BVRI SURFACE PHOTOMETRY OF ISOLATED SPIRAL GALAXIES

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ABSTRACT

A release of multicolor broadband (BVRI) photometry for a subsample of 44 isolated spirals drawn from the Catalogue of Isolated Galaxies is presented. Total magnitudes and colors at various circular apertures, as well as some global structural/morphological parameters, are estimated. Morphology is reevaluated through optical and sharply filtered R-band images, \((B-I)\) color index maps, and archived near-IR \(JHK\) images from the Two Micron All Sky Survey. The CAS structural parameters (concentration, asymmetry, and clumpiness) were calculated from the images in each of the bands. The fraction of galaxies with well-identified optical/near-IR bars (SB) is 63\%, while another 17\% show evidence of weak or suspected bars (SAB). The sample average value of the maximum bar ellipticity is \(e_{\text{max}} \approx 0.4\).

Half of the galaxies in the sample show rings. We identify two candidates for isolated galaxies with disturbed morphology. The structural CAS parameters change with the observed band, and the tendencies they follow with morphological type and global color are more evident in the redder bands. In any band, the major difference between our isolated spirals and a sample of interacting spirals is revealed in the \(A-S\) plane. A deep and uniformly observed sample of isolated galaxies is intended for various purposes, including (1) comparative studies of environmental effects, (2) comparing model predictions of galaxy evolution, and (3) evaluating the change of galaxy properties with redshift.

Key words: galaxies: interactions — galaxies: irregular — galaxies: photometry — galaxies: spiral — galaxies: structure

Online material: color figures, extended figure set

1. INTRODUCTION

The concept of a “field” population of galaxies as distinct from the group/cluster populations has existed since the earliest days of extragalactic astronomy (Hubble 1936), and it is used recurrently in studies aimed at exploring the effects of large-scale environment on galaxy properties. However, the definition of “field” is fuzzy. The distribution of galaxies in space is actually strongly clustered, and a large fraction of them are prone to form gravitationally bound multiple systems, from very populated clusters to loose groups, the majority being in normal groups (Tully 1987). Isolation is an important requirement beyond the concept of field galaxies. A galaxy is isolated if it has not suffered any interaction with another normal galaxy or with a group environment over a Hubble time, or at least since approximately half of its mass was assembled. This makes the observational finding and study of isolated galaxies important because, among other reasons, (1) they can be used as comparison objects in studies of the environmental effects on galaxies belonging to groups and clusters, and (2) they are ideal for comparing with theoretical and model predictions of galaxy evolution.

The fact that properties of galaxies change with environment has been known for a long time. The main observable dependencies on environment, from cluster centers to the sparse field, are seen in the morphological mix, the global colors, and the specific star formation (SF) rate; for recent reviews, see Park et al. (2007), Avila-Reese et al. (2005b), and references therein. These properties are inferred mainly from photometric observations. In fact, to study observationally the effects of high-density environments on galaxy properties, a good understanding of isolated, non-perturbed galaxies is necessary. These galaxies are also required as a control sample for studying interacting galaxies. For example, in Hernández-Toledo et al. (2005; see also Conselice 2003, hereafter C03) we have compared the photometric concentration, asymmetry, and clumpiness (CAS) parameters of local interacting and field disk galaxies with the aim of establishing a relatively easy way to identify interacting disk galaxies in high-redshift samples.

Among isolated galaxies, the observational study of disk galaxies is of special interest because, on one hand, they are expected to be more drastically affected by environmental and interaction effects, and on the other hand, according to the current paradigm of cosmic structure formation, the formation of disks inside hierarchically growing cold dark matter (CDM) halos is a generic process. A large amount of work has been done in modeling the evolution of (isolated) disk galaxies. Well-observed samples of isolated disk galaxies are hence important in order to compare with model predictions (e.g., Avila-Reese & Firmani 2000; Cole et al. 2000; Boissier & Prantzos 2001; Firmani & Avila-Reese 2000; Yang et al. 2003; Zavala et al. 2003; Pizagno et al. 2005; Dutton et al. 2007; Kassin et al. 2006; Gnedin et al. 2007).

A uniformly selected and observed sample of isolated disk galaxies is also crucial for studying intrinsic secular processes that are able to affect the structure, morphology, and dynamics of galaxies, for instance, the formation and evolution of bars, circular rings, lopsidedness, and bulges. However, chances are that isolated galaxies may show evidence of disturbances not associated with intrinsic processes, which opens the necessity of exploring other alternatives. Along these lines, cosmological numerical simulations within the CDM model show that inside the galaxy-size halos there survives a large population of subhalos (Klypin et al. 1999; Moore et al. 1999), but reionization and feedback could inhibit the formation of luminous (satellite) galaxies inside most of these subhalos (e.g., Bullock et al. 2000;
Benson et al. 2002). The subhalos and the associated gas clouds could produce signs of distortion in isolated galaxies (Trentham et al. 2001; Pisano et al. 2002). If these signs are clear, then observations in the radio could reveal the presence of 21 cm hydrogen line emission associated with a pure gas companion galaxy. But if such an emission is absent, there is still the possibility that the “perturber” is just a dark matter (sub)halo without any baryonic component (Trentham et al. 2001). Recently, Karachentsev et al. (2006), by analyzing a large sample of isolated galaxies, have reported the finding of four such possible cases.

