An Atlas of *Hubble Space Telescope* Ultraviolet Images of Nearby Galaxies

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**ABSTRACT**

We present an atlas of UV (\(\sim 2300\) Å) images, obtained with the *Hubble Space Telescope* (*HST*) Faint Object Camera, of the central \(22'' \times 22''\) of 110 galaxies. The observed galaxies are an unbiased selection constituting about one half of a complete sample of all large (\(D > 6''\)) and nearby (\(V < 2000\) km s\(^{-1}\)) galaxies. This is the first extensive UV imaging survey of normal galaxies. The data are useful for studying star formation, low-level nuclear activity, and UV emission by evolved stellar populations in galaxies. At the *HST* resolution (\(\sim 0.05''\)), the images display an assortment of morphologies and UV brightnesses. These include bright nuclear point sources, compact young star clusters scattered in the field or arranged in circumnuclear rings, centrally-peaked diffuse light distributions, and galaxies with weak or undetected UV emission. We measure the integrated \(\sim 2300\) Å flux in each image, classify the UV morphology, and examine trends between these parameters and the optical properties of the galaxies.

**Subject headings:** atlases – ultraviolet: galaxies – galaxies: structure – galaxies: active – galaxies: star clusters – galaxies: nuclei
1. Introduction

Ultraviolet (UV) imaging is a powerful tool for the study of galaxies. Recent star formation and low-level nuclear activity can be traced and measured in UV images, unhindered by the bright background of the older stellar populations which dominate in visual bands. The source of UV emission in some quiescent early-type galaxies can also be studied with UV imaging. Prior to the launch of the Hubble Space Telescope (HST), few galaxies were imaged in the UV. These few were mostly Local Group spiral galaxies observed at low angular resolution using rocket-borne telescopes on brief flights (see Bohlin et al. 1990, and references therein). This situation has improved in recent years with the flight of UV-imaging telescopes on the Space Shuttle (e.g., Landsman et al. 1992; Hill et al. 1992), although the angular resolution is still low and the number of galaxies observed is small, due to the limited mission duration. In this respect, HST, with its high sensitivity and angular resolution, has opened up a new frontier. Summaries of recent HST UV-imaging studies of galaxies appear in Benvenuti, Macchetto, & Schreier (1996).

We have carried out a UV imaging survey with the pre-COSTAR HST Faint Object Camera (FOC) of the central regions of 110 large nearby galaxies, selected randomly from a complete sample of 240 galaxies. The main purposes of the survey are (a) to detect low-luminosity active galactic nuclei (AGNs), exploiting the high contrast of a nuclear UV continuum source above the low UV background from stars, and (b) to study star formation in the central regions of the galaxies; by observing at ∼ 2300 Å, the survey images detect primarily the youngest existing stellar populations and thus provide a clean probe of the most recent sites of active star formation, uncontaminated by light from more evolved stars. The power of this technique, especially when augmented by the high HST angular resolution, has been recently demonstrated in UV studies of starbursts by Conti & Vacca (1994), Meurer et al. (1995), and Maoz et al. (1996).

Maoz et al. (1995) presented data from the survey for nine galaxies displaying bright compact nuclear UV sources, five of which are potential low-luminosity AGNs. Maoz et al. (1996) analyzed the images of five additional galaxies having circumnuclear star-forming rings, and showed that much of the star formation in the rings is confined to massive compact clusters that are probably bound. In a forthcoming work (Ho et al. 1996b) we will use the UV images to analyze the star-formation properties of all the galaxies in the sample.

In this paper, we present images and basic data for the 110 galaxies observed. The images provide a reference for the UV brightness and morphology of the galaxies in the sample, which can be used as a general guide to the UV properties of the centers of galaxies, and as an aid in extracting the actual data from the HST archive. We also provide a classification of the UV morphology, additional notes on some of the galaxies and what is seen in their images, and a measurement of the ∼ 2300 Å flux integrated over the image. We tabulate these together with the larger-scale properties of the galaxies and (for the northern galaxies) the spectroscopic nuclear classification from Ho, Filippenko, & Sargent (1995, 1996a). In §2, below, we describe the sample selection and the observations. In §3 we present tables listing the galaxy parameters, a pictorial atlas of the data, and notes on some of the individual galaxies. In §4 we intercompare the UV and optical properties of the galaxies and provide a brief summary.

2. Observations

The sample from which the observed galaxies were chosen consists of all galaxies in the UGC and ESO catalogs (Lauberts & Valentijn 1989) with heliocentric velocities available in the literature and less than 2000 km s$^{-1}$, and photographic diameters (as defined in the catalogs) greater than 6′. A total of 22 galaxies were removed from this initial sample of 262 galaxies during subsequent stages of the sample definition. In 21 of these, no nuclear position could be defined because they were too diffuse, too low in surface brightness, or edge-on with strong dust lanes. One galaxy (ESO 1331−4517) had a bright foreground star near the nucleus, which would have endangered the HST instruments. This left a well-defined sample of 240 galaxies with observable nuclei.

Twenty-seven galaxies from this sample were not included in our target list because they were proposed targets of other HST UV-imaging programs. However, we have subsequently obtained from the HST archive the data for seven of these galaxies which were actually observed with an instrumental configuration similar to the one we used (FOC + UV filter at ∼ 2300 Å).

Digitized photographs from the GASP archive at
Space Telescope Science Institute (STScI) of all potential target galaxies were examined and the coordinates of the nucleus determined to \( \sim 1'' - 2'' \) precision by computing the centroid of the light distribution. In a few cases, as evidenced by the eventual HST images, the galaxy nucleus position was off by up to \( \sim 5'' \), due to isophote distortion by dust features in the GASP images.

The observations were done in Snapshot mode – i.e., targets were chosen from the target list by the STScI staff based on the convenience of their location on the sky. The brief exposure was used to fill the gaps left in the observing schedule after other science programs had been scheduled. The observed galaxies are therefore an unbiased selection from the complete sample.

Among the galaxies described in this paper, 103 were successfully observed with HST while the program was active, in 1993, March through July. We supplement these observations with data for the seven out of the 27 “embargoed” galaxies that were observed with HST between 1991 and 1995. We therefore have data for a total of 110 galaxies out of the complete sample of 240 galaxies. Observations were unsuccessful for four galaxies due to wrong coordinates (NGC 660) or telescope malfunction (NGC 3714, ESO 0514–3709, and NGC 3137); we do not count these among the successful 110 observations, even though data files for them exist in the HST archive.

