both bands. This raises the possibility that the off-nuclear source is the active nucleus of a second galaxy in the final stages of a merger with NGC 4736, or perhaps it is related to jet activity originating in the nucleus. This is discussed in more detail below.

3.7. *UV color of type-1 and type-2 LINERs*

Inspection of Table 2 reveals another interesting result. In terms of the Galactic-reddening-corrected UV color $f_\lambda(\mathrm{F250W})/f_\lambda(\mathrm{F330W})$, there is an apparent trend that LINER 1s are, on average, blue, and LINER 2s are red. This is illustrated in Fig. 3.6, showing histograms of the UV color for LINER 1s and LINER 2s. The populations (at least as probed by our small sample) seem to overlap at $f_\lambda(\mathrm{F250W})/f_\lambda(\mathrm{F330W}) \approx 1$. We have excluded four objects from this plot:

NGC 4258, which we have listed as an object of uncertain type, has the reddest nucleus in our sample. Pogge et al. (2000) have presented evidence that this object is a borderline case between UV-bright and UV-dark objects, and is likely partially obscured and reddened by foreground dust. Furthermore, its narrow [OIII]/Hβ ratio of 10 puts it firmly in the Seyfert regime (Ho et al. 1997a), distinct from the other nuclei in the sample, which are LINERs or borderline LINERs. Its broad Hα wings, which could give it a type-1 classification, are also peculiar in the sense that both the permitted and the forbidden lines in its spectrum have broad bases, especially in polarized light (Barth et al. 1999b).

NGC 4552 was classified by Ho et al. (1997a) as "T2:", meaning a transition object between a LINER and an H II nucleus, with no evidence of a broad Hα component, and an uncertain classification. The uncertainty is driven by the weakness of the emission lines, which in the ground-based optical spectrum are superposed on bright stellar emission from the center of the galaxy. Since the narrow emission lines are so faint, an even-weaker broad component would have been impossible to detect, and the classification of NGC 4552 as a type-1 or type-2 LINER was limited by the signal-to-noise ratio of the spectral data (L.C. Ho, private communication). Indeed, Cappellari et al. (1999) analyzed an HST/FOS spectrum of NGC 4552, in which, at HST resolution, the nucleus can be better isolated from the surrounding starlight. They found that the emission lines have a significant broad component, with velocities of 3000 km s^{-1}, typical of type-1 objects. However, this broad component was present in both the permitted *and* the forbidden lines, in contrast to other type-1 AGNs, but reminiscent of the situation in NGC 4258. It is therefore unclear whether NGC 4552 should be considered a type-1 or a type-2, and we exclude it from the UV-color analysis. [Incidentally, Cappellari et al. (1999) classified NGC 4552, using the narrow-line ratios measured with HST, as a borderline case between a LINER and a Seyfert, rather than as a transition case between a LINER and an H II nucleus.] We note that a problem in detecting a faint broad component does not exist at the same level for the other LINER 2s in our sample, which are considerably brighter than NGC 4552. In the UV as well, NGC 4552 is, by far, the faintest source in our sample, and one of the least luminous.

NGC 4736b, the off-nuclear source, was excluded from the UV-color analysis because we know nothing about its nature, let alone if it is a type-1 or type-2 object.

NGC 6500 was excluded from the plot because it has no obvious nuclear source whose color can be measured. This leaves 14 objects in the plot – six LINER 1s and eight LINER 2s.

One LINER 2, NGC 4569, is very blue, contrary to the "1=blue/2=red" trend. However, it is a peculiar object in other respects as well. Maoz et al. (1998) have shown that its UV spectrum is completely dominated by the light from O-type stars, and it has failed to show AGN characteristics in any spectral band. In the present study, it is one of the three objects that are not variable even on decade timescales. Barth & Shields (2000) have calculated photoionization models specifically for this object, and have shown that, under particular conditions, a young stellar cluster can produce the observed optical emission-line spectrum. (Specifically, a sufficient number of Wolf-Rayet stars must be present, implying both an instantaneous starburst and a current age of 3-5 Myr.) Perhaps NGC 4569 is a peculiar case of a starburst-driven LINER, and therefore differs from other LINER 2s also in its UV color.

If our apologies for the excluded and the outlier nuclei are justified, and there is a true UV color distinction between LINER 1s and LINER 2s, this may be the first independent observable that can predict the existence of broad Hα in a LINER, even if only for LINERs that are at the extreme red and blue ends of the color distribution. It is tempting to speculate that the redness of LINER 2s is produced by intervening dust, and that this dust somehow obscures the broad-line region, in some analogy to the unification schemes applicable to Seyfert 1s and 2s. However, such a scenario, at least in its simplest version, will not work. There is, at most, a factor ~ 2 difference in the UV color ratio of the LINER 1s and LINER 2s (see Fig. 3.6). Assuming a dust screen with a standard Galactic extinction curve, a ratio of 2 between the continuum attenuations at 2500 Å and 3300 Å implies an attenuation of flux in the Hα spectral region by only a factor of 2.4. If anything, one would expect the broad emission lines, which come from an extended region, to be even less attenuated than the continuum. In other words, in LINER 2s the "hidden" broad Hα flux would be lowered by a factor ~ 2, relative to LINER 1's. Such a small reduction would probably not hinder the detection of broad components in type-2 objects, many of which are quite bright. To further investigate a possible role of dust, we have searched for correlations between the UV color we measure and the Balmer decrements of the objects in the sample, or the estimated host galaxy extinctions, as tabulated by Ho et al. (1997a). No trend was found. There is also no obvious relation between UV color and radio power, as tabulated by Nagar et al. (2002). Thus, the UV color may indicate some other link between the shape of the nonstellar continuum and the presence or the visibility of a broad-line region.

On the other hand, even in high-luminosity AGN, there is seldom good agreement between dust extinction measures at different wavelengths, probably because of a combination of optical depth and geometry effects. Furthermore, considering the challenge of detecting weak broad Hα wings, a factor 2 reduction may play some role after all. For example, by isolating galactic nuclei from the surrounding stellar light using the small spectroscopic apertures possible with HST, several LINERs, although previously classified as LINER 1s from the ground, have revealed also broad double-peaked Hα profiles (Ho et al. 2000; Shields et al. 2000). Thus, further work is required both to confirm the suggested trend of UV color with type, and to understand the effect.

3.8. *UV color variation*

In terms of the temporal variation in UV color of the sources, one can see from Table 2 that the color remains constant, to within the errors, when the flux varies. The sole exception is NGC 4203, which is significantly bluer when it is brighter, as is commonly observed in many high-luminosity AGNs (e.g., Giveon et al. 1999). Note that this is also the object with the largest amplitude of variations. Thus, it may be that similar color changes occur in some of the other objects, but the color changes are too small to be seen when the flux variation amplitude is small. Indeed, Tsvetanov et al. (1998) have reported, for M87 at optical wavelengths, a continuum that bluens as it brightens. However, two of the galaxies with relatively large variation amplitudes, NGC 3998, NGC 4579, keep their color constant to within a few percent when they vary, so the brighter-bluer phenomenon is not universal.

4. NOTES ON INDIVIDUAL OBJECTS

NGC 404 – HST UV spectroscopy of this LINER 2 nucleus by Maoz et al. (1998) showed clear absorption signatures of OB stars. However, the relative shallowness of the absorptions meant that the light from massive stars was diluted by another component, comparable in flux, which could be a featureless AGN continuum, or the light from less massive stars in an aging or continuous starburst. Nagar et al. (2000) did not detect a radio core in this galaxy, to a limit of 1 mJy. A *Chandra* X-ray image presented by Eracleous et al. (2002) shows a compact nuclear source with 0.5-8 keV luminosity of 1×10^{37} erg s^{-1}, surrounded by some faint blobs.

In our new ACS images, the nucleus consists of a compact core on top of a diffuse halo of $\sim 0.5''$ diameter, and several surrounding faint sources. Since only one epoch was obtained for this object, we cannot say anything about short-term variability. However, the 2500 Å flux is $\approx$ 60% of the level measured by the 1994 spectroscopy analyzed by Maoz et al. (1998; 115×10^{-17} erg cm^{-2} s^{-1} Å^{-1}). This difference is likely real, given that: a) it is conceivable that slit losses could lead to an underestimate of the flux in a spectroscopic observation, but it is difficult to imagine what would lead to an overestimate. Indeed, from analysis of the FOS target acquisition records, Maoz et al. (1998) noted that NGC 404 had been at the edges of its peak-up scans, possibly leading to some light loss; b) The HST/FOS measurements by Maoz et al. (1998) for other objects (e.g., NGC 4569), taken with the same setup, do agree well with the new measurements, arguing against systematic calibration problems. Furthermore, the 1994 FOS spectroscopy indicated a UV flux of only 65% of that obtained with the HST/FOC imaging measurement in 1993 by Maoz et al. (1995; 180×10^{-17} erg cm^{-2} s^{-1} Å^{-1} at 2300 Å). These measurements imply that the nucleus has faded by a factor ~ 3 at 2500 Å between 1993 and 2002. Again, for some objects there is excellent agreement between the FOC, FOS, and ACS measurements, lending credence to this conclusion. At most, 60% of the UV light in the spectrum obtained in 1994 was contributed by an AGN, with the rest coming from young stars (Maoz et al. 1998), and therefore it appears that the AGN component at 2500 Å has faded by a large factor between 1994 and 2002.

