SPIRAL GALAXIES WITH HST/NICMOS. II. ISOPHOTAL FITS AND NUCLEAR CUSP SLOPES

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ABSTRACT

We present surface brightness profiles for 56 of the 78 spiral galaxies observed in the HST/NICMOS2 F160W snapshot survey introduced in Paper I of this series, as well as surface brightness profiles for 23 objects out of the 41 that were also observed in the F110W filter. We fit these surface brightness profiles with the Nuker law of Lauer et al. and use the smooth analytical descriptions of the data to compute the average nuclear stellar cusp slopes $\langle \gamma \rangle$ in the $0.1-0.5$ radial range. Our main result is the startling similarity between the nuclear stellar cusp slopes $\langle \gamma \rangle$ in the near-infrared compared with those derived in the visual passband. This similarity has several implications: (1) Despite the significant local color variations that are found in the nuclear regions of spirals and that are documented in Paper I, there are typically little or no optical-NIR global color gradients, and thus no global stellar population variations, inside $\sim 50-100$ pc from the nucleus in nearby spirals. (2) The large observed range of the strength of the nuclear stellar cusps seen in the HST optical study of spiral galaxies reflects a physical difference between galaxies and is not an artifact caused by nuclear dust and/or recent star formation. (3) The dichotomy between $R^{1/4}$ bulges, with steep nuclear stellar cusps $\langle \gamma \rangle \sim 1$, and exponential bulges, with shallow nuclear stellar cusps $\langle \gamma \rangle < 0.3$, is also not an artifact of the effects of dust or recent star formation. (4) The presence of a surrounding massive disk appears to have no effect on the rise of the stellar density distribution within the innermost hundred parsecs of the $R^{1/4}$ spheroids. These results imply a breakdown within the family of exponential bulges of the nuclear versus global relationships that have been found for the $R^{1/4}$ spheroids. Such a breakdown is likely to have significant implications concerning the formation of exponential bulges and their connection with the $R^{1/4}$ spheroids.

Key words: galaxies: bulges — galaxies: nuclei — galaxies: spiral — galaxies: structure

1. INTRODUCTION

This is the second of two papers in which we report the results of a Hubble Space Telescope (HST) Near Infrared Camera and Multi-Object Spectrometer (NICMOS) snapshot survey of the nuclear regions of nearby spirals in the near-infrared (NIR). As discussed in more detail in the companion paper (Carollo et al. 2001a, hereafter Paper I), we have previously conducted an optical HST snapshot survey of the same targets with the WFPC2. The optical survey has shown that the innermost few hundred parsecs of spirals contain nuclear bars, spiral-like, ringlike, or irregular distributions of recent star formation and dust, and in many cases central spatially resolved, photometrically distinct $``nuclei''$ significantly brighter than their surroundings (Carollo et al. 1997c; Carollo, Stiavelli, & Mack 1998, hereafter C98; Carollo & Stiavelli 1998, hereafter CS98; Carollo 1999). The optical survey has furthermore shown that in the $V$-band massive early-type spiral bulges have steep nuclear stellar cusps, i.e., cusp slopes $\gamma \gtrsim 1$ in the power-law approximation of the surface brightness profile $I(r) \sim r^{-\gamma}$ as $r \to 0\prime.1$. This is similar to what is observed for elliptical galaxies of comparable luminosities (Jaffe et al. 1994; Lauer et al. 1995; Forbes, Franx, & Illingworth 1995; Carollo et al. 1997a, 1997b; Faber et al. 1997). In contrast, the later type systems often host bulgelike central structures with an exponential rather than $R^{1/4}$-law radial profile (``exponential bulges,'' see also Courteau, de Jong, & Broeils 1996 and references therein) and show shallow nuclear stellar cusps $\gamma \lesssim 0.3$ and nuclear stellar densities at least a factor 10 lower than those that have been inferred for the massive $R^{1/4}$ bulges (CS98).