All of our images were obtained with the HST f/96 FOC (Paresce 1990) in its “zoomed” 1024 x 512-pixel mode with 0.022'' x 0.044'' pixels, giving a field of view of 22'' x 22''. The F220W filter was used. This is a broad-band filter with an effective wavelength of \( \sim 2300 \) Å and effective bandpass of \( \sim 500 \) Å. The exposure time was 10 minutes per galaxy. We will refer to this configuration and exposure time as the “standard setup.” The images were processed by STScI’s “pipeline” reduction (Baxter et al. 1994), after which the pixel scale is 0.0225''/pixel\(^{-1}\). The data were obtained before the HST repair mission at the end of 1993, and therefore are affected by spherically aberrated optics. As a result, the point-spread function (PSF) consists of a sharp core of full width at half maximum (FWHM) \( \sim 0.05'' \) that contains about 15% of the light, with the rest of the light spread in a complex low-level “halo” with a radius of several arcseconds (Burrows et al. 1991). In the observing mode we have used, the FOC is limited in its dynamic range to 255 counts (8 bits) per zoomed pixel; additional signal causes the counts to “fold over” and start again from 0. Another problem is that the detected count rate becomes nonlinear, gradually saturating for bright sources (see Baxter et al. 1994). The central pixels of most of the compact bright sources detected in the images may be in the nonlinear regime, and the brightest of them are clearly saturated. In several galaxies where we report the brightness and/or angular size of individual compact sources, our analysis relies mainly on the wings of the PSF, which have low count rates (\( \lesssim 0.05 \) s\(^{-1}\) pixel\(^{-1}\)), using the algorithms described by Maoz et al. (1995, 1996). We model the PSF using a well-exposed F220W image of a star observed with the FOC f/96 256 x 256 pixel mode, which has a large dynamic and linear range (but small field of view). Such empirical PSFs are required for work in the UV (Baxter et al. 1994).

As in Maoz et al. (1995, 1996), we translate the FOC counts to a flux density \( f_\lambda \) at 2270 Å assuming 1 count s\(^{-1}\) = 1.66 x 10\(^{-17}\) erg s\(^{-1}\) cm\(^{-2}\) Å\(^{-1}\), based on the on-line calibration data available from STScI for the FOC and F220W filter, with a 25% increase in sensitivity of the 512 x 1024 zoomed-pixel mode relative to the 512 x 512 pixel mode (Baxter et al. 1994). This calibration assumes a spectrum that is constant in \( f_\lambda \). As detailed in Maoz et al. (1995), the F220W count-rate vs. \( f_\lambda \) at 2270 Å is weakly dependent on the spectral slope, with a change of only a few percent for a large range in slopes. The uncertainty in the absolute flux is \( \sim 20\% \) when measuring individual compact sources (Baxter et al. 1994), but can be as small as \( \sim 5\% \) when measuring the UV flux integrated over large areas (e.g. \( \sim 150 \) arcsec\(^2\); Meurer 1995), if the background can be reliably determined.

An additional concern in UV imaging photometry is the presence of “red leaks” through the F220W filter, which we define as light of wavelength \( \lambda > 3200 \) Å that may pass the low, but non-zero, transmission of the filter at these wavelengths. This can be a problem when observing very red sources, e.g., the centers of the early-type galaxies in our sample. Tests by the FOC team indicate that the F220W transmission curve is not significantly changed from that measured before launch (Baxter et al. 1994), i.e., it peaks at \( \sim 2200 \) Å and falls monotonically to the red, decreasing by a factor of \( \sim 1000 \) between 2200 Å and 4400 Å. Using this transmission curve together with the FOC+HST efficiency as a function of
wavelength, and the spectral energy distribution templates of early-type galaxies measured by Kinney et al. (1996), we calculate that a $V$-band surface brightness of 13.7 mag arcsec$^{-2}$ produces one red-leak count per dezoomed pixel in a 600 s FOC+F220W exposure. In other words, an (unrealistic) galaxy with no flux below 3200 Å needs to have a $V$ surface brightness brighter than 13.7 mag arcsec$^{-2}$ in order to be detected through the red leak in our standard setup.

Lauer et al. (1995) have measured with the pre-COSTAR HST the $V$-band surface-brightness profiles of 45 nearby early-type galaxies. None of their galaxies have an observed (i.e. before deconvolution of the aberrated PSF) surface brightness brighter than 13.7 mag arcsec$^{-2}$ within a radius of 0.1”, so none would have a detected red-leak signal in our FOC exposures, even within this small (4.4 FOC pixels) radius. At a radius of 1”, where we can still detect a clear UV signal with the FOC from many of the early-type galaxies in our sample, Lauer et al. (1995) measure a surface brightness of 15 mag arcsec$^{-2}$ for the brightest galaxies in their sample, and typically 17–18 mag arcsec$^{-2}$. We conclude that, even without any assumptions about the shape of the spectrum at wavelengths $\lambda < 3200$ Å, the red leak contributes negligibly to the signal we detect from the reddest galaxies over most of the field of view.

We note that NGC 2997, a spiral galaxy with a circumnuclear ring, has an HST WFPC2 6000 Å image which Maoz et al. (1996) have analyzed in conjunction with its FOC 2300 Å image. We have convolved the 6000 Å image, which is free of spherical aberration, with the pre-COSTAR PSF, and measured the surface-brightness profile. The nuclear region, which at a radius of 0.1” has a $V$ surface brightness of 14.6 mag arcsec$^{-2}$, is expected to produce only 0.4 FOC counts pixel$^{-1}$ through the F220W red leak. The nuclear region is, indeed, undetected in the UV image, as expected if the F220W transmission curve has its pre-launch values longward of 3200 Å. This comparison also sets an upper limit, of a factor of 2, by which the F220W transmission curve could be off from its pre-launch value. As a further test, we note that two of the galaxies for which Lauer et al. (1995) present $V$-band profiles, NGC 1023 and NGC 4636, are in our sample as well, and for both we detect with the FOC faint centrally-peaked diffuse light distributions. In NGC 1023, we measure with the FOC 2.3 counts pixel$^{-1}$ at the 0.1” radius, while Lauer et al.’s (1995) observed $V$-band surface brightness at this radius, of 14.8 mag arcsec$^{-2}$ (T. Lauer, private communication), is similar to that of NGC 2997, which produces no detected F220W counts. NGC 4636 has 1/2 as many FOC counts as NGC 1023 at 0.1”, even though its observed $V$ surface brightness is 8 times lower at this radius (T. Lauer, private communication). The FOC counts for both NGC 1023 and NGC 4636 must therefore be dominated by true UV flux. This is also confirmed for NGC 1023 by the flux at 2300 Å measured with the International Ultraviolet Explorer (IUE; Kinney et al. 1993), which is consistent with the flux deduced from the FOC observation, assuming no red leak (see §3.3).