NGC 1052 – This galaxy hosts the archetypical LINER 1 nucleus, which has many AGN characteristics: weak broad Hα wings, which become dominant in polarized light, revealing a "hidden broad-line region" (Barth et al. 1999a); an "ionization cone" (Pogge et al. 2000), reminiscent of those seen in some Seyfert galaxies, aligned with the direction of radio lobes and X-ray knots (Kadler et al. 2004); a variable radio core (Vermeulen et al. 2003); and H_2O megamaser emission (Claussen et al. 1998). Unfortunately, in our HST snapshot program this object was imaged in the UV only once. Nevertheless, in 2002 the UV flux was at half its level in the 2200 Å region of a 1997 HST/FOS spectrum (Gabel et al. 2000), as measured by Pogge et al. (2000; 15×10^{-17} erg cm^{-2} s^{-1} Å^{-1}). As argued above for NGC 404, the sense of the difference (a lower flux in the imaging observation), and the reliability of the FOS calibration for other objects argue that this factor of 2 decline is real. If so, there is a significant AGN contribution to the UV light of this nucleus.

M81 – This nucleus is formally a Seyfert 1 (Ho et al. 1997a), since its [OIII]/Hβ ratio is 30% above the (rather arbitrary) border between LINERs and Seyferts. This is close enough that we can safely consider it a borderline LINER/Seyfert case. It has numerous AGN features, including a variable and double-peaked broad Balmer line component (Bower et al. 1996; Ho et al. 1996), a broad-line AGN-like UV spectrum (Ho et al. 1996; Maoz et al. 1998), and at VLBI resolution, a stationary radio core and a one-sided variable jet (Bietenholz et al. 2000). In our current observations, M81 was imaged at five epochs. At four of the epochs, the nucleus displays little or no variations in either F250W or F330W, with amplitudes of variation limited to $< 2-3\%$. The flux level at 2500Å , 200×10^{-17} erg cm^{-2} s^{-1} Å^{-1}, is similar to the one measured by Maoz et al. (1998) at 1500 Å in the 1993 HST/FOS spectrum of Ho et al. (1996) – 150×10^{-17} erg cm^{-2} s^{-1} Å^{-1}. [From an analysis of the FOS target acquisition records, Maoz et al. (1998) deduced that M81 was located at the edges of its peak-up scans, possibly leading to some light loss.] The ACS-measured flux at 2500 Å in these four epochs is also the same as the 2200 Å flux estimated by Maoz et al. (1998) by extrapolating the 1996 WFPC2 measurement at $\sim$ 1600 Å by Devereux et al. (1997). However, the nucleus brightened by $\sim 9\%$ in both F250W and F330W filters at one epoch, February 2, 2003. The correlated variation in the fluxes in the two bands, and the lack of anything suspect on that date (e.g., the nucleus appears unresolved, just as at other epochs), favor that this variation is real. Therefore, of order 10% or more of the 2500 Å and 3300 Å UV continua in this object are nonstellar in nature. M81 is the bluest object in our sample in terms of f_λ(F250W)/f_λ(F330W) color.

NGC 3368 – There is no significant variation in either UV band between the two epochs at which this LINER 2 was observed. However, the 2500 Å flux is a factor of 4.5 higher than the 2200 Å flux measured in 1993 with HST/FOC by Maoz et al. (1996; 5×10^{-17} erg cm^{-2} s^{-1} Å^{-1}). The large amplitude of this long-term variation makes it credible, despite the difficulties of photometry with the FOC. Note that for the nucleus of NGC 3486, which had a 2200 Å flux in 1993 (10×10^{-17} erg cm^{-2} s^{-1} Å^{-1}; Maoz et al. 1996) comparable to that of NGC 3368, there is good agreement, to 8%, between the old FOC measurement and the current ACS measurement. Thus, NGC 3368 appears to be another LINER 2 in which the UV is dominated by AGN emission, despite the fact that no other AGN features (e.g., a radio core; Nagar et al. 2002) have been detected to date.

NGC 3486 – This nucleus is one of three objects in our sample (the others are NGC 4569 and NGC 5055) that show no significant short-term or long-term variations. It is a relatively high-ionization object, borderline between LINERs and Seyferts, and which Ho et al. (1997) have actually classified as a Seyfert 2 (its [OIII]/Hβ ratio is 40% above the formal LINER/Seyfert border). Its nonvariability may be related to its class, as the UV continuum of Seyfert 2's is dominated by either scattered nuclear light or starlight (González-Delgado et al. 1998). The 2500 Å flux level, 10.8×10^{-17} erg cm^{-2} s^{-1} Å^{-1}, is in excellent agreement with the 2200 Å level in 1993, 10×10^{-16} erg cm^{-2} s^{-1} Å^{-1}, measured with the HST/FOC by Maoz et al. (1996). Since this is another object without other AGN features (e.g., at a resolution of 1″, no radio core at 6 cm and 20 cm was detected to a 3σ limit of 0.12 mJy beam^{-1} by Ho & Ulvestad 2001), it is tempting to label it as a non-AGN LINER. Note, however, that we imaged it on only two, closely spaced (by 1 month), epochs. For comparison, M81 and M87, which are clearly AGNs with variable UV flux, were also near their "historical" UV level in the present observations and were constant in our two closely spaced epochs (for M87) or in four out of five epochs (for M81). Thus, detection of short-term variability in NGC 3486 might have been possible with better temporal sampling.

NGC 3642 – The 8% peak-to-peak amplitude variations in F250W of this radio-undetected (Nagar et al. 2000) LINER 1 are significant at > 98% confidence, based on χ^2. Fluctuations seen in the F330W band are not significant, for our assumed photometric uncertainty, although the sense of these fluctuations is correlated with those in F250W, suggesting they may also be real. The 30% increase in 2500 Å flux compared to the 2200 Å WFPC2 measurement in 1994 by Barth et al. (1998; 19×10^{-17} erg cm^{-2} s^{-1} Å^{-1}) is not obviously significant, given the different bandpasses and the UV sensitivity fluctuations of WFPC2. The small, but significant, F250W variations show that at least a fraction of the UV flux is nonstellar. Interestingly, Komossa et al. (1999) found no evidence in this galaxy for X-ray variations on short (5 months) or long (years) timescales.

NGC 3998 – This variable radio-cored (Filho et al. 2002) LINER 1 displayed a monotonic 20% decline in UV flux in both bands, F250W and F330W, over the 11 months we observed it. On long timescales, its mean 2500 Å flux level in 2003 was about 5 times lower than reported by Fabbiano et al. (1994; 10^{-14} erg cm^{-2} s^{-1} Å^{-1}) at 1740 Å in 1992, based on FOC measurements. The large amplitude of this long-term variation makes it credible, despite the different bandpasses and the problems with FOC linearity and dynamic range. Thus, nonstellar light has dominated the UV output of the nucleus over the past decade, and likely still contributes a significant or dominant fraction.

NGC 4203 – This nucleus is a LINER 1 having a double-peaked Hα profile (Shields et al. 2000) and a variable radio core (Nagar et al. 2002). The radio core remains unresolved at the milli-arcsecond scale, and Anderson et al. (2004) have shown that its spectrum is most consistent with that of a jet pointed within < 45° to our line of sight. At Chandra resolution its compact X-ray nucleus is embedded in soft diffuse emission of 50″ diameter (Terashima & Wilson 2003). Its short-term UV variability was the largest in our sample, with a factor of 1.5 between maximum and minimum in F250W, and 1.4 in F330W, and with the variations in the two bands clearly correlated. Almost all of the variation occurred between the first two epochs, separated by 8 months. The 2500 Å flux level in 2003 was 3-4 times higher than in the HST/WFPC2 2200 Å measurement by Barth et al. (1998; 21×10^{-17} erg cm^{-2} s^{-1} Å^{-1}), obtained in 1994. This long-term variation is likely real, given its large amplitude, despite the different bandpasses and the UV photometric instability of WFPC2. As already noted, this is the only object in which we detect significant color changes, presumably because the variation amplitude is large enough to reveal the color changes. The sense of the color change, as in luminous AGN (e.g., Giveon et al. 1999), is that the nucleus is bluer when it is brighter.