The visual-band WFPC2 results are potentially severely affected by dust and recent star formation in the central regions of spirals; the NIR window is less sensitive to such $``polluting''$ factors and thus is much better suited than the...
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visual passband for investigating the underlying older stellar populations. We have therefore followed up the WFPC2 survey with a NICMOS2 (0.075 pixel⁻¹ scale) snapshot survey in the H (F160W) passband and, for a fraction of the galaxies, also in the J (F110W) band. In Paper I we described the properties of the NICMOS sample and the procedure adopted for the basic reduction of the images, and we discussed the NIR images and the optical-NIR color maps of spirals at HST resolution. There we also described the methodology used to measure the sizes and luminosities of the photometrically distinct nuclei and discussed the statistical NIR and optical-NIR properties of the nuclear regions of spirals, including the distinct nuclei, as a function of Hubble type. Jointly with the WFPC2 data, the NICMOS data also provide nuclear optical-NIR colors, i.e., information on the nuclear stellar populations. These are important for understanding the evolutionary history of the central regions of spirals. We have presented in Carollo et al. (2001b) a discussion of the optical-NIR HST colors of bulges and nuclei in our sample.

In this paper we present the isophotal fits performed on the NICMOS2 images in order to investigate the nuclear stellar structure that underlies the distinct nuclei and the nuclear dust patches and barlike, ringlike, and armlike features. Specifically, we (1) describe the methodology adopted to perform the isophotal fits and present the nuclear surface brightness profiles (§ 2; the brightness profiles are available in electronic format upon request); (2) describe the results of modeling the nuclear surface brightness profiles with the analytical law introduced by Lauer et al. (1995) and use these analytical descriptions to derive the strength of the nuclear stellar cusp slopes in the NIR (§ 3); (3) present and discuss the results of our analysis as a function of global galactic properties (§ 4). We summarize in § 5. Consistently with the previous papers, here we adopt $H_0 = 65 \text{ km s}^{-1} \text{ Mpc}^{-1}$.

2. DERIVATION OF THE SURFACE BRIGHTNESS PROFILES

The derivation of the surface photometry was carried out in IRAF by using the ELLIPSE task. For all the galaxies we first performed the isophotal fits without masking the knots of star formation and the dust lanes frequently present in the images. For the galaxies with strong star formation or dust patterns, these fits turned out to be a very poor representation of the smooth distribution of the underlying stellar light which we seek to parametrize. For these objects we therefore rederived the final isophotal fits after masking out stars and other knotlike sources such as H II regions and strong dust lanes. In some galaxies the distinct nucleus is slightly offset from the center of the isophotes (Paper I); in these cases the nucleus was simply masked out before performing the isophotal fit. The isophotal analysis could be derived for 56 galaxies in the H band and for 23 objects in the J band; in the remaining galaxies, the images had too little signal-to-noise ratio or the morphology was too irregular for performing a reliable isophotal fit. We chose not to carry out any point-spread function (PSF) deconvolution of the images before fitting the isophotes, but to convolve instead the analytical models of the surface brightness profiles described in § 3 with the NICMOS PSF before comparing them with the observed data points. Typically, no suitable star was present in the NICMOS2 field of view of the target galaxies; appropriate PSFs for the F110W and F160W filters were thus derived with the TinyTim software package (Krist 1997). The approach of convolving the models with the PSF, rather than deconvolving the images, helps to minimize the effects of a simulated PSF, which does not perfectly represent the true PSF.

Absolute photometric calibration in the AB magnitude system was obtained by applying zero-point corrections. These were taken to be equal to $Z_{\text{NIC2,F110W}} = 23.25$ and $Z_{\text{NIC2,F160W}} = 23.11$ for the F110W and the F160W filter, respectively, so that

$$m_\lambda = -2.5 \log(\text{counts s}^{-1}) + Z_{\text{NIC2,}\lambda} + 5 \log(0.075) \ ,$$

where the 5 log (0.075) term accounts for the pixel size. The calibrated surface brightness profiles were corrected for Galactic extinction by using the values published by Burstein & Heiles (1984). Figures 1a–1d show the derived 56 H-band surface brightness profiles, and Figures 1e–1f show the 23 similar measurements in the J band.