The seven archival images which we also include in this atlas were obtained with different FOC formats, UV filters, and exposure times, providing modified fields of view, bandpasses, and sensitivities. One of these, of NGC 4151, was obtained in 1995, after the first HST servicing mission, and so is free of spherical aberration. We elaborate on these differences for each archival exposure in §3.3.

3. The Atlas

3.1. Tables

The parameters of the 110 observed galaxies are listed in Table 1 (southern galaxies) and Table 2 (northern galaxies). Following is a column-by-column description of the table entries, and how they are derived.

(1) NGC designation of the galaxy. Footnote “a” denotes archival images, generally obtained with a different FOC format, filter, or exposure time than those of the program galaxies. See §3.3 for details.

(2) UGC designation of the galaxy (northern galaxies only).

(3) 1950 coordinates, to one-minute accuracy, as listed in the UGC and ESO catalogs. This datum can be useful for unambiguously identifying the galaxies in these and other catalogs, since listed coordinates for such large galaxies may vary by arcminutes from catalog to catalog. Also, some galaxies in the ESO catalog are designated solely by means of these coordinates.

(4)(5) J2000 coordinates of the nucleus, as measured in the STScI GASP system (see §2). These coordinates are generally accurate to $\sim 1” - 2”$.

(6) $V_h$ – Heliocentric velocity, as listed in the UGC
or ESO catalogs, in km s$^{-1}$. The selection criterion for inclusion in the sample was $V_b < 2000$ km s$^{-1}$.

(7)(8) $D_a$, $D_b$ – Major and minor axis diameters, in tenths of arcminutes, from the UGC and ESO catalogs. The selection criterion for inclusion in the sample was $D_a > 60$.

(9) $B_{mag}$ – Integrated $B$ magnitude, from the UGC and ESO catalogs.

(10) $T$ – Hubble type, using de Vaucouleurs’ T-type classification from the RC3 catalog (de Vaucouleurs et al. 1991). The correspondence is approximately as follows: E: $-6$ to $-4$; S0: $-3$ to 0; Sa: 1; Sb: 3; Sc: 5; Sd: 7; Irr: 10.

(11) Classif. – Hubble type and luminosity class using the classification, when available, from the Revised Shapley-Ames Catalog of Bright Galaxies (Sandage & Tammann 1987).

(12) Sp. – (northern galaxies only) – Spectral classification of the nucleus, from Ho et al. (1995, 1996a). The designation is as follows. L – LINER (low-ionization nuclear emission-line region); H – H II nucleus; T – “transition” source, between LINER and H II; S – Seyfert nucleus; A – “absorption-line” nucleus with no detected emission lines. A colon denotes an uncertain classification. The Ho et al. classification is based on the Filippenko & Sargent (1985, 1986) optical spectroscopic survey of the nuclei of a flux-limited ($B < 12.5$ mag) sample of 486 northern galaxies. All but three of the northern galaxies in the HST survey (which is diameter- and redshift-limited) are included in the Filippenko & Sargent (1985) sample. The effective aperture of the optical observations is $2'' \times 4''$. The Ho et al. (1996a) classification is assigned after careful subtraction of absorption-line template spectra, leaving behind only the emission-line residual; see Ho et al. (1996a) for further details.

(13) HST UT observation date.

(14) Image rootname in the HST archive, useful for retrieving the actual data.

(15)(16) $f_{UV}, \sigma$ – Total $f_\lambda$(2270 Å) in units of $10^{-15}$ erg s$^{-1}$ cm$^{-2}$ Å$^{-1}$, integrated above the background over the entire area of the image, and 1$\sigma$ uncertainty. The area of each image is $22'' \times 22''$, except for some of the archival exposures (marked with footnote “a” in column 1), which were taken with a different FOC format. See §3.3 for details. The background was determined as follows. The mean counts per pixel were measured in seventeen $200 \times 200$-pixel squares in the frame, excluding occulting fingers and distortions in the FOC field (see Baxter et al. 1994), and the median counts per pixel were measured over the entire exposed part of the frame. The mean of the two lowest among these 18 measurements was used as the background value, and the standard deviation of the five lowest among the 18 measurements was used as the uncertainty in the background. The uncertainty in the background was propagated to an uncertainty on the total net counts in the image. The count rate above the background was converted to a UV flux density as described in §2. The flux uncertainty due to the background uncertainty was combined in quadrature with a 5% absolute calibration uncertainty (Meurer 1995) to produce the quoted flux uncertainty. Except for bright and concentrated sources, the flux uncertainty is dominated by the uncertainty in the background determination. The cause of artificial background variations across the image is imperfect flat-fielding. Furthermore, a systematic error in background determination is unavoidable due to the small field of view, which covers only a fraction of the optical extent of these galaxies. Some of this systematic error is accounted for by the above procedure for estimating the background uncertainty. Nevertheless, the total UV fluxes quoted here agree well with the 2300 Å fluxes measured for those galaxies that have also been observed with IUE (Kinney et al. 1993; see also Meurer 1995), which has a comparable entrance aperture. This suggests that the regions of the images with the lowest counts are, in fact, devoid of significant UV emission. The UV fluxes given here should be used with care, and in conjunction with the UV-morphology classification (column 17) and the visual appearance of the image. For example, there is low significance to the flux that is listed for a galaxy whose image appears blank. The UV fluxes are uncorrected for Milky Way or external extinction.

(17) Morph. – UV morphologies roughly describing the HST image, with the following symbols. B – blank image; W – weak or nearly absent UV emission; S – star-forming morphology, with knots and compact sources of UV emission; F – diffuse, centrally concentrated emission; P – unresolved nuclear point-source; R – circumnuclear star-forming ring. Some comments on each of these types follow.