NGC 4258 – The galaxy with the famous masing water disk (Watson & Wallin 1994; Miyoshi et al. 1995), whose Keplerian rotation curve gives the second most accurately measured central black hole mass (after the Milky Way), has been variably classified as a LINER 1 or a Seyfert 1.9. In the spectrum of Ho et al. 1997a, its emission-line ratio of [OIII]/Hβ = 10, which is 3 times greater than the the formal border between LINERs and Seyferts and hence well in the Seyfert domain. Wilkes et al. (1995) and Barth et al. (1999b) showed that the spectrum in polarized light has emission lines that are broader than the lines in the total flux spectrum. However, this is seen not only in the Balmer lines but in most of the forbidden lines as well, with the width of the lines in the polarized spectrum depending on the critical density of the transition. The phenomenon is thus different from that of the hidden broad-line regions revealed in polarized light in some Seyfert 2 galaxies. Possible explanations for the effect are the presence of a structure that obscures and polarizes the inner parts of the narrow-line region (Barth et al. 1999b), or a broadening of the lines due to the impact of the jet on the emission line gas (see, e.g., Wilson et al. 2000).

Our measurements indicate significant fluctuations in nuclear flux, with a peak-to-peak amplitude of 16% in F250W and 8% in F330W. Contrary to the other objects with significant variations detected in both bands, the variations in this galaxy are not perfectly correlated between the bands, particularly on the third epoch. Pogge et al. (2000) estimated the 2200 Å flux from a F218W WFPC2 image from 1997, at 7×10^{-17} erg cm^{-2} s^{-1} Å^{-1}. Given the photometric UV instability of WFPC2 (for which Pogge et al. made no correction), and the significant red leak in the WFPC2+F220W configuration, plus the fact that this is the reddest nucleus in our sample in terms of f_λ(F250W)/f_λ(F330W) color, the WFPC2 flux level is consistent with the mean ACS F250W level, 5.2×10^{-17} erg cm^{-2} s^{-1} Å^{-1}. Thus, there is no evidence for long-term variation between 1997 and 2003. As already noted, this object is also anomalous in the sense that it has some type-1 characteristics but its UV color is red. Pogge et al. (2000) argued that it likely undergoes foreground reddening, perhaps by the dust in the molecular gas disk that produces this galaxy's observed water masers.

M87 – Although a LINER 2 (Ho et al. 1997a), with no detected broad component to its Balmer lines, M87 has numerous AGN features, most notably its prominent radio-through-X-ray jet. We obtained only two epochs on this object, separated by 40 days, and showing only marginally significant (94% confidence, based on χ^2) variation in F250W and no significant variation in F330W. However, as noted above, Perlman et al.

(2003) monitored M87 with ACS/HRC and the F220W filter at five epochs between November 2002 and May 2003. Their light curve, which includes the two epochs obtained by us, shows clear nuclear variability, with about 20% peak-to-peak amplitude. The 2500 Å flux is about half that measured by Maoz et al. (1996; 1×10^{-15} erg cm^{-2} s^{-1} Å^{-1}) using an archival HST/FOC image from 1991. There is thus no doubt that AGN emission contributes significantly to the nuclear UV flux from this object. The radio-to-X-ray emission in the jet is certainly synchrotron. Hence it is likely that the nuclear UV emission is also synchrotron emission from the jet, or at least has a very strong jet contribution.

NGC 4552 – As already noted above, the classification of this nucleus is uncertain. Ho et al. (1997a) labeled it a type-2 object, on the border between LINERs and H II regions, with no detected broad Hα component. Cappellari et al. (1999), analyzing an HST/FOS spectrum, found the narrow-line ratios were borderline between LINERs and Seyferts, and detected a broad component in both the Balmer lines and in the forbidden lines. It is therefore unclear whether this galaxy is more akin to type 1s or type 2s. Its blue f_λ(F250W)/f_λ(F330W) color is certainly reminiscent of type 1s. Between the two epochs at which we observed it, the nucleus brightened by 20% in both UV bands. This confirms the previous reports of long-term variability in this object by Cappellari et al. (1999; see §1). The mean of the two 2500 Å data points, 2×10^{-17} erg cm^{-2} s^{-1} Å^{-1}, is the same as was measured with HST/FOS in 1996 by Cappellari et al. (1999), and close to their HST/FOC measurements obtained in 1993, 1.5×10^{-17} erg cm^{-2} s^{-1} Å^{-1} (in F220W) and 1.8×10^{-17} erg cm^{-2} s^{-1} Å^{-1} (in F275W).

NGC 4569 – A "transition" nucleus between an H II nucleus and a LINER 2 (Ho et al. 1997a), this object is one of three that showed no variations in either UV band. Its constancy is not surprising, since Maoz et al. (1998) showed, based on its UV spectrum, that at least 80% of the UV flux is stellar. (Of course, this left room for a 20% AGN component, but we have found no evidence for such a component in the present experiment). The mean 2500 Å flux level we measure with ACS, $(0.992\pm0.005)\times10^{-14}$ erg cm^{-2} s^{-1} Å^{-1}, is in excellent agreement with previous measurements at $\sim$ 2200 Å – FOS: 1.05×10^{-14} erg cm^{-2} s^{-1} Å^{-1} (Maoz et al. 1998) – FOC: 1.0×10^{-14} erg cm^{-2} s^{-1} Å^{-1} (Maoz et al. 1995) – and WFPC2: 1.1×10^{-14} erg cm^{-2} s^{-1} Å^{-1} (Barth et al. 1998). This agreement lends credence to the detection of long-term variations in similar comparisons for the other objects in our sample.

NGC 4579 – This nucleus, classified by Ho et al. (1997a) as a transition case between a LINER 1 and a Seyfert 1.9, has a radio core that remains unresolved at the milli-arcsecond scale, with a spectrum that is most consistent with that of a jet pointed within $<40^\circ$ to our line of sight (Anderson et al. 2004). Our new images show in sharp detail the disk/spiral arm around the point-like central source, already visible in the UV image by Maoz et al. (1995; 1996). Its X-ray morphology, as viewed with Chandra, is a very bright nucleus surrounded by soft diffuse emission from the circumnuclear star-forming ring (Eracleous et al. 2002; Terashima & Wilson 2003). Barth et al. (1996) noted a factor 3 fading in UV flux between the 1993 FOC images of Maoz et al. (1995) and their own FOS observations in 1994, obtained 19 months later. This apparent large variation was further studied by Maoz et al. (1998), who again concluded it is likely real. Our current data leaves no doubt regarding the large variability of this object. Between the two epochs at which it was observed, separated by less than a month, it brightened by 7% in both UV bands. The mean flux level at 2500 Å in 2003, 61×10^{-17} erg cm^{-2} s^{-1} Å^{-1}, is between, but significantly different from, the two previous measurements at $\sim$ 2200 Å: 33×10^{-17} erg cm^{-2} s^{-1} Å^{-1} (Maoz et al. 1998) and 110×10^{-17} erg cm^{-2} s^{-1} Å^{-1} (Maoz et al. 1995).

NGC 4594 – The LINER 2 nucleus of the Sombrero galaxy appears unresolved and isolated at 2500 Å, as previously seen at 2400 Å by Crane et al. (1994). The nucleus shows large short-term variations, with 20% peak-to-peak amplitude in F250W and 11% in F330W, which are clearly correlated in the two bands. The 2500 Å flux is at 2/3 of its level measured with the FOS in 1995 (Nicholson et al. 1998; Maoz et al. 1998), a change that is likely real.

NGC 4736 – This ringed Sab galaxy has a LINER 2 nucleus, an exceptionally bright central surface brightness in the optical and infrared, and is thought to be an aging starburst (e.g., Waller et al. 2001, and references therein). VLA measurements with resolution 0.″15 reveal an unresolved nuclear source with flux 1.7 mJy at 2 cm (Nagar et al. 2004). There is a 6″ offset between the position of the radio core, and the position of the optical nucleus reported by Cotton et al. (1999), based on a measurement from the digitized Palomar Sky Survey (POSS). However, the optical position of the nucleus given by Cotton et al. (1999) is erroneous. We find agreement to better than 1 arcsecond between the 15 GHz radio core position, the radio core position reported by the VLA-FIRST survey (Becker et al. 1995), the optical position we measure from digitized POSS plates, and the near-IR nuclear position from the 2MASS survey (Jarrett et al. 2003). From all of these, the J2000 coordinates of the radio-through-IR nucleus are RA: $12^h50^m53^s\!.06$ DEC: $41^\circ07'12.''7$.