3. ANALYTICAL FITS TO THE SURFACE BRIGHTNESS PROFILE

A few analytical expressions have been proposed to date to describe the surface brightness profiles in the inner regions of galaxies. For spiral galaxies, the presence of photometrically distinct nuclei leads to the question of whether it is best to include these subcomponents in the analytical description of the nuclear surface brightness profiles. CS98 tested whether the optical nuclear light profiles of spirals could be fitted by a standard exponential profile with the addition of a second component describing a steep nuclear cusp, i.e., by

$$I(R) = I_0 \left(1 + \frac{R}{R_c}\right)^{-\gamma} \exp\left(-\frac{R}{R_b}\right) .$$

For radii $R$ much smaller than the “cusp” radius $R_c$, this profile describes a cusp with slope $\gamma'$. $I_0$ is the central brightness of the exponential component, and $R_b$ the exponential scale length. CS98 found no physically meaningful fit for any of the galaxy light profiles with the exception of one, this demonstrating that “steep-cusp exponentials” could exist and that a simple fitting procedure of the analytical light profile (eq. [2]) would identify them. The lack of a good fit for most cases indicates, however, that the distinct nuclei present in several galaxies cannot be described as a steepening of the light profile: these sources are a photometrically distinct component on top of the underlying galaxy light. Thus a central nucleus that sits right on top on the center of the isophotes needs to be “excluded” from the parametrization. For the latter we adopted the expression introduced by Lauer et al. (1995) for the elliptical galaxies (“Nuker law”) and used by CS98 for the I’-band light profiles of spirals. This choice allows us to directly compare the optical and NIR results obtained for the spiral galaxies, as well as systematic differences between spiral and earlier type galaxies. The Nuker law reads:

$$I(r) = 2^{(3-\gamma)/\alpha} I_b \left(\frac{R_b}{r}\right)^{\alpha} \left[1 + \left(\frac{r}{R_b}\right)^{\gamma - \beta/\alpha}\right] .$$

The parameter $\gamma$ measures the steepness of the rise of the
profile toward the very center; i.e., the value of $\gamma$ in $I(r) \sim r^{-\gamma}$ as $r \rightarrow 0$; $R_b$ is the break radius where the profile flattens in some cases to a shallower slope; $\beta$ is the slope of the outer profile; $\alpha$ controls the sharpness of the transition between inner and outer profile; $I_b$ is the surface brightness at $R_b$.

In Figure 1 we show the PSF-convolved analytical best fits superposed on the $H$- and $J$-band surface brightness profiles, respectively. For each galaxy fitted in the $H$-band, Table 1 lists the radial range of the reported best fit and the corresponding best-fit values for $R_b$, $\alpha$, $\beta$, $\gamma$, and $\mu_b = -2.5 \log I_b$. Table 2 lists the similar parameters for the $J$-band fits.

Since the intrinsic form of the light profile of the nuclei is not known, there is clearly an uncertainty associated with removing the nucleus contribution from a galaxy light profile. We quantified this uncertainty by performing several fits to the light profile of the same galaxy after varying the inner radial cutoff. In Tables 1 and 2 the listed error bars for the parameters refer to the largest between the following two quantities: (1) the formal errors of the reported best fits and (2) the differences between values obtained from the various fits performed within the different radial ranges.

### 3.1. The Average Logarithmic Slope $\langle \gamma \rangle$

For the galaxies where a continuous rise of the light profile is observed down to the resolution of the data, the fits with the Nuker law are indeterminate; nonetheless, they still yield a smooth analytical representation of the data that is unaffected by PSF and central distinct-nucleus effects. Thus, these analytical fits remain best suited for deriving a global representation of the galactic stellar light in the NIR. To this purpose we computed, from the smooth curves provided by the best fits of equation (3) to the $J$ and $H$ light profiles, respectively, the average logarithmic slopes $\langle \gamma_J \rangle$ and $\langle \gamma_H \rangle$. The radial range adopted for deriving these average logarithmic slopes was $0''1-0''5$, i.e., coincident with the range

![Figure 1](image-url)
adopted by CS98 for deriving an analogous quantity from the optical light profiles of spiral galaxies. This radial range is equivalent to a physical scale \( \sim 50 \text{–} 100 \text{ pc} \) at the average galaxy distance of \( \sim 25 \text{ Mpc} \).