We have rechecked the coordinates and pointing of the blank (“B” morphology) images, and verified that they are not cases of telescope mispointing. As a check on the pointing accuracy, there are about 40
images which display a feature that can be securely associated with the nucleus of the galaxy. In almost all cases it is within 3″ of the center of the image, as expected from the combined uncertainty in the GASP coordinates of the nucleus and the HST pointing accuracy. In the few cases where the nucleus is further from the image center, this has been traced to inaccurate input coordinates (see §3.3). The blank images are also not the result of foreground Milky-Way extinction, except for two galaxies, NGC 1560 and NGC 6946, which lie near the Galactic plane. Dust in the disks of the galaxies themselves is probably a factor, since 10 out of 13 galaxies with B morphologies have minor-to-major axis ratios less than 0.5 (i.e., an inclination > 60°). The fact that the centers of many galaxies are weak UV emitters is confirmed by the detection of very weak (“W-type”) but significant and centrally concentrated emission in many of the galaxies, which establishes that the galactic nucleus is, indeed, in the field of view.

The compact sources seen in the “S-type” morphologies are probably compact young star clusters, or in some cases individual O and B stars. Similar objects have been detected with HST in a variety of starburst environments (e.g., Meurer et al. 1995; Maoz et al. 1996). They will be studied in further detail by Ho et al. (1996b).

The diffuse “F-type” emission occurs in some of the early-type spirals and the ellipticals in the sample. We believe that, in general, this observed feature is dominated by actual UV emission from an evolved spheroidal stellar population (the “UV-upturn”; see, e.g., Burstein et al. 1988), rather than visual-band emission leaking through the F220W filter, based on several tests described in §2. In individual cases, however, confirmation by means of blue and near-UV imaging photometry of the center of each of these galaxies is required.

Galaxies with bright nuclear UV point sources (“P-type”) have been discussed in detail by Maoz et al. (1995), especially in the context of low-luminosity AGNs. They showed that ~ 20% of the northern LINER galaxies display a nuclear point source in the FOC images, with a UV flux that, if extrapolated beyond the Lyman limit, could be sufficient to produce the observed strength of optical emission lines through photoionization. While this was the first direct detection of what may be the AGN-like ionizing source in LINER galaxies, it raised the question of why such a source is not detected in 80% of LINERs. Several of the P-type sources in in this paper, especially the weak ones and those in archival images, were not included in Maoz et al. (1995). However, the fraction of “UV-bright” LINERs, or LINERs plus Seyferts, remains unchanged. For example, among the 35 northern galaxies with spectral classification T, L, or S (transition-type, LINER, or Seyfert), nine have a nuclear UV point source.

The five circumnuclear rings in the sample (designated “R”) have been discussed in detail by Maoz et al. (1996), who showed that a large, possibly dominant fraction of the UV light in these objects is emitted by the numerous compact sources distributed along the rings. These sources are probably young and massive star clusters that will remain bound, similar to those seen with HST in other starburst environments.

3.2. Pictorial Atlas

Figures 1 and 2 are grey-scale representations of the FOC images of the southern and northern galaxies, respectively. Each of the six frames on each page has a scale of 22″ × 22″, and has been rotated so that north is up and east is to the left. Archival exposures are marked with an asterisk next to the galaxy name, and in some cases have a different field of view and sensitivity; see §3.3 for details. The grey scale of each image is chosen to bring out the most interesting details. However, these snapshots cannot convey all of the useful information in many of the images, and the reader is advised to refer to §3.3, or to retrieve the actual data from the HST archive, if complete details are required. This is true both for bright sources, where a single grey scale cannot show details of different contrast, and for weak sources (“W-type” morphology), where the faint emission is lost in the reproduction.

3.3. Notes on Individual Objects

3.3.1. Southern Galaxies

NGC 247 (0044−2102).– This late-type galaxy has a bright UV point source at a position consistent with the optical nucleus of the galaxy, which has an H II-like spectrum (Maoz et al. 1995). In addition there are numerous compact sources in the image. See Maoz et al. (1995) for further details.

NGC 300 (0052–3757).– There are about a dozen
compact sources in the UV image, the brightest of which is resolved (FWHM ≈ 0.2") and is probably at the nucleus of this face-on Sd galaxy. The second brightest source, 3" to the east, is unresolved (FWHM < 0.1").

NGC 1079 (0241−2912).– The small (4" diameter) circumnuclear star-forming ring seen in the HST image of this S0 galaxy was discovered by this survey. A detailed study, including rotation curves along the major axis and photometry of the compact young star clusters that contribute much of the UV light, can be found in Maoz et al. (1996).

NGC 1291 (0315−4117).– The central peak of the diffuse UV-light distribution may be unresolved in this SBa galaxy.

NGC 1332 (0324−2130).– This is an inclined S0 galaxy. A thin, unresolved dust lane crosses the diffuse light distribution about 0.3" northeast of the central peak from south-east to north-west, along the orientation of the galaxy’s major axis.

NGC 1385 (0335−2440).– This is a disturbed-looking Scd galaxy. The field of view includes part of some large structure, possibly the western spiral arm of the galaxy, that is bright in the UV and includes compact sources and diffuse emission. The UV-dark northern portion of the image is at the end of a large dusty spiral arm that crosses the northern part of the galaxy in optical images. The nuclear position is difficult to determine in optical images, and the bright knot on the western side of the UV image could be the galaxy nucleus.

NGC 1433 (0340−4722).– The circumnuclear star-forming ring seen in the UV image of this SBb galaxy is studied in detail by Maoz et al. (1996).

NGC 1512 (0402−4329).– The circumnuclear star-forming ring seen in the UV image of this SBB galaxy is studied in detail by Maoz et al. (1996); ~ 40% of the UV light comes from compact young star clusters distributed along the ring. About 25% of the UV light is from the single bright “super star cluster” on the south-east side, which has an observed UV luminosity L_\lambda (2300\AA) \approx 10^{37} \text{ erg s}^{-1} \text{ A}^{-1} and a radius of only 2–3 pc.

NGC 1543 (0411−5751).– The UV image of this SB0/a galaxy shows a centrally-peaked diffuse light distribution with an unresolved core or a faint central point source.

ESO 0450−2519. – The single weak source detected in this diffuse late-type spiral galaxy is unresolved or marginally resolved.

NGC 2997 (0943−3057).– This circumnuclear star-forming ring is studied in detail by Maoz et al. (1996). Utilizing also a V-band HST exposure of this galaxy, they show that the numerous compact (few pc radius) sources distributed along the ring are most probably young (< 100 Myr) and massive (\sim 10^5 M_\odot) clusters of stars that are gravitationally bound. These clusters, which appear similar to those in the many galaxies with “S-type” UV morphology presented here, may therefore evolve into objects similar to globular clusters.