Maoz et al. (1995) noted a second UV source, of brightness comparable to the nuclear one, 2.″5 to the north of the nucleus (at position angle -2.4°). The distance to this galaxy is $\sim$ 4.9 Mpc, taking the mean between 5.2 Mpc found by Tonry et al. (2001) from surface brightness fluctuations, and 4.66 Mpc found by Karachentsev et al. (2003) based on the tip of the red-giant branch. At this distance, the separation between the two UV sources is 60 pc. Maoz et al. (1995) speculated that the off-nuclear source, which we designate NGC 4736b, could be the active nucleus of a galaxy that had merged with NGC 4736. Perhaps this merger triggered the past starburst and the peculiar morphological and kinematic features observed in this galaxy.

Maoz et al. (1996) measured in 1993 the FOC 2200 Å fluxes of the nuclear UV source, which we designate NGC 4736, and of NGC 4736b, as 19×10^{-17} erg cm^{-2} s^{-1} Å^{-1} and 26×10^{-17} erg cm^{-2} s^{-1} Å^{-1}, respectively. NGC 4736 varied slightly during the current program, and only in the last measurement in F250W. Nevertheless, NGC 4736 was 2.5 times brighter in 2003 than in 1993. Given the large amplitude of the change in NGC 4736, and the reliability of the FOC photometry for several apparently non-variable objects, we believe the factor 2.5 brightening of the nucleus is real. As for NGC 4736b, its mean flux level is similar to that measured in 1993 by Maoz et al. (1996). However, in the present measurements this off-nuclear source shows significant, correlated F250W and F330W fluctuations with peak-to-peak amplitudes of 5%. We note that, due to the large brightnening of the nuclear UV source, NGC 4736b was 30% brighter than NGC 4736 in 1993, while in 2003 the nucleus was 70% brighter than NGC 4736b. We conclude that we have detected long-term UV variations in the nucleus of NGC 4736, and short-term variations in the off-nuclear source NGC 4736b, indicating significant nonstellar contributions to the UV fluxes of both sources. We also note that the two sources have quite different UV colors, with the nuclear source being red and NGC 4736b being blue.

We have searched the VLA archive for deep radio observations of this galaxy, to see if object b has, at any time, shown up as a radio source. We have found seven different VLA epochs of observation of NGC 4736 between December 1984 and February 2000, with useful data at 2 to 20 cm. In addition, NGC 4736 was monitored at eight epochs at 3.5 cm between June and October 2003 by Körding et al. (2005). In none of these radio maps do we see a signal at the position of the northern, off-nuclear, source. The deeper archival images are from December 1984 and January 1985, from which we can put a 3σ upper limit of 150 μJy on the radio flux at 20 cm and 6 cm, respectively, and from December 1988, which puts a 3σ upper limit of 300 μJy at 20 cm. The Körding et al. (2005) data from 2003 place a 3σ upper limit of 150 μJy at each epoch, or an upper limit 60 μJy from the eight epochs combined. Interestingly, in the higher-resolution observations among these datasets, the nuclear source is resolved into two sources of comparable flux, separated by $0\farcs99$, at position angle $-49°$. This second source, which is reported and described in detail by Körding et al. (2005), may be the result of jet activity in the nucleus, or some other radio source that is very close to the nucleus.

High spatial resolution *Chandra* X-ray images of NGC 4736 were obtained by Eracleous et al. (2002). They detected an unresolved nuclear source with a 0.5-8 keV luminosity of 5.9×10^{38} erg s^{-1}, and 39 other sources, presumably X-ray binaries and supernova remnants, distributed around the nucleus. However, they did not detect an X-ray source at the position of NGC 4736b, to a luminosity limit of 1×10^{36} erg s^{-1}. Interestingly, variability data shown by Eracleous et al. (2002) suggest that nucleus may be variable in the X-rays on hour timescales, with a measured excess variance of 0.06 ± 0.04.

Alternatively to the binary AGN scenario, the variable off-nuclear UV source NGC 4736b could be related to jet activity emerging from the nucleus. For example, the off-nuclear source could be at a location where gas is heated by beamed radiation, or it could be synchrotron radiation from freshly accelerated particles at the end of a jet, with a spectrum that is hard enough to avoid detecting this knot in radio. Such a scenario would be reminiscent of NGC 1052, where Kadler et al. (2004) find spatial offsets between optical, X-ray, and radio knots associated with the jet.

To further investigate the nature of the two UV sources requires high spatial resolution optical-UV observations that will elucidate the spectral properties of each of the sources. At present, it is not clear whether the LINER 2 spectrum attributed to the central parts of this galaxy is emitted by the nuclear source NGC 4736a, the off-nuclear source NGC 4736b, or both.

NGC 5055 – This transition H II/LINER 2 nucleus is not variable in our data. The nuclear UV source is clearly extended, with a FWHM of $0.14''$. The 2500 Å flux level, 76.4×10^{-17} erg cm^{-2} s^{-1} Å^{-1}, is virtually identical to that measured with the FOS in 1996 by Maoz et al. (1998), though 25% less than the 1993 FOC measurement by Maoz et al. (1995). The latter difference is also consistent with non-variability, considering the uncertainties in FOC photometry, which are further complicated by the extended nature of this source. Like the other non-variable LINER 2 in our sample, NGC 4569, the FOS UV spectrum of this object indicates a $> 50\%$ hot-star contribution to the UV flux (Maoz et al. 1998). Our results suggest that NGC 5055 is a member of the minority of LINERs whose UV flux is all or mostly from stars.

NGC 6500 – This LINER 2 has several AGN traits, including a radio-core (Nagar et al. 2000), and a jet-like linear structure seen with the VLBA (Falcke et al. 2000) As seen in Fig. 1, and known from previous imaging with WFPC2 by Barth et al. (1998), NGC 6500 does not have a clear nuclear UV source. The UV morphology of the central region consists of a diffuse central light distribution, on which are superposed a number of faint sources, some compact and some extended, within a diameter of $\sim 0\farcs5$. It may actually be a "UV-dark" LINER (like 75% of all LINERs; Maoz et al. 1995; Barth et al. 1998), that happens to possess some scattered circumnuclear star formation. Maoz et al. (1998) noted that its observed UV luminosity at 1300 Å, extrapolated to the far UV, is insufficient to power its Hα luminosity. Terashima & Wilson (2003) found that the nuclear X-ray emission observed with Chandra is anomalously faint given the Hα luminosity and the X-ray vs. Hα correlation observed in other AGNs, and proposed that the nucleus is heavily obscured in X-rays. Our large-aperture measurements for this galaxy (see §2) indicate no variability in F330W, but fluctuations in F250W that are formally significant at 99% confidence, and driven mainly by a 5% drop at the last epoch. There is nothing suspect with the data at this last epoch. There is a compact source $9''$ east of the nucleus that appears in the first two epochs and the last epoch (in the third epoch it is obstructed by the HRC "occulting finger"), and which can serve as a local calibrator. Its flux is constant to 0.7%, and its FWHM is similar at all three epochs. However, we are not certain of the reality of the 5% decline at the last epoch for a number of reasons: the large aperture and the diffuse nature of the object increase the susceptibility of the measurement to small fluctuations due to centering differences. We do not have an independent photometric stability check for such a diffuse source, as we do for the compact nuclear sources, through monitoring of the star cluster NGC 6681 by Boffi et al. (2004) – see §3.2. Indeed, the amplitude of the decline on the last epoch depends on the choice of region used to determine the background level, and for some choices the decline is only 2%. The fairly large variation at one epoch, observed solely in one filter is contrary to what we have seen in all the other objects, where large variations are mirrored in the two bands. We have blinked and compared the images of the four epochs to try to identify a particular knot in the nuclear region that declined in brightness on the last epoch, but have not been able to reach a definitive conclusion. The 2500 Å flux, 31×10^{-17} erg cm^{-2} s^{-1} Å^{-1}, is similar to that measured by Maoz et al. (1998) at 2200 Å from the Barth et al. (1997) FOS spectrum taken in 1994, and to that measured with WFPC2 in 1995 by Barth et al. (1998). In both cases, the UV flux was 27×10^{-17} erg cm^{-2} s^{-1} Å^{-1}. The difference between our, and these earlier, measurements is not significant, especially considering the extended nature of the source.