Computing an average slope within the \( 0^\circ.1 \text{–} 0^\circ.5 \) radial range has the advantage of producing a description of the nuclear profile that is independent of its particular parametrization. On the other hand, the average nuclear slopes are more sensitive to distance effects than is the asymptotic slope \( \gamma \). In galaxies with otherwise identical surface brightness profiles, the more the surface brightness profiles deviate from a pure power law, the more the average slope values vary with distance. However, this is not a problem in our data set, since most of our galaxies typically lie within \( 20 \ h_0^{-1} \text{ Mpc} \) and none lies beyond \( 40 \ h_0^{-1} \text{ Mpc} \).

The values of \( \langle \gamma^H \rangle \) and \( \langle \gamma \rangle \) are reported also in Tables 1 and 2. The associated error bars refer to the largest between (1) the formal errors of the logarithmic fits and (2) the standard deviations obtained when estimating \( \langle \gamma \rangle \) by using all the fits derived using different radial cutoffs and that provided a physically meaningful description of the given light profile. These error bars are typically smaller than \( \sim 0.2 \).

4. RESULTS AND DISCUSSION

The almost ubiquitous presence of dust and often of star formation knots in the central regions of spiral galaxies implies that a significant fraction of the optical light from the nuclei of spirals could either be absorbed by dust, similarly to what was suggested for the “shallow-core” elliptical galaxies by Silva & Wise (1996), or be dominated by recently formed stars. This means that in principle significant differences in nuclear stellar cusp slopes could be expected when deriving these quantities by using optical and near-infrared data. The latter are much less affected by recent star formation, dust absorption, and reddening in the nucleus and thus provide a better representation of the rate of density increase in the underlying stellar populations with respect to the bluer wavelengths). In Figure 2 (left) we plot the comparison between the average nuclear cusp slopes \( \langle \gamma^H \rangle \) and the similar estimates \( \langle \gamma^V \rangle \) obtained from the WFPC2 study (CS98; in Fig. 2, right, the comparison between the average nuclear cusp slopes obtained from the F160W images and those obtained from the F110W images shows excellent agreement between the two estimates, so that results similar
Fig. 1e

Fig. 1f
to those discussed for the $H$ band hold when the $J$-band data are used instead). There is a small trend for the galaxies with the steepest NIR cusp slopes to have steeper optical slopes. Although in principle this could be due to a small nuclear color gradient in the direction of a bluer center in these systems, the most likely explanation for the trend is that it comes from a spurious residual effect of the wider PSF in the NIR images. The errors bars are larger than the scatter between points. The major uncertainty in estimating the nuclear cusp slopes arises from the unknown shape of the underlying nuclear stellar profile; independently deriving the cusp slopes in the different wavelength regions leads to a correlation in the errors if the shapes are intrinsically similar in the different passbands. Independent of these considerations, by far the most striking result that comes out from this plot is the very good agreement between the average nuclear cusp slopes obtained for any galaxy in the optical and in the NIR wavelength regions.

Diffuse dust effects cannot in principle be ruled out; however, it is unlikely that they may conspire so well to reproduce for all systems the same nuclear cusp slopes in the optical and in the NIR wavelength region. A more plausible explanation is that these systems are more likely to be associated with the galaxy’s bulges, which is a plausible hypothesis given the well-known characteristic of the optical and NIR nuclear cusps being associated with the galaxy’s bulges.
interpretation is that, once the patches of dust and the knots of star formation are properly masked out from the optical images, both the visual and the NIR passbands provide a fair representation of the underlying nuclear stellar populations in spiral galaxies. The similarity between the visual and NIR average nuclear cusp slopes has two immediate consequences. First, it implies that there are small or no global color gradients within the innermost \( \leq 100 \) pc from the galaxy centers. In the absence of “tuned” conspiracies between dust and stellar populations ages/metallicities, this in turn means that within that region there are no major global variations in the stellar population properties of nearby spirals, in contrast with the widespread local color variations documented in Paper I, which imply significant local variations in stellar populations, star formation rates, and/or dust. Second, the similarity implies that the large range in nuclear stellar cusps observed in both wavelength regions is due to real differences in the rate of increase of the stellar density, rather than to dust or recent star formation effects.