NGC 4976 (1305−4914).– The UV image of this bright S0 galaxy shows only a faint, centrally-peaked diffuse light distribution with an unresolved core or a weak central point source.

NGC 5084 (1317−2133).– The UV image of this S0 galaxy shows only a faint, centrally-peaked diffuse light distribution with an unresolved core or a very weak central point source, with flux of order a few 10^{-18} \text{ erg s}^{-1} \text{ cm}^{-2} \text{ A}^{-1}.

NGC 5102 (1319−3622).– The archival UV image of this nuclear-starburst S0 galaxy (e.g., Bica & Alloin 1987) is a 1137 s F220W exposure with the 512 \times 512 pixel f/96 FOC format, which gives a field of view of 10'' \times 10''. A bright, unresolved central point source is evidenced by the saturated central pixels and the sharp diffraction rings, surrounded by a high surface-brightness elliptical light distribution with major axis oriented north-east to south-west. A linear structure, probably an edge-on disk, can be traced out to about 1'' from the nucleus on both sides along the same direction.

NGC 5253 (1337−3123).– This nearby (4.1 Mpc; Sandage et al. 1994) starburst galaxy has been studied from radio to X-ray wavelengths, including IUE UV spectroscopy, which has revealed Wolf-Rayet spectral features (see Kinney et al. 1993, and references therein, for a summary). The FOC image presented here has been extensively studied by Meurer et al. (1995). This archival HST image is a 500 s exposure with the F220W filter plus a F1ND neutral-density filter, which provides a factor 2.5 attenuation in flux. The exposure is therefore 1/3 as deep as our standard-setup exposures. Nevertheless, the image shows numerous bright sources. As shown by Meurer et al. (1995), these are compact young star clusters of the type detected with HST in other starburst environments, as well as individual stars. This galaxy has the highest total UV flux in the sample.

ESO 2159−5132. – The image of this nearby irreg-
ular galaxy shows a large number of compact sources, most of which are probably individual O and B stars.

NGC 7462 (2260−4106). The compact sources and diffuse emission in this nearly edge-on Sc galaxy are concentrated in a narrow strip running approximately east-west, along the galaxy’s major axis.

ESO 2333−3903. This faint but strongly-nucleated Sd galaxy has an unresolved (FWHM < 0.1") and weak central UV source, with a 2300 Å flux \( \sim 1 \times 10^{-16} \text{ erg s}^{-1} \text{ cm}^{-2} \text{ Å}^{-1} \).

3.3.2. Northern Galaxies

M31 (NGC 224, UGC 454, 0040+4100). This archival image of the center of the Andromeda galaxy is one of three exposures described in detail by King et al. (1992) and King, Stanford, & Crane (1995). It is a 1677 s exposure with the f/48 FOC in its 512 × 1024 “zoomed” pixel mode, providing a 44" × 44" field of view. The filter is F175W, whose peak transmission is at \( \sim 1900 \text{ Å} \). Considering the response of this setup and the exposure time, the image is similar in sensitivity to the standard setup. The image shows bright, centrally-peaked diffuse emission that is asymmetric at its peak. King et al. (1995) show that this peak coincides with the fainter of two peaks seen in optical HST images, and with the dynamical center of the galaxy (Lauer et al. 1993). Many individual stars are also visible, and are discussed in detail by King et al. (1992).

NGC 404 (UGC 718, 0106+3527). This S0 galaxy contains one of the UV-bright LINERs studied in detail by Maoz et al. (1995), showing a prominent unresolved nuclear point source.

NGC 672 (UGC 1256, 0145+2711). The image of this Sd galaxy shows a resolved (FWHM \( \approx 0.2" \)) central source, plus several additional faint compact sources.

NGC 1023 (UGC 2154, 0237+3850). This is an SB0 galaxy that has also been observed with IUE (Kinney et al. 1993). The integrated flux from the weak, centrally-concentrated diffuse emission seen in the HST image agrees well with the IUE 2300 Å flux. This galaxy has also been imaged with HST by Lauer et al. (1995) in the V band, where it displays an unusually high central surface brightness. After de-convolution with the spherically-aberrated PSF, they estimate a surface brightness of 12.7 mag arcsec\(^{-2}\) in the central 0.022", and 13.8 mag arcsec\(^{-2}\) at the 0.1" radius. As in the other 45 early-type galaxies they have studied, the brightness profile continues to increase with decreasing radius all the way down to the HST angular resolution limit. The weak emission we detect from this galaxy in the UV, compared with the high visual surface brightness, confirms that the red leak through the F220W filter makes a negligible contribution to the counts we detect in the UV in other objects (see §2, and notes on NGC 4636, below).

NGC 1560 (UGC 3060, 0427+7146). The absence of UV flux from this galaxy may be due in part to its low Galactic latitude (+16°), at which a factor \( \sim 5 \) extinction in 2300 Å flux is expected (Burstein & Heiles 1982).

NGC 2903 (UGC 5079, 0929+2143). This “hot-spot” Sc galaxy has been observed with IUE, and its spectrum indicates the presence of a mixture of early- and late-type stars (Kinney et al. 1993). The HST image shows many bright compact sources, presumably young star clusters.

NGC 3079 (UGC 5387, 0958+5555). There is very little UV emission detected in the image of this LINER galaxy. There is a hint of a dust lane crossing the image from north to south, at an orientation matching that of the galaxy’s major axis.

NGC 3319 (UGC 5789, 1036+4156). The elongated diffuse emission in the UV image is aligned with the strong bar of this Scd galaxy. There is an unresolved (FWHM < 0.1") nuclear source with \( f_\lambda(2300 \text{ Å}) = 1.4 \times 10^{-16} \text{ erg s}^{-1} \text{ cm}^{-2} \text{ Å}^{-1} \), and several faint compact sources.

NGC 3344 (UGC 5840, 1040+2511). This starburst nucleus has a bright unresolved nuclear point source and has been studied in more detail by Maoz et al. (1995).