5. DISCUSSION AND CONCLUSIONS

Our UV monitoring program has revealed, by means of variability, that an AGN component contributes to the UV emission of most UV-bright LINERs. Variability is detected irrespective of spectral type (1 or 2) and whether or not a nuclear radio source has been detected. LINERs are present in the majority of massive galaxies, and the true fraction of LINER galaxies that have a nuclear UV source, after accounting for extinction, is likely close to unity (Barth et al. 1998; Pogge et al. 2000). This conclusion implies that, not only do most galaxies have central black holes, but that the black holes are also accreting and emitting in the UV. The extreme-UV extension of the observed UV, beyond the Lyman limit, is the main ionizing agent in these objects, and it determines the optical line ratios that define LINERs and distinguish them from other nuclei (e.g., H II, Seyfert). Our results provide some of the strongest evidence to date that, in the majority of cases, a LINER spectrum in fact signals the presence of nonstellar activity (i.e., an AGN). Our data confirm previous reports of large-amplitude UV variability in several LINERs (see §1), but now with a stable photometric setup, applied systematically to a moderate-sized sample.

We have identified only three galaxies with UV nuclei that show neither short-term ($\lesssim 1$ yr) nor long-term ($\gtrsim 1$ yr) variations. In all three cases, there is previous evidence that stars dominate the UV emission – based on UV spectra in NGC 4569 and NGC 5055 (Maoz et al. 1998), and on the Seyfert 2 classification (Ho et al. 1997a) in the case of NGC 3486, combined with the fact that the observed UV emission in Seyfert 2s often comes from stars (González-Delgado et al. 1998). However, even in these three cases, it is possible that UV variability would be detected in an experiment with denser or longer-term sampling.

Interestingly, all three galaxies without detected UV variations have no detected radio cores, to 1 mJy sensitivity for NGC 4569 and NGC 5055 (Nagar et al. 2000) and to 0.12 mJy sensitivity for NGC 3486 (Ho & Ulvestad 2001). Conversely, all the LINERs that do have detected radio cores have variable UV nuclei. Of course, there are three galaxies (NGC 404, NGC 3368, and NGC 3642) with no detected radio core that do display UV variations, but radio cores may be revealed by more sensitive observations of these objects. If deeper radio observations revealed cores in the three UV-variable LINERs, but not in the three UV-stable LINERs, a perfect correspondence would exist between the presence of radio cores and UV variability.

Could stars produce the observed UV variations? The 2500 Å luminosities of the variable nuclei in our sample, as seen in Table 2, are distributed more or less evenly in the range $L_\lambda(2500\ \text{Å}) \sim 10^{35.6} - 10^{37.7}$ ergs s^{-1} Å^{-1}. The most luminous "normal" stars are blue supergiants, among which those with effective temperatures of $1 - 3 \times 10^4$ K (spectral classes B0–A0) have the highest near-UV luminosities. Bresolin et al. (2004) recently monitored 70 blue supergiants in the galaxy NGC 300 over a 5-month period, and found 15 of them to be variable, with V-band amplitudes of $8 - 23$%. The mean V band absolute magnitude of these variable supergiants is $M_V = -7.3$, and the most luminous one (of spectral type B9) has $M_V = -8.7$. Using spectral models by Kurucz for B9 supergiants to obtain the flux ratio between the V band and 2500 Å, the UV luminosities for the typical and for the most luminous supergiants are $L_\lambda(2500\ \text{Å}) = 10^{34.6}$ ergs s^{-1} Å^{-1} and $L_\lambda(2500\ \text{Å}) = 10^{35.2}$ ergs s^{-1} Å^{-1}, respectively. Thus, even the least luminous galactic nuclei in our sample have luminosities about an order of magnitude larger than typical blue supergiants, but short-term variability amplitudes of 15–20%, comparable to those of the most variable supergiants. Furthermore, the large amplitude variations we see in many of the LINERs are not expected in supergiants. Therefore, individual supergiants in the galactic nuclei are not plausible candidates for producing the observed level of UV variability in the LINERs.

Stars more luminous than blue supergiants, by an order of magnitude, do exist – Wolf-Rayet (WR) stars (e.g., Conti 2000) and luminous blue variables (LBVs; e.g., Humphreys & Davidson 1994) with bolometric luminosities up to $L_{bol} \sim 10^{40}$ ergs s^{-1}. These are massive stars, nearing the end of their evolution and radiating near the Eddington limit. LBV variation amplitudes on timescales of months are $\lesssim 10$% (Humphreys & Davidson 1994), whereas WN8 stars, which are the most variable among WRs, sometimes vary in the optical by a few percent on week-to-month timescales (Marchenko et al. 1998). Based on luminosity and variation amplitude alone, individual LBVs and WR stars could perhaps produce the UV variations in part of the lower-luminosity half of our sample. However, the variations seen in the most luminous objects in our sample certainly cannot be explained in this way, and, based on continuity, one can then argue that stars are not the source of variations in any of the LINERs. Nevertheless, we cannot rule out the possibility that individual evolved stars dominate the light output in a few of the low-luminosity objects. For example, spectroscopy of NGC 4736b, with a luminosity of $L_\lambda(2500\ \text{Å}) = 10^{36}$ ergs s^{-1} Å^{-1}, could reveal if it is a LBV or WR star, rather than a second merging nucleus.

Returning to the AGN interpretation, the *variable* flux that we have measured in each UV band, in the absence of any extinction corrections, provides a firm *lower* limit to the AGN flux in that band. This observed lower limit can be used to test accretion models for each of these low-luminosity AGNs. It can also be argued that the *total* UV flux provides an *upper* limit on the UV emission, but the sensitivity of the UV to uncertain extinction corrections makes such an upper limit less robust. The VLBA images of Falcke et al. (2000) and Nagar et al. (2002) have shown that at least some of the radio emission in LINERs is contributed by jets, rather than by an actual accretion flow. Anderson et al. (2004) have obtained multifrequency VLBA spectra for the unresolved milli-arcsecond core in six low-luminosity AGNs (including three LINERs, two of which, NGC 4203 and NGC 4579, are in our sample). They showed that the radio spectra are inconsistent with expectations from accretion flows (cf. Nagar et al. 2001), but that the spectra, luminosity, and size limits are consistent with emission from jets that are pointed toward us to within $\lesssim 50^\circ$. The observed radio flux must therefore constitute only an upper limit on radio emission from the accretion flow itself.

Strictly speaking, X-ray data, too, provide only upper limits to the flux from the accretion flow, since even with the excellent spatial resolution of *Chandra*, non-nuclear X-ray sources (low-mass X-ray binaries, supernova remnants, diffuse emission) can be included in the beam, and may contribute to the X-ray flux. As an extreme example, in M32 the nuclear X-ray source produces only 1% of the total X-ray luminosity within a radius of 30 pc of the nucleus (Ho et al. 2003), yet this is the area covered by a $\sim 1''$-diameter beam at 10 Mpc, the typical distance to a galaxy in our sample. Nevertheless, the excellent astrometric agreement ($\lesssim 0\farcs5$) beween X-ray and radio positions in low-luminosity AGNs (e.g., Terashima & Wilson 2003), and the absence of close by ($<$ few arcseconds) X-ray sources indicates that, in most such AGNs, the X-rays originate from the active nucleus.

At optical and IR wavelengths, the nuclear emission cannot be detected, at present, in the face of the bright stellar backgrounds, and in the extreme-UV only indirect, model-dependent estimates of the SED can be obtained by attempting to reproduce the UV-through-IR emission line fluxes and ratios. The current flux limits (lower limits to the emission from the accretion flow in the UV, from our present results, and upper limits in the radio and X-rays, from previous observations) thus provide a potentially powerful test of accretion models. The observed SED can similarly be compared to the predictions of jet models. In this case, the UV emission should be connected to emission at other wavelengths and to the assumed black-hole mass by a relation analogous to the radio/X-ray correlation seen in low-accretion-rate black holes (Merloni et al. 2003; Falcke et al. 2004) We intend to carry out such comparisons to models in a future paper.

Our data for NGC 4736 have revealed the first example of a variable off-nuclear UV source, giving new grounds to previous speculation (Maoz et al. 1995, 1996) that this is a "wandering black hole" from the nucleus of another galaxy that has recently merged with this one. This hypothesis (and the alternative, that it is an individual WR or LBV star, see above) can be tested with straightforward high-spatial-resolution observations in radio, optical, UV, and X-ray bands. The observational evidence for the existence of systems of massive black hole pairs has been reviewed recently by Komossa (2003). The best current candidate for a double AGN is NGC 6240, a relatively nearby (redshift $z = 0.024$) ultraluminous infrared galaxy. Both nuclei of NGC 6240 are probably LINERs (Raffanelli et al. 1997), both are compact radio sources at 1.4 and 5 GHz (Colbert et al. 1994; Gallimore & Beswick 2004), and both emit hard X-ray continua and Fe Kα lines (Komossa et al. 2003). The $1.5''$ separation of the nuclei in NGC 6240, for an assumed distance of 100 Mpc, corresponds to a projected physical scale of ~ 700 pc, compared to only 60 pc between the possible double nuclei of NGC 4736. Another, somewhat more ambiguous, case is NGC 3256, a merging galaxy system at a distance of about 40 Mpc. In this case, two nuclear sources, with a projected separation of $5\farcs2$, i.e., about 1 kpc, are detected in near-infrared and X-rays (Lira et al. 2002) and in radio (Neff et al. 2003), with a radio-to-X-ray flux ratio that is characteristic of low-luminosity AGN. In the central CD galaxy of the cluster Abell 400, the twin-jetted double radio source 3C 75 (Owen et al. 1985), is a spectacular example of a binary AGN, though with a rather large separation of 7 kpc. Identification and study of new examples of binary AGN, especially as nearby as NGC 4736, can shed light on the issue of the rate of coalescence of supermassive black holes (e.g., Quinlan & Hernquist 1997).