In Figure 3 we show the average slope \( \gamma_H \) as a function of the Hubble type of the host galaxy. There is a clear trend showing that the nuclear cusp slope decreases with increasing Hubble type; i.e., late-type galaxies have shallower

\[
\begin{array}{|c|c|c|c|c|c|c|c|}
\hline
\text{Name} & \text{Radial Range} & R_b & \alpha & \beta & \gamma & \mu_b & \langle \gamma \rangle \\
\text{(arcsec)} & \text{(arcsec)} & & \text{mag} & & \text{mag} & \text{mag} & \text{mag} \\
\hline
N406 & 0.30–8.00 & 3.17 & 15.49 & 0.56 & 0.16 & 19.27 & -0.15 \\
N772 & 0.00–8.00 & 0.44 & 5.42 & 1.02 & 0.97 & 15.13 & -0.98 \\
N972 & 0.03–5.00 & 1.01 & 95.99 & 0.91 & 0.56 & 16.15 & -0.51 \\
N1398 & 0.00–8.00 & 0.84 & 2.45 & 1.14 & 0.56 & 14.74 & -0.54 \\
N2082 & 0.40–5.00 & 2.09 & 1.50 & 0.77 & 0.27 & 18.93 & -0.27 \\
N2196 & 0.30–8.00 & 2.80 & 0.98 & 1.65 & 0.64 & 17.11 & -0.68 \\
N3067 & 0.00–5.00 & 1.15 & 3.99 & 0.65 & 0.60 & 17.53 & -0.55 \\
N3277 & 0.30–8.00 & 0.66 & 32.94 & 1.30 & 0.90 & 15.40 & -0.88 \\
N3949 & 0.30–8.00 & 5.96 & 1.73 & 2.28 & 0.27 & 18.48 & -0.25 \\
N4527 & 0.00–8.00 & 1.01 & 2.21 & 1.45 & 0.29 & 15.06 & -0.33 \\
N5678 & 0.30–8.00 & 0.00 & 8.47 & 0.94 & 0.52 & 14.00 & -0.93 \\
N5985 & 0.00–7.70 & 1.64 & 25.12 & 0.99 & 0.77 & 17.65 & -0.73 \\
N7162 & 0.40–5.00 & 2.03 & 1.18 & 0.77 & 0.33 & 18.89 & -0.34 \\
N7217 & 0.00–8.00 & 0.50 & 10.00 & 0.94 & 0.40 & 14.72 & -0.39 \\
\hline
\end{array}
\]