Homogeneous observational data samples of isolated disk galaxies are crucial for obtaining transparent scaling relationships and correlations that can be appropriately compared with model predictions (see, e.g., Zavala et al. 2003). In recent years, some groups have been working on the compilation and observation of such samples (e.g., Pisano et al. 2002; Allam et al. 2005; Koopmann & Kenney 2006). For galaxies in voids, which are the most likely to be isolated, see Rojas et al. (2004, 2005). It is worth mentioning that the important requirements for all these samples are as follows: well-defined and strong isolation criteria, uniform-quality data acquisition in several wavelengths, and completeness when possible.

We have carried out optical CCD photometry for a representative set of galaxies in the northern Catalogue of Isolated Galaxies (CIG; Karachentseva 1973). This is one of the best-defined and most complete catalogs of isolated galaxies. The aim of this paper is to present a global BVRI photometric and morphological analysis for a subsample of 44 spiral galaxies from the CIG. We strongly emphasize that all the observations were done with the same CCD detector. After applying uniform reduction and analysis procedures, a homogeneous set of photometric and morphological data is guaranteed. CIG galaxies cover a wide range in luminosities, surface brightnesses, morphological types, and colors. Their relative simplicity and closeness, as compared with galaxies in other environments, offer a unique opportunity for a more detailed and less confused interpretation of their structural, photometric, and morphological properties.

The outline of the paper is as follows: Section 2 summarizes the selection criteria applied to the isolated galaxy sample that are relevant to our photometric study and describes the observations and reduction techniques used here. Section 3 presents a comparison of our estimated total magnitudes against those in the literature. In §4 we discuss the observed morphology based on mosaic R-band and R-band sharp-filtered images, (B – I) color index maps, and composed near-infrared (NIR) JHK images extracted from the Two Micron All Sky Survey (2MASS) archives. Emphasis is put on the presence of disturbed morphology. Section 5 presents our estimates of the optical (BVRI) and NIR JK-band CAS structural parameters. In §6 we explore and discuss some basic correlations among the BVRI-JK photometric and structural parameters in this sample that could be useful for comparative studies involving galaxies in other environments. Section 7 provides a summary of the paper. Finally, an Appendix is devoted to the presentation of BVRI magnitudes at two other concentric circular apertures.

2. THE DATA SAMPLE

2.1. Isolated Spiral Galaxies from the Karachentseva Catalog

We have carried out an observational program at the Observatorio Astronómico Nacional at San Pedro Mártir (OAN-SPM), Baja California, Mexico, devoted to obtaining uniform CCD photometric data for one of the most complete and homogeneous samples of isolated galaxies currently available, the CIG of Karachentseva (1973). This sample amounts to more than 1050 galaxies in the northern hemisphere. The CCD BVRI images in the Johnson-Cousins system were obtained with a SITE1 detector attached to the 1.5 and 0.84 m telescopes at OAN-SPM, covering an area of about 4.3’ × 4.3’ and 7.2’ × 7.2’, with a typical seeing of 1.7’ and a scale of 0.51” pixel−1 and 0.85” pixel−1, respectively.

The original number of galaxies in three observing runs amounts to 52 galaxies. From these, we eliminated six galaxies obtained under bad observing conditions and two ellipticals, yielding a final sample of 44 isolated spiral galaxies for the present study. We applied no special strategy in selecting this current subset. Availability of observing time and weather conditions were the main factors constraining the number of observed galaxies. Some aspects of the selection criteria for the CIG sample that are most relevant to the present and further photometric analyses are stated here.

The isolated galaxies in the CIG sample were selected from a visual search of the Palomar Sky Survey. The catalog samples the sky north of δ ≥ −3°. The vast majority of objects are found in high Galactic latitude regions (b ≥ 20°), and as a sample, it is reasonably complete (~90%) in the magnitude range 13.5 ≤ m_UV ≤ 15.7 (Hernández-Toledo et al. 1999). The selection criteria used in assembling the CIG can be expressed by the following relations:

\[ x_{i1} > 20a_i, \]
\[ 0.25a_i < a_i < 4a_i, \]

where \( x_{i1} \) is the apparent separation between the candidate isolated galaxy of apparent diameter \( a_i \) and any other neighboring galaxy of apparent diameter \( a_i \). Under these criteria, any other galaxy of comparable size (\( a_i = a_i \)) should be at a distance of at least 20 times its diameter (projected on the sky) from the isolated galaxy.