We have found a possible UV-color-based indicator of whether a LINER is a type-1 or type-2 object. If confirmed, this would be the first LINER property that is found to be linked with the presence or absence of a broad Balmer emission line component. As we have argued above, reddening by dust is not obviously the mechanism behind the suggested trend – the factor ~ 2 difference in the UV color ratio of type 1s and type 2s, if produced by a dust screen, would correspond to a mere factor of 2.4 increase in the extinction of a hypothetical broad Hα line in LINER 2s. Instead, we argue that the instrinsic color of the UV continuum is related to the existence or the visibility of a BLR. For example, the physical conditions under which a BLR can form could depend on the present accretion mode, which might be reflected in the UV color. Nevertheless, as we have pointed out, some combination of dust, geometry, optical depth and selection effects may be, after all, behind the observed trend of UV color with LINER spectral type. Furthermore, the trend itself needs to be confirmed with a larger sample. This is not a simple task, since we have imaged all known LINERs that have a compact nucleus in the space-UV. A larger sample of such objects could be assembled by means of UV imaging (e.g., with GALEX) and subsequent optical spectroscopic classification to identify the LINERs. UV imaging need not necessarily be from space – the UV nuclei of our current sample are prominent in the F330W band, so such objects could potentially be indentified by ground-based observations near the atmospheric UV cutoff. Larger samples of LINERs could also be produced by studying a fainter sample of galaxies than that of Ho et al. (1997a), based, for example, on the Sloan Digital Sky Survey, or by surveying the Southern hemisphere.

After we submitted this paper, Totani et al. (2005) reported discovering optical nuclear variability in a "blind" variability search among $\sim$ 1000 massive galaxies at redshifts $z \sim 0.3 - 0.4$. They found six nuclei with estimated variability amplitudes of order unity over a one-month timescale, with marginal evidence for day-to-day variations. Spectroscopy of one of the six variable nuclei revealed a LINER spectrum at $z = 0.33$, with an Hα flux implying a specific optical luminosity $L_\lambda = 2 \times 10^{37}$ erg s^{-1} Å^{-1}, quite similar to the objects studied in this paper. It appears plausible that Totani et al. (2005) have discovered, at $z \sim 0.3$, the large-amplitude-variability tail of the variations we have found in nearby LINERs. Assuming that of order one-half of early-type galaxies are LINERs (Ho et al. 1997a), and that one-fourth of LINERs have unobscured optical/UV continua (Maoz et al. 1995; Barth et al. 1998), there would be in the data of Totani et al. of order 100 galaxies of the type we have studied here. Since only one galaxy among the 15 that we monitored with HST on month-long time scales showed a variability amplitude of order unity (NGC 4203, which varied by $\sim 40\%$), it is to be expected that Totani et al. would detect about six such cases.

We thank Tricia Royle for her expert assistance in the implementation of the observing program, and Luis Ho, Eva Schinnerer, Amiel Sternberg, Joe Shields, and an anonymous referee, for useful advice and input. This work was funded in part by grant GO-9454 from the Space Telescope Science Institute, which is operated by AURA, Inc., under NASA contract NAS 5-26555. This research has made use of the NASA/IPAC Extragalactic Database (NED) which is operated by the JPL, Caltech, under contract with NASA. This publication also makes use of data products from the Two Micron All Sky Survey, which is a joint project of the University of Massachusetts and IPAC/Caltech, funded by NASA and the NSF.

REFERENCES

Anderson, J. M., Ulvestad, J. S., & Ho, L. C. 2004, ApJ, 603, 42
Antonucci, R. R. J., & Miller, J. S. 1985, ApJ, 297, 621
Barth, A. J., Filippenko, A. V., & Moran, E. C. 1999a, ApJ, 515, L61
Barth, A. J., Filippenko, A. V., & Moran, E. C. 1999b, ApJ, 525, 673
Barth, A. J., Ho, L. C., Filippenko, A. V., & Sargent, W. L. W. 1998 ApJ, 496, 133
Barth, A. J., Reichert, G. A., Filippenko, A. V., Ho, L. C., Shields, J. C., Mushotzky, R. F., and Puchnarewicz, E. M. 1996, AJ, 112, 1829
Barth, A. J., Reichert, G. A., Ho, L. C., Shields, J. C., Filippenko, A. V., & Puchnarewicz, E. M. 1997, AJ, 114, 2313
Barth, A. J. & Shields, J. C. 2000, PASP, 112, 753
Becker, R. H., White, R. L., & Helfand, D. J. 1995, ApJ, 450, 559
Bietenholz, M. F., Bartel, N., & Rupen, M. P. 2000, ApJ, 532, 895
Boffi, F. R., Bohlin, R. C., & De Marchi, G. 2004, Instrument Science Report ACS 2004-05 (Baltimore: STScI)
Bower, G. A., Wilson, A. S., Heckman, T. M., & Richstone, D. O. 1996, AJ, 111, 1901
Braatz, J. A., Wilson, A. S., & Henkel, C. 1997, ApJS, 110, 321
Bresolin, F., Pietrzyński, G., Gieren, W., Kudritzki, R., Przybilla, N., & Fouqué, P. 2004, ApJ, 600, 182
Cappellari, M. et al. 1999, ApJ, 519, 117
Cecil, G., et al. 2000, ApJ, 536, 675
Claussen, M. J., Diamond, P. J., Braatz, J. A., Wilson, A. S., & Henkel, C. 1998, ApJ, 500, L129
Colbert, E. J. M., Wilson, A. S., & Bland-Hawthorn, J. 1994, ApJ, 436, 89
Colina, L., Garcia Vargas, M. L., Mas-Hesse, J. M., Alberdi, A., & Krabbe, A. 1997, ApJ, 484, L41
Colina, L., & Arribas, S. 1999, ApJ, 514, 637
Colina, L., Gonzalez Delgado, R., Mas-Hesse, J. M., & Leitherer, C. 2002, ApJ, 579, 545
Conti, P. S. 2000, PASP, 112, 1413
Cotton, W. D., Condon, J. J., & Arbizzani, E. 1999, ApJS, 125, 409
Crane, P., et al. 1993, AJ, 106, 1371
Devereux, N., Ford, H., & Jacoby, G. 1997, ApJ, 481, L71
Eracleous, M., Shields, J. C., Chartas, G., & Moran, E. C. 2002, ApJ, 565, 108
Fabbiano, G., Fassnacht, C., & Trinchieri, G. 1994, ApJ, 434, 67
Falcke, H. & Biermann, P. L. 1999, A&A, 342, 49
Falcke, H., Nagar, N.M., Wilson, A.S., & Ulvestad, J.S. 2000, ApJ, 542, 197
Falcke, H., Körding, E., & Markoff, S. 2004, A&A, 414, 895
Ferrarese, L. & Merritt, D. 2000, ApJ, 539, L9
Filho, M. E., Barthel, P. D., & Ho, L. C. 2002, A&A, 385, 425
Freedman, W. L., et al. 2001, ApJ, 553, 47
Gabel, J. R., Bruhweiler, F. C., Crenshaw, D. M., Kraemer, S. B., & Miskey, C. L. 2000, ApJ, 532, 883
Gallimore, J. F. & Beswick, R. 2004, AJ, 127, 239
Gavazzi, G., Boselli, A., Scodeggio, M., Pierini, D., & Belsole, E. 1999, MNRAS, 304, 595
Giveon, U., Maoz, D., Kaspi, S., Netzer, H., & Smith, P.S. 1999, MNRAS, 306, 637
González Delgado, R. M., Heckman, T., Leitherer, C., Meurer, G., Krolik, J., Wilson, A. S., Kinney, A., & Koratkar, A. 1998, ApJ, 505, 174
Heckman, T. M. 1980, A&A, 87, 152
Herrnstein, J. R., et al. 1999, Nature, 400, 539
Ho, L. C., Filippenko, A. V., & Sargent, W. L. W. 1996, ApJ, 462, 183
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
Ho, L. C., Rudnick, G., Rix, H., Shields, J. C., McIntosh, D. H., Filippenko, A. V., Sargent, W. L. W., & Eracleous, M. 2000, ApJ, 541, 120
Ho, L. C., Terashima, Y., & Ulvestad, J. S. 2003, ApJ, 589, 783
Ho, L. C. & Ulvestad, J. S. 2001, ApJS, 133, 77
Humphreys, R. M. & Davidson, K. 1994, PASP, 106, 1025
Jarrett, T. H., Chester, T., Cutri, R., Schneider, S. E., & Huchra, J. P. 2003, AJ, 125, 525
Kadler, M., Kerp, J., Ros, E., Falcke, H., Pogge, R. W., & Zensus, J. A. 2004, A&A, 420, 467
Karachentsev, I. D., et al. 2002, A&A, 389, 812
Karachentsev, I. D., et al. 2003, A&A, 398, 467
Kauffmann, G., et al. 2003, MNRAS, 346, 1055
Kinney, A. L., Bohlin, R. C., Calzetti, D., Panagia, N., & Wyse, R. F. G. 1993, ApJS, 86, 5
Komossa, S., Böhringer, H., & Huchra, J. P. 1999, A&A, 349, 88
Komossa, S., Burwitz, V., Hasinger, G., Predehl, P., Kaastra, J. S., & Ikebe, Y. 2003, ApJ, 582, L15
Komossa, S. 2003, in "The Astrophysics of Gravitational Wave Sources", ed. J. Centrella, AIP, in press, astro-ph/0306439
Körding, E., & Colbert, E., & Falcke, H. 2005, A&A, submitted
Lira, P., Ward, M., Zezas, A., Alonso-Herrero, A., & Ueno, S. 2002, MNRAS, 330, 259
Maoz, D., Filippenko, A. V., Ho, L. C., Rix, H.-W., Bahcall, J. N., Schneider, D. P., and Macchetto, F. D. 1995, ApJ, 440, 91
Maoz, D., Filippenko, A.V., Ho, L.C., Macchetto, F.D., Rix, H.-W., & Schneider, D.P. 1996, ApJS, 107, 215
Maoz, D., Koratkar, A. P., Shields, J. C., Ho, L. C., Filippenko, A. V., & Sternberg, A. 1998, AJ, 116, 55
Marchenko, S. V., Moffat, A. F. J., Eversberg, T., Morel, T., Hill, G. M., Tovmassian, G. H., & Seggewiss, W. 1998, MNRAS, 294, 642
Merloni, A., Heinz, S., & di Matteo, T. 2003, MNRAS, 345, 1057
Miyoshi, M., Moran, J., Herrnstein, J., Nakai, N., Diamond, P., & Inoue, M. 1995, Nature, 373, 127
Nagar, N.M., Falcke, H., Wilson, A.S., & Ho, L.C. 2000, ApJ, 542, 186
Nagar, N. M., Wilson, A. S., & Falcke, H. 2001, ApJ, 559, L87
Nagar, N.M., Wilson, A.S., Falcke, H., & Ulvestad, J.S. 2002, A&A, 392, 53
Nagar, N. M., Falcke, H. & Wilson, A. S., 2004, A&A, in press,
Newman, J. A., Ferrarese, L., Stetson, P. B., Maoz, E., Zepf, S. E., Davis, M., Freedman, W. L., & Madore, B. F. 2001, ApJ, 553, 562
Nicholson, K. L., Reichert, G. A., Mason, K. O., Puchnarewicz, E. M., Ho, L. C., Shields, J. C., & Filippenko, A. V. 1998, MNRAS, 300, 893
Owen, F. N., Odea, C. P., Inoue, M., & Eilek, J. A. 1985, ApJ, 294, L85
Pavlovsky, C., et al. 2004, "ACS Instrument Handbook", Version 5.0, (Baltimore: STScI).