\textbf{Notes.---} The columns in the table list (left to right): galaxy name, the radial range of the reported best-fit parameters, and the corresponding best-fit values for \( R_b, \alpha, \beta, \gamma, \) and \( \mu_b = -2.5 \log I_b \). The last column on the right lists the values of the average nuclear stellar cusp \( \langle \gamma \rangle \) computed within \( 0''1–0''5 \). When available and for easy reference, we report in the last column the \( V \)-band measurements of the nuclear stellar cusp slope \( \langle \gamma \rangle \) published in CS98.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{fig2}
\caption{\textit{Left:} \( V \)-band average nuclear slope \( \langle \gamma \rangle \) inside \( 0''1–0''5 \) reported in CS98 vs. the similar measurement in the \( H \) band. There is a very good agreement between the optical and the NIR measurements. \textit{Right:} As in left panel, but the comparison is now between the \( H \)- and the \( J \)-band measurements. There is very good agreement between the two estimates.}
\end{figure}
nuclear cusp slopes than earlier type spirals. A straightforward way to assess the statistical significance of this trend is to derive the distributions of $\langle \gamma \rangle$ values separately for each morphological type and to verify by means of a Kolmogorov-Smirnov test whether these distributions could be drawn from the same one. The number of objects per morphological type in our sample, however, is too small to draw a firm conclusion. We therefore binned galaxies in only two groups, one with Hubble types earlier than or equal to $T = 3$ and the other with types later than this “threshold,” respectively; this division provides bins with roughly equal numbers (23 and 15 objects). The two derived distributions show a probability of only $\approx 5\%$ of being drawn from the same parent distribution. A similar probability is obtained by changing the threshold type of $\pm 1$, although the two bins in these cases are differently populated (29 and 15 objects for $T = 2$ and 7 and 37 objects for $T = 4$). The dispersion in the Hubble type versus $\langle \gamma \rangle$ relation is large, however, and in particular galaxies with intermediate types $\sim 3 \pm 1$ cover the entire range of nuclear stellar cusp slope values, from very shallow to very steep. The NICMOS light profiles are not extended enough in radius to perform a bulge-disk decomposition; however, the latter is available for several objects from our previous WFPC2 survey. Using this information on the bulge light profile, in Figure 3 we identify galaxies with different bulge properties: open squares represent galaxies with $R^{1/4}$-law bulge light profiles, while filled squares represent galaxies with exponential bulges. Galaxies for which no fit to the bulge component is available are represented by four-pointed stars. The $R^{1/4}$ bulges are confined to the earlier types and have on average steep cusps $\langle \gamma \rangle$, in contrast with the exponential bulges, which are confined to the intermediate types and have on average rather shallow stellar cusps. Interestingly, the only galaxy with a very steep nuclear cusp among the group with Hubble type $\geq$ Sbc is NGC 2344, which is also the only galaxy in that group which hosts an $R^{1/4}$-type bulge. While it is possible that NGC 2344 has been incorrectly classified, it is a fact that $R^{1/4}$ and exponential bulges are both found embedded in the intermediate-type spirals (Courteau et al. 1996; Carollo et al. 1998).

The difference in nuclear behavior between exponential and $R^{1/4}$ bulges is further illustrated in Figure 4a, where we show the $\langle \gamma \rangle$ versus the absolute $V$ bulge magnitude for our sample of spirals. Symbols for the exponential and $R^{1/4}$ bulges are as in Figure 3. The dichotomy between the two classes of bulges is quite evident at any given luminosity in the range of overlap, with the exponential bulges showing significantly shallower cusp slopes than the $R^{1/4}$ bulges. Within the caveats of the small number statistics, there is no evidence for galaxies belonging to the different “nuclear morphological classes” introduced in Paper I (galaxies with concentrated nuclear star formation mixed with dust; galaxies with diffuse blue nuclear regions; galaxies with regular nuclear/circumnuclear dust; and galaxies with irregular nuclear/circumnuclear dust) occupying any particular region of the $M_V$ versus $\langle \gamma \rangle$ diagram (Fig. 4, right). Significantly shallower cusp slopes for exponential relative to $R^{1/4}$ bulges were also found in the WFPC2 data (CS98); indeed, this result is a corollary of stating that there is good agreement between the $\langle \gamma \rangle$ derived in the optical and in the NIR (Fig. 2, left). The NIR data are, however, important to make sure that the dichotomy between steep cusp slopes in $R^{1/4}$-law systems and shallow cusps in exponential bulges is not again not a spurious result driven by the almost ubiquitous presence of dust and recent star formation in the centers of spirals, but a real physical effect that extends to the parsec scales the structural difference that exists between these systems on the kiloparsec scales. As discussed in CS98, this dichotomy is not the result of a trivial inward extrapolation of the two different analytical forms, since the $\langle \gamma \rangle$ values are obtained from a different radial range than that used to perform the bulge $R^{1/4}$-law or exponential fits, that was taken $>1''$.