NGC 3368 (UGC 5882, 1044+1205). The UV image of this bright Sab LINER galaxy has a single, unresolved compact source with \( f_\lambda(2300 \text{ Å}) \sim 5 \times 10^{-17} \text{ erg s}^{-1} \text{ cm}^{-2} \text{ Å}^{-1} \) about 0.1" north of the centroid of a weak diffuse light distribution. We have verified by means of a ground-based CCD image that the source is at the galaxy’s nucleus position. It is 5.5" south of the center of the image because the galaxy nucleus coordinates input to HST were off by that much due to galaxy isophote distortion by a dust lane in the GASP image. This is another example of a “UV-bright” LINER (Maoz et al. 1995), though with a central point source fainter by 1-2 orders of magnitude. In contrast to the other UV-bright LINERs, whose observed UV fluxes are sufficient to explain their observed emission-line fluxes by photoionization, in this
source the observed UV flux is 20 times less than the minimum required (see Maoz 1996). This LINER is therefore reddened or not excited through photoionization, and could be an intermediate case between UV-bright and UV-dark.

NGC 3486 (UGC 6079, 1057+2914).—There is a weak \( f_{\lambda}(2300 \text{ Å}) = 1 \times 10^{-16} \text{ erg s}^{-1} \text{ cm}^{-2} \text{ Å}^{-1} \), unresolved (FWHM < 0.1") point source in the nucleus of this galaxy, which is a LINER/weak-Seyfert 2 (Ho et al. 1996a). The H\( \alpha \) flux measured by Ho et al. (1996a) is about \( 1 \times 10^{-14} \text{ erg s}^{-1} \text{ cm}^{-2} \). Using the argument of Maoz et al. (1995) and Maoz (1996) in the cases of other LINERs in the sample, a power-law extrapolation beyond the Lyman limit of the observed UV flux provides enough ionizing photons to explain the observed H\( \alpha \) flux through photoionization in this object as well. The central point source could therefore be the AGN continuum source.

NGC 3521 (UGC 6150, 1103+0014).—The central diffuse light distribution in the UV image of this Sbc galaxy has a double-peaked appearance, apparently because it is crossed by an obscuring dust feature. The feature is reminiscent of the X-shaped dust lanes in M51 (NGC 5194; see below), but this requires confirmation with data of higher signal-to-noise ratio (S/N).

NGC 3627 (UGC 6346, 1117+1315).—The nucleus of this bright Sb galaxy has a prominent optical emission line spectrum that is intermediate between that of a LINER and an H II nucleus (Ho et al. 1996a). The UV image shows a weak, diffuse centrally-peaked light distribution. It is offset from the image center due to an inaccuracy in the nuclear position that was estimated from a GASP image and input to \textit{HST}. There is a hint of spiral structure which, however, requires confirmation.

NGC 3718 (UGC 6524, 1129+5320).—This Sa galaxy has a prominent optical LINER spectrum, including a broad H\( \alpha \) component similar to that of Seyfert 1 galaxies (Ho et al. 1996a). Its UV image is blank, and this may be related to the fact that the optical line ratios are indicative of reddening. A dust lane that crosses optical images of the galaxy near the nucleus is a candidate agent of these effects.

NGC 4151 (UGC 7166, 1208+3941).—This is probably the best studied Seyfert 1 galaxy. The archival image is a 900 s exposure with the \textit{f/48 FOC} in its \( 512 \times 1024 \) “zoomed” pixel mode. The image was taken after the \textit{HST} refurbishment mission and the installation of COSTAR, and so is free of spherical aberration. The field of view is \( 28'' \times 28'' \), with a de-zoomed pixel size of 0.014". The image was obtained with a combination of the F220W and F275W filters, giving an effective peak transmission at \( \sim 2450 \text{ Å} \). Considering the response of this setup and the exposure time, the image has 1/4 the sensitivity of the standard setup for diffuse sources, but better sensitivity to compact sources because of the improved optics. The bright Seyfert 1 nucleus is strongly saturated. Its brightness cannot be reconstructed, as in Maoz et al. (1995), due to the absence of the spherical-aberration diffraction rings. In addition to the nuclear point source, there is a diffuse-light distribution centered \( 2'' \) south of the nucleus. Excluding the counts from the central source, the flux from the diffuse component is \( 1.2 \times 10^{-13} \text{ erg s}^{-1} \text{ cm}^{-2} \text{ Å}^{-1} \). This value casts doubt on the component’s reality, since measurements with \textit{IUE}, whose aperture would include much of this extended (and presumably non-variable) emission, have been at times up to a factor of 6 lower at this wavelength (e.g., Ulrich et al. 1991). The diffuse component may be an artifact of the poor quality of the \textit{f/48 FOC} flat-field, or of a dark current in this camera, which has had operational problems since December 1992. The large arc to the west is an artifact.

NGC 4192 (UGC 7231, 1211+1510).—This highly-inclined Sb galaxy has a nucleus with strong optical emission lines, with line ratios intermediate between a LINER and an H II nucleus, and indicative of reddening (Ho et al. 1996a). Its UV image shows three amorphous knots of very weak emission.

NGC 4214 (UGC 7278, 1213+3637).—This starburst Magellanic irregular galaxy has been studied in the UV with \textit{IUE} (Huchra et al. 1983; Hartmann, Geller, & Huchra 1986), and in the optical (Sargent & Filippenko 1991), and shows Wolf-Rayet signatures. The archival \textit{HST} FOC image shown here is analyzed, along with \textit{HST} spectroscopy, by Leitherer et al. (1996). It is a 1200 s exposure with the standard format, but with a F2ND neutral density filter, which attenuates the flux by a factor of 5, in addition to the F220W filter. The sensitivity is then 0.4 times that of the standard setup. The image shows a bright central point source, surrounded by numerous compact sources. Most of the total UV flux, which is in excellent agreement with that measured by \textit{IUE} at 2300 Å (Kinney et al. 1993), comes from the central source. Leitherer et al. (1996) argue that most of the fainter sources are individual stars. This galaxy has
the second largest total UV flux in the sample (after NGC 5253).

NGC 4438 (UGC 7574, 1225+1317).– The UV image of this S0 galaxy shows only a weak amorphous patch of UV emission, about 5′′ in size. Filippenko & Sargent (1985) note that the strong LINER-like emission that is seen in optical spectra comes from an extended region.

M87 (NGC 4486, UGC 7654, 1228+1240).– This is the central elliptical galaxy in the Virgo cluster and a much-studied AGN, with a LINER nucleus and a jet that is visible at radio, optical, and UV wavelengths. UV images of the nucleus and the jet have been previously published by Boksenberg et al. (1992). This archival image is a 1200 s exposure with the FOC/96 in its “normal” (i.e., unzoomed) 512 × 512 pixel format, giving a 10′′ × 10′′ field of view, and the standard F220W filter. The exposure is 1.6 times more sensitive than the standard setup. The image shows a bright central point source, and the knots of the UV jet emerging westward. The UV flux from the central point source, 1 × 10^{−15} erg s^{−1} cm^{−2} Å^{−1}, is sufficient to provide the observed Hα flux through photoionization, as in the other UV-bright LINERs in the sample (Maoz et al. 1995; Maoz 1996).