Perlman, E. S., Harris, D. E., Biretta, J. A., Sparks, W. B., & Macchetto, F. D. 2003, ApJ, 599, L65
Pogge, R.W., Maoz, D., Ho, L.C., & Eracleous, M. 2000, ApJ, 532, 323
Quataert, E., di Matteo, T., Narayan, R., & Ho, L. C. 1999, ApJ, 525, L89
Quinlan, G. D. & Hernquist, L. 1997, New Astronomy, 2, 533
Rafanelli, P., Schulz, H., Barbieri, C., Komossa, S., Mebold, U., Baruffolo, A., & Radovich, M. 1997, A&A, 327, 901
Reynolds, C.S., Di Matteo, T., Fabian, A.C., Hwang, U., & Canizares, C.R. 1996, MNRAS, 283, L111
Roberts, T. P. & Warwick, R. S. 2000, MNRAS, 315, 98
Shakura, N. I. & Sunyaev, R. A. 1973, A&A, 24, 337
Shields, J. C., Rix, H., McIntosh, D. H., Ho, L. C., Rudnick, G., Filippenko, A. V., Sargent, W. L. W., & Sarzi, M. 2000, ApJ, 534, L27
Smith, B. J., Harvey, P. M., Colome, C., Zhang, C. Y., Difrancesco, J., & Pogge, R. W. 1994, ApJ, 425, 91
Storchi-Bergmann, T., et al. 1995, ApJ, 443, 617
Tanvir, N. R., Ferguson, H. C., & Shanks, T. 1999, MNRAS, 310, 175
Terashima, Y., Ho, L. C., & Ptak, A. F. 2000, ApJ, 539, 161
Terashima, Y. & Wilson, A. S. 2003, ApJ, 583, 145
Tonry, J. L., Dressler, A., Blakeslee, J. P., Ajhar, E. A., Fletcher, A. B., Luppino, G. A., Metzger, M. R., & Moore, C. B. 2001, ApJ, 546, 681
Totani, T., Sumi T., Kosugi, G., Yasuda, N., Doi, M., & Oda, T. 2005, ApJL, in press, astro-ph/0501520
Tran, H. D. 1995, ApJ, 440, 565
Tremaine, S., et al. 2002, ApJ, 574, 740
Tsvetanov, Z. I., Hartig, G. F., Ford, H. C., Dopita, M. A., Kriss, G. A., Pei, Y. C., Dressel, L. L., & Harms, R. J. 1998, ApJ, 493, L83
Tully, R. B. 1988, "Nearby Galaxies Catalog", Cambridge and New York, Cambridge University Press, 1988, 221 p.
Vermeulen, R. C., Ros, E., Kellermann, K. I., Cohen, M. H., Zensus, J. A., & van Langevelde, H. J. 2003, A&A, 401, 113
Waller, W. H., et al. 2001, AJ, 121, 1395
Watson, W. D. & Wallin, B. K. 1994, ApJ, 432, L35
Wilkes, B. J., Schmidt, G. D., Smith, P. S., Mathur, S., & McLeod, K. K. 1995, ApJ, 455, L13
Wilson, A. S., Yang, Y., & Cecil, G. 2001, ApJ, 560, 689
Wrobel, J. M. 1984, ApJ, 284, 531
Yuan, F., Markoff, S., Falcke, H., & Biermann, P. L. 2002, A&A, 391, 139