Shown in Figure 4 (left) as dots are also the measurements obtained for a sample of elliptical galaxies from a similar NICMOS study conducted by Quillen, Bower, & Stritzinger (2000). The comparison between the ellipticals and the massive $R^{1/4}$-law bulges of spirals shows that the latter have average nuclear cusp slopes similar to those of elliptical galaxies of similar luminosity. Again this was suggested by the optical data, but it is now unambiguously demonstrated by the NIR observations. The fact that $R^{1/4}$ disk-embedded bulges have nuclear stellar cusps (and thus densities) indistinguishable from those of diskless elliptical galaxies of similar luminosities suggests that for these systems the presence of a large-scale disk, which in principle may alter the nuclear structure of the embedded spheroid, has in fact little or no influence on the spheroid.

For the $R^{1/4}$ spheroids, the correlation between the total spheroid luminosity, as described by $M_{sph}$, and the strength of the nuclear stellar cusp, as described by $\langle \gamma \rangle$, is not the only known relationship between a global and a nuclear quantity. The total spheroid luminosity has been found to correlate also with the mass of the central black hole $M_{BH}$ (e.g., Magorrian et al. 1998); in fact, an even better correlation is found between the central black hole mass $M_{BH}$ and the mass of the spheroid $M_{sph}$ as described by its velocity
These relationships imply a “triangular” correlation for $R^{1/4}$ spheroids between $M_{\text{sph}}$, $M_{\text{BH}}$, and $\gamma$, drawn schematically in the bottom panel of Figure 5, which is likely to hold valuable information on the process of $R^{1/4}$-type spheroid formation. Our result that at any given total luminosity (and thus likely mass) of overlap, the exponential bulges have systematically lower nuclear stellar cusps than their $R^{1/4}$ relatives may be indicative of a breakdown of the above “triangular” relationship, as illustrated schematically in the top panel of Figure 5. Indeed, the fact that the exponential bulges do not lie on the $M_{\text{sph}}$-$\gamma$ correlation that holds for the $R^{1/4}$ spheroids could imply that for these systems at least one of the other two correlations, either the $M_{\text{BH}}$-$\gamma$ or the $M_{\text{sph}}$-$M_{\text{BH}}$, or even both, must also break down. An alternative is that what we are observing for the exponential bulges is not a breakdown of the $M_{\text{sph}}$-$\gamma$ correlation and a consequent breaking of the triangular relation among $M_{\text{sph}}$, $M_{\text{BH}}$, but rather a similar triangular relationship, “displaced,” however, to a different region of parameter space. A displaced triangular relationship for the exponential bulges could explain the $M_{\text{BH}}$ estimate for the Milky Way bulge: this is the only exponential bulge for which the black hole mass has been accurately measured and found to be significantly smaller than what is expected on the basis of the $\sigma-M_{\text{BH}}$ correlation valid for the $R^{1/4}$ spheroids. Kinematic information for a significant sample of exponential bulges is still missing, and is awaited to clarify whether or not the processes that form the exponential bulges produce a global to nuclear connection of the kind found in the $R^{1/4}$ spheroids. Either way, it is clear that either the disappearance or the modification of the nuclear versus global relationships for the exponential bulges requires abundant dispersion $\sigma$; Ferrarese & Merritt 2000; Gebhardt et al. 2000).
consideration in the context of understanding the formation of this class of spheroids and their connection if any with the $R^{1/4}$ spheroids.

5. SUMMARY

Using the NICMOS data set introduced in Paper I, we have presented the results of the isophotal fits performed on the F160W images (56 galaxies) and on the F110W images (23 objects). We have modeled the derived surface brightness profiles with the analytical law introduced by Lauer et al. (1995) and used the smooth analytical representation of the data to compute the strength of the average nuclear cusp slopes ($\gamma$). Our findings about the NIR structural properties of spiral galaxies are very similar to those that we had obtained by investigating for the same systems in the optical wavelength region. This lack of a major difference between the visual and the NIR analysis of the nuclear stellar density cusps carries important consequences for our understanding of the nuclear structure of spiral galaxies, since it establishes that the diversity unveiled in their central regions is not an artifact of “polluting” effects but the manifestation of real nuclear differences in systems with different global properties.

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