NGC 4569 (UGC 7786, 1234+1326),– This Sab galaxy contains one of the UV-bright LINERs studied in more detail by Maoz et al. (1995). Apart from the bright unresolved nuclear point source, there is some faint extended emission 0.65′′ south of the nucleus.

NGC 4579 (UGC 7796, 1235+1205).– This is one of the UV-bright LINERs studied in more detail by Maoz et al. (1995), showing a bright unresolved nuclear point source. The main source is surrounded by several fainter sources, giving the diffraction rings in the image their asymmetric appearance.

NGC 4636 (UGC 7878, 1240+0257).– This E/S0 galaxy has an optical LINER spectrum, with broad Hα wings (Ho et al. 1996a). The UV image shows diffuse, centrally-concentrated emission. This galaxy has also been imaged with HST by Lauer et al. (1995) in the V band, where it shows similar structure. The V-band brightness profile increases with decreasing radius down to the HST resolution, though with a shallower slope than most of the other early-type galaxies studied by Lauer et al. (1995). They estimate (after deconvolution with the spherically-aberrated PSF) a surface brightness of 16.5 mag arcsec^{−2} in the central 0.022′′, and 16.7 mag arcsec^{−2} at the 0.1′′ radius. The comparable UV brightnesses of this galaxy and NGC 1023 (which was also imaged by Lauer et al. 1995), despite the much higher optical surface brightness of NGC 1023, confirms that the red leak through the F220W filter contributes negligibly to the counts in the FOC exposures, and that most of the signal detected in the FOC exposures is, in fact, the result of UV flux (see §2.2 and notes on NGC 1023).

NGC 4725 (UGC 7989, 1248+2546).– This bright SBb galaxy hosts a weak Seyfert 2 nucleus (Ho et al. 1996a). The UV image shows a diffuse centrally-peaked light distribution, with a marginally resolved core of width ≈ 0.2′′.

NGC 4736 (UGC 7996, 1248+4123).– This ringed Sab galaxy has many peculiar features, suggesting it is in the final stages of a merger. It is one of the UV-bright LINERs studied in more detail by Maoz et al. (1995), and has two bright unresolved UV point sources, one on the nucleus and one 2.5′′ to the north. Using the algorithm of Maoz et al. (1996), we measure for the nuclear point source a UV flux density f_{UV}(2300 Å) = 1.9 × 10^{−16} erg s^{−1} cm^{−2} Å^{−1}, and for the northern source f_{UV}(2300 Å) = 2.6 × 10^{−16} erg s^{−1} cm^{−2} Å^{−1}. The nuclear point source sits on top of a high surface-brightness diffuse component that extends into a number of concentric arcs. Several fainter compact sources are also visible.

NGC 4866 (UGC 8102, 1256+1426).– The UV image of this Sa galaxy, whose nucleus has a LINER spectrum (Ho et al. 1996a), shows a weak, centrally-peaked diffuse light distribution. There is a hint of a dust lane crossing the nucleus in the UV image, but this needs confirmation with higher S/N.

NGC 5005 (UGC 8256, 1308+3719).– This is a bright Sbc galaxy with a LINER nucleus (Ho et al. 1996a). We have compared the gross features of the UV image to a narrow-band ground-based Hα image, and verified that the faint diffuse emission that appears several arcseconds west of the center in the UV image is in fact the nucleus of the galaxy. The knot of UV sources on the south-east edge of the image corresponds in the ground-based image to an Hα knot. There may be a very faint compact V-shaped source of UV emission on top of the diffuse nuclear emission, but this requires confirmation at higher S/N.

NGC 5055 (UGC 8334, 1313+4217).– This is one of the UV-bright LINERs studied in more detail by Maoz et al. (1995), showing a bright marginally-resolved nuclear point source. Many fainter compact
sources are also visible in the northern and southern corners of the image.

M51 (NGC 5194, UGC 8493, 1327+4727).– This face-on Sbc Seyfert 2 galaxy forms an interacting pair with NGC 5195 and has been the focus of many studies. The archival HST image is a 2277 s exposure with the f/96 FOC in its “normal” (i.e., unzoomed) 512 × 512 pixel format, giving a 10″ × 10″ field of view, and the F275W filter, at an effective wavelength ∼ 2800 Å. The longer wavelength and exposure time make this image about 8 times more sensitive than the standard setup. The image shows X-shaped dust lanes crossing the bright diffuse light distribution, previously noted in visual-band HST images (Ford et al. 1992; see Maran & Kinney 1993), and a number of compact sources on the outskirts of the field.

NGC 5195 (UGC 8494, 1327+4731).– This is the companion galaxy interacting with M51 (NGC 5194). The UV image is nearly blank, with only some faint diffuse emission.

NGC 5248 (UGC 8616, 1335+0908).– This Sbc galaxy contains one of the circumnuclear star-forming rings studied in detail by Maoz et al. (1996).

NGC 5322 (UGC 8745, 1347+6026).– This is an E4 elliptical galaxy with a weak LINER nucleus (Ho et al. 1996a). The UV image shows weak, diffuse, centrally-concentrated structure that is elongated in the east-west direction, like the galaxy’s major axis in optical images. A pre-COSTAR HST V-band image of the galaxy (Lauer et al. 1995) shows similar structure, and also a thin dust lane crossing the nucleus. There is a hint of this dust lane, also in the east-west direction, in the UV image.

NGC 5474 (UGC 9013, 1403+5354).– This Scd galaxy is one of a group that is tidally interacting with the large galaxy M101 (NGC 5457; Kinney et al. 1993). The image shows many compact sources, presumably young star clusters and individual O and B stars.

NGC 5866 (UGC 9723, 1505+5557).– The UV image of this S0 galaxy displays weak, amorphous emission. The optical spectrum of the nucleus is a “transition type” between LINER and H II, with weak broad Hα wings (Ho et al. 1996a).

NGC 6946 (UGC 11597, 2033+5959).– This is a well-known low-surface-brightness, face-on, Scd starburst galaxy (e.g., DeGioia-Eastwood 1985; Devereux & Young 1993). The absence of UV flux in the FOC exposure may be due in part to its low Galactic latitude (+12°), at which a factor ∼ 5 extinction in 2300 Å flux is expected (Burstein & Heiles 1982).