TABLE 1
OBSERVATIONS AND PHOTOMETRY

Object (1)	Exp. F250W (2)	Exp. F330W (3)	UT-Date (4)	M.J.D. (5)	f_λ F250W (6)	σ (7)	f_λ F330W (8)	σ (9)
NGC 404	300	300	2002-10-28	175.1	73.57	0.86	85.27	0.90
NGC 1052	300	300	2002-10-18	165.4	7.65	0.27	8.97	0.16
M81	300	300	2002-08-05	91.5	198.35	2.09	126.51	1.31
			2002-11-27	205.9	199.07	2.10	125.77	1.31
			2003-02-02	272.9	214.31	2.25	140.01	1.45
			2003-04-07	336.5	200.98	2.12	130.01	1.35
			2003-06-12	402.3	202.54	2.13	128.93	1.34
NGC 3368	600	300	2002-10-25	172.1	22.53	0.30	30.00	0.36
			2003-05-10	369.0	21.99	0.29	29.63	0.35
NGC 3486	600	300	2003-04-06	335.7	10.70	0.19	18.11	0.24
			2003-05-10	369.4	10.82	0.19	18.11	0.24
	···	1200	2003-06-03	393.5	···	···	18.24	0.20
NGC 3642	300	300	2002-10-02	149.3	25.28	0.41	22.19	0.28
			2003-01-20	259.3	24.50	0.41	22.24	0.28
			2003-04-12	341.3	24.62	0.42	22.34	0.28
			2003-05-26	385.5	23.55	0.40	21.74	0.28
NGC 3998	60	60	2002-07-01	56.0	220.46	2.91	168.38	1.96
			2002-11-13	191.3	210.84	2.82	162.35	1.90
			2003-03-05	303.3	193.63	2.66	145.96	1.74
			2003-04-05	334.4	185.68	2.58	146.38	1.75
			2003-05-29	388.4	182.69	2.56	140.14	1.69
NGC 4203	300	300	2002-07-03	58.7	77.51	0.90	46.45	0.52
			2003-03-05	303.0	54.98	0.68	34.58	0.40
			2003-04-07	336.8	54.20	0.68	35.27	0.41
			2003-04-20	349.0	50.68	0.64	33.69	0.39
			2003-06-13	403.8	53.79	0.67	35.95	0.41
NGC 4258	600	300	2002-07-06	61.1	5.02	0.15	11.58	0.19
			2002-10-21	168.3	4.78	0.14	10.79	0.18
	···	1140	2002-12-07	215.2	···	···	10.82	0.12
		300	2003-04-17	346.5	5.56	0.15	10.82	0.18
			2003-06-28	418.1	5.26	0.15	11.58	0.19
M87	300	300	2003-03-31	329.8	56.24	0.70	48.64	0.54
			2003-05-10	369.0	54.44	0.68	48.19	0.53
NGC 4552	1500	750	2003-03-23	321.7	1.79	0.06	1.34	0.05
			2003-06-03	393.2	2.15	0.06	1.63	0.05
NGC 4569	60	60	2002-07-03	58.1	999.53	10.55	841.30	8.65
			2003-02-02	272.6	983.03	10.38	840.11	8.63
			2003-03-31	329.8	988.35	10.44	832.59	8.56
			2003-04-29	358.0	999.23	10.54	834.64	8.58
NGC 4579	300	300	2003-03-17	315.2	59.05	0.72	40.34	0.46
			2003-04-12	341.9	63.17	0.77	43.42	0.49
NGC 4594	300	300	2003-03-24	322.5	6.93	0.27	14.37	0.21
			2003-05-05	364.9	8.43	0.28	16.13	0.23
			2003-06-09	399.4	7.05	0.27	15.37	0.22
NGC 4736	300	300	2003-03-20	318.6	47.63	0.61	72.87	0.78
			2003-04-03	332.8	47.09	0.61	74.03	0.79
			2003-04-17	346.6	47.75	0.62	72.72	0.78
			2003-06-21	411.2	49.48	0.63	73.19	0.78
NGC 4736b	300	300	2003-03-20	318.6	28.21	0.44	20.74	0.27
			2003-04-03	332.8	29.94	0.45	21.32	0.27
			2003-04-17	346.6	28.27	0.44	20.42	0.27
			2003-06-21	411.2	29.64	0.45	21.50	0.28
NGC 5055	300	300	2002-07-19	74.0	77.57	0.92	91.32	0.97
			2003-03-12	310.3	77.27	0.92	89.56	0.95
			2003-03-31	329.9	76.38	0.91	90.48	0.96
			2003-04-22	351.1	75.66	0.90	91.24	0.97
			2003-07-02	422.5	75.00	0.90	91.30	0.97
NGC 6500	300	300	2002-07-06	61.0	31.49	0.62	27.11	0.37
			2003-04-13	342.1	31.85	0.62	27.27	0.38
			2003-04-20	349.9	32.51	0.63	26.63	0.37
			2003-06-10	400.3	29.70	0.61	27.58	0.38

NOTE. — (2)-(3)- Exposure time, in seconds. An empty entry indicates the same exposure time as above it; (5)- Modified Julian Date −2452400; (6)-(9)- Nuclear flux densities and 1σ errors in units of 10^{-17} erg cm^{-2} s^{-1} Å^{-1}. NGC 4736b is the off-nuclear UV source in NGC 4736. See text for details of photometry and calibration.

TABLE 2
MEASURED PROPERTIES

Object (1)	type (2)	radio (3)	D Mpc (4)	Ref (5)	$\bar{f}_\lambda$ F250W (6)	$\bar{f}_\lambda$ F330W (7)	$\log L_\lambda$ F250W (8)	UV color (9)	n (10)	$\chi^2_{\rm dof}$ F250W (11)	$\Delta/\bar{f}$ F250W (12)	$\chi^2_{\rm dof}$ F330W (13)	$\Delta/\bar{f}$ F330W (14)	Δ color (15)	σ (16)
NGC 404	2	N	3.05	a,b	73.57	85.27	36.11	.97	1	...	...	...	...	...	...
NGC 1052	1	Y	18.03	a	7.65	8.97	36.57	.90	1	...	...	...	...	...	...
M81	1	Y	3.63	a,e	203.05	130.25	36.77	1.83	5	**9.28**	.08	**18.36**	.11	.97	.02
NGC 3368	2	N	10.67	a,f	22.26	29.81	36.58	.78	2	1.73	.02	.55	.00	.97	.03
NGC 3486	2	N	7.40	g	10.76	18.15	35.93	.62	2	.20	.00	.15	.00	1.00	.03
NGC 3642	1	N	27.50	g	24.49	22.13	37.40	1.13	4	**3.22**	.07	.91	.02	1.04	.03
NGC 3998	1	Y	13.14	a	198.66	152.64	37.68	1.34	5	**41.01**	.19	**51.13**	.18	1.00	.03
NGC 4203	1	Y	15.14	a	58.23	37.19	37.26	1.60	5	**263.09**	.46	**160.50**	.34	1.11	.02
NGC 4258	?	Y	7.30	a,c,i	5.16	11.12	35.59	.48	5	**5.08**	.15	**5.20**	.07	1.08	.05
M87	1	Y	15.42	a,h	55.34	48.42	37.29	1.19	2	3.52	.03	.35	.00	1.02	.02
NGC 4552	?	Y	15.35	a	1.97	1.49	35.89	1.44	2	**18.62**	.18	**16.17**	.19	.99	.06
NGC 4569	2	N	11.86	h	992.54	837.16	38.38	1.30	4	.60	.01	.24	.00	1.01	.02
NGC 4579	1	Y	20.99	h	61.11	41.88	37.65	1.58	2	**14.62**	.07	**20.00**	.07	.99	.02
NGC 4594	2	Y	9.08	a	7.47	15.29	35.97	.52	3	**9.32**	.19	**16.25**	.11	1.08	.06
NGC 4736	2	Y	4.89	a,d	47.99	73.20	36.21	.68	4	**2.69**	.05	.56	.01	1.03	.02
NGC 4736b	?	N	4.89	a,d	29.01	20.99	35.99	1.43	4	**4.03**	.06	**3.33**	.05	1.01	.03
NGC 5055	2	N	7.40	g	76.38	90.78	36.77	.87	5	1.44	.03	.63	.01	1.01	.02
NGC 6500	2	Y	39.70	g	31.39	27.15	38.07	1.38	4	**3.92**	.09	1.10	.03	1.06	.03

REFERENCES. — a - Tonry et al. (2001); b - Karachentsev et al. (2002); c - Newman et al. (2001); d - Karachentsev et al. (2003); e - Freedman et al. (2001); f - Tanvir et al. (1999); g - Tully (1988); h - Gavazzi et al. (1999); i - Herrnstein et al. (1999).

NOTE. — (2)- Type-1 or type-2 object, depending on presence or absence, respectively, of broad Hα. NGC 4258 and NGC 4552 do not fall easily into either category (see text), and the spectral type of the off-nuclear source NGC 4736b is unknown. These three are marked with a "?"; (3) - compact radio core detected (Y) or undetected (N); (4) - distance; (5) - distance reference (see below). When several measurements exist for a galaxy, their average was adopted; (6)-(7) - flux density, averaged over all epochs, in units of $10^{-17}{\rm erg\,cm^{-2}\,s^{-1}\,Å^{-1}}$; (8) - log of monochromatic luminosity at 2500 Å, corrected for Galactic extinction, in units of ergs ${\rm s^{-1}\,Å^{-1}}$; (9) - UV color, f_λ(F250W)/f_λ(F330W), after correction for Galactic reddening (see text); (10) - number of epochs at which observations were made; (11), (13) - χ^2 per degree of freedom compared to a constant at the mean level. Values implying variability at > 95% confidence are in boldface; (12), (14) - peak-to-peak variation amplitude, with noise subtracted in quadrature, as a fraction of mean flux; (15)-(16) - UV color change between the two epochs with extreme fluxes – $[f_{\rm max}$(F250W)/f_{max}(F330W)]/ $[f_{min}$(F250W)/f_{min}(F330W)] – and its uncertainty.