NGC 7331 (UGC 12113, 2234+3409).– This bright Sb galaxy has the optical spectrum of a “transition object” between a LINER and an H II nucleus (Ho et al. 1996a). The UV image shows a faint but strongly peaked diffuse light distribution, and some additional emission on the eastern edge of the field.

4. Summary

We have presented HST UV images of the central regions of 110 large nearby galaxies. The observed galaxies are an unbiased selection from a complete sample of all large and nearby galaxies. This is the first such UV imaging survey of normal galaxies. The images display an assortment of morphologies and UV brightnesses. These include bright unresolved (< 0.1″, usually corresponding to a few pc) nuclear point sources, compact young star clusters scattered in the field or arranged in circumnuclear rings, centrally-peaked diffuse light distributions, and galaxies with weak or undetected UV emission. For every galaxy, we have measured the integrated ∼ 2300 Å flux, classified the UV morphology, and tabulated these parameters along with others from the literature.

From intercomparing the galaxy parameters, the following trends emerge. As seen in Figure 3, the centrally-peaked diffuse (F-type) UV morphology tends to occur in spirals earlier than type Sc, and in S0s and ellipticals. This UV morphology is therefore the signature of a spheroidal population, although not all spheroids produce it. Galaxies with this morphology tend to have a lower UV flux, integrated over the central 20″, than others. The central UV flux of the F-types is not correlated with the integrated B magnitude of the entire galaxy. However, there are no galaxies in the sample fainter than B ≈ 12 mag with an F-type morphology (or, for that matter, with a nuclear point source [P]). The latter three properties can be seen in Figure 4.

Conversely (see Figure 3), the star-forming (S-type) UV morphology tends to occur more in late-type galaxies, but it can be found in all Hubble types. The highest integrated central UV fluxes occur in galaxies with S-type morphology although, again, a large range in flux exists. In these S-types, the central UV flux is correlated with the galaxy’s integrated B magnitude, but with a large scatter. These trends are shown in Figure 4. Galaxies that are null (B) or weak
UV emitters do not have significantly fainter integrated $B$ magnitudes than galaxies that are UV-bright. As already noted, the fraction of galaxies with B-type morphology that have an inclination $> 60^\circ$ is 10/13, as opposed to the 1/2 expected from a random distribution (and which the other types obey). This suggests that dust in the disk of a nearly edge-on galaxy sometimes stifles completely what may have been a W-type emitter. On the other hand, the converse is not true; we find no trend of UV flux with axis ratio, and many highly-inclined galaxies are plentiful UV emitters.

Comparing the northern sample’s UV properties to the optical spectral classification of Ho et al. (1996a), we find that galaxies with a star-forming (S) UV morphology never have a “pure” LINER-type (L) spectrum. This is as expected, since the UV sources in the S-types are probably young star clusters or individual O and B stars, whose ionization will add H II-like spectral features to a LINER spectrum. Also, galaxies with a nuclear point source are never devoid of emission lines in the optical spectrum (spectral classification “A”) suggesting that, if a nuclear UV continuum source is present, there is usually enough gas in the nucleus to be ionized by it and produce emission lines. As shown in Figure 5, the highest central UV fluxes are measured in galaxies with an H II-like ("H-class") optical spectrum, and the median UV flux of this class is several times higher than that of galaxies with the other types of nuclear spectra. This is also not surprising, since Ho et al. (1996a) show that such spectra tend to occur in late-type galaxies, and we have found (see above) that these are the Hubble types with the highest UV fluxes.

The data we have presented can be useful for studying star formation and low-level nuclear activity in galaxies, for identifying galaxies with significant “UV-upturn” emission from an evolved stellar population, and for searching for interconnections between these phenomena. These are the subjects of recent and forthcoming publications based on this survey.

We are grateful to J. N. Bahcall for his contribution to the earlier stages of this survey, to T. Lauer for providing information on the central surface brightness of two early-type galaxies, and to the referee, A. Sandage, for constructive comments. This work was supported by grant GO-3519 from the Space Telescope Science Institute. D. M. and H. -W. R acknowledge support by the U.S.-Israel Binational Science Foundation grant 94-00300.

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Fig. 1.— Grey-scale representations of the FOC images of the southern galaxies. Each of the six frames on each page has a scale of $22'' \times 22''$, and has been rotated so that north is up and east is to the left. Archival exposures are marked with an asterisk next to the galaxy name, and in some cases have a different field of view and sensitivity; see §3.3 for details. The grey scale of each image is chosen to bring out the most interesting details. However, these snapshots cannot convey all of the useful information in many of the images, and the reader is advised to refer to §3.3, or to retrieve the actual data from the HST archive, if complete details are required.

Fig. 2.— Same as Figure 1, for the northern galaxies.

Fig. 3.— The distribution of galaxy Hubble types (labeled according to de Vaucouleurs’s T-types) for galaxies with a star-forming (“S-type”; dotted histogram) UV morphology, and galaxies with a diffuse centrally-peaked (“F-type”; solid histogram) UV morphology. F-types tend to occur in earlier-type galaxies, and are apparently associated with a galaxy spheroid. S-type UV morphologies are found preferentially in the centers of late-type spirals, but can occur in all Hubble types.
Fig. 4.— Observed flux density at 2300 Å, integrated over the central 22'' × 22'' of each galaxy, vs. $B$ magnitude integrated over the whole galaxy, for galaxies with F-type UV morphologies (filled circles) and S-type UV morphologies (empty circles). The central UV flux of F-types is uncorrelated with the galaxy’s integrated $B$ magnitude, but such a morphology is found in the sample only in galaxies brighter than $B = 12$ mag. For S-types, on the other hand, the central UV flux appears to be loosely correlated with the total $B$ magnitude. The typical UV flux from F-types is several times lower than that of S-types, which have the highest UV fluxes in the sample.

Fig. 5.— The distribution of central UV flux density, as observed with the FOC, for galaxies with an H II-like optical nuclear spectrum (“H-type” spectral classification; solid histogram), and galaxies with other optical nuclear classifications (Absorption (A), Seyfert (S), LINER (L), or transition-type (S); dotted histogram). Galaxies with H II-like optical nuclear spectra tend to have higher integrated central UV flux, and the galaxies with the highest UV fluxes are of this type.