Assuming a typical galaxy diameter \( D \sim 20 \) kpc and a peculiar velocity relative to the Hubble flow \( V \sim 150 \) km s⁻¹ (Rivolo & Yahil 1981), the time required for an intruder galaxy to traverse 20 diameters is \( \sim 2 \times 10^9 \) yr. This is a first-order estimate of the time since the last equal-size galaxy-galaxy interaction for a CIG system, and it suggests that CIG galaxies are reasonably isolated. It is therefore expected that only the intrinsic properties of the individual galaxies in the CIG should influence the observed photometric and morphological properties.

Karachentseva (1973) included other isolation criteria (coded as 1 and 2 in her original catalog) depending on whether or not other galaxies, within a factor of 4 in size, were found near a 20 diameter boundary or even whether a galaxy was definitely not isolated according to the CIG criteria. Less isolated galaxies account for less than 5% of our CIG sample and have been excluded from the present study.

2.2. Data Reduction

A journal of the photometric observations is given in Table 1. Column (1) gives the original catalog number, and columns (2)–(9) give the number of frames per filter, the integration time (in seconds), and the seeing conditions (in arcseconds).

Table 2 reports some relevant information on the observed isolated galaxies obtained from the literature. Column (1) gives the CIG number, column (2) reports other identifications, column (3) gives the apparent total B magnitude from the Lyon Extragalactic Database (LEDA), column (4) gives the Hubble type from LEDA, column (5) gives the apparent total B magnitude
from the NASA/IPAC Extragalactic Database (NED),\(^2\) and column (6) gives the radial velocity in kilometers per second, corrected for Virgocentric infall from LEDA.

Images were debiased, trimmed, and flat-fielded using standard IRAF\(^3\) procedures. First, the bias level of the CCD was subtracted from all exposures. A run of 10 bias images was obtained per night, and those were combined into a single bias frame, which was then applied to the object frames. The images were flat-fielded using sky flats taken in each filter at the beginning and/or end of each night.

Photometric calibration was achieved by nightly observations of standard stars of known magnitudes from the PG 0231+051 field of stars (Landolt 1992) with a color range \(-0.3 \leq (B - V) \leq 1.5\) and \(-0.1 \leq (B - I) \leq 3.0\). Once the principal extinction coefficients in \(B, V, R,\) and \(I\) were estimated, the transformations of the instrumental magnitudes to a standard system were calculated according to the following equations:

\[
B - b = \alpha_B + \beta_B (b - v)_0, \\
V - v = \alpha_V + \beta_V (b - v)_0, \\
R - r = \alpha_R + \beta_R (b - v)_0, \\
I - i = \alpha_I + \beta_I (v - r)_0, 
\]

where \(B, V, R,\) and \(I\) are the standard magnitudes, \(b, v, r,\) and \(i\) are the instrumental (and air-mass-corrected) magnitudes.

### TABLE 1

| CIG  | \(B\)  | \(\langle B_{\text{FWHM}} \rangle\) | \(V\)  | \(\langle V_{\text{FWHM}} \rangle\) | \(R\)  | \(\langle R_{\text{FWHM}} \rangle\) | \(I\)  | \(\langle I_{\text{FWHM}} \rangle\) |
|------|-------|-----------------|-------|-----------------|-------|-----------------|-------|-----------------|
| 1    | 1 \times 1200 | 2.3             | 1 \times 600 | 2.4             | 1 \times 300 | 2.1             | 1 \times 300 | 2.4             |
| 4    | 1 \times 1200 | 2.3             | 1 \times 600 | 2.2             | 1 \times 300 | 2.0             | 2 \times 150 | 1.8             |
| 8    | 1 \times 1200 | 2.3             | 1 \times 600 | 2.2             | 1 \times 300 | 2.3             | 1 \times 300 | 2.5             |
| 12   | 1 \times 1200 | 2.1             | 2 \times 600 | 2.3             | 2 \times 300 | 2.0             | 2 \times 300 | 1.8             |
| 18   | 2 \times 1200 | 2.1             | 1 \times 600 | 2.5             | 1 \times 300 | 2.3             | 1 \times 300 | 2.2             |
| 24   | 1 \times 1200 | 2.1             | 1 \times 600 | 2.3             | 1 \times 300 | 1.9             | 2 \times 150 | 1.6             |
| 30   | 2 \times 1200 | 2.0             | 1 \times 600 | 2.3             | 2 \times 150 | 1.9             | 2 \times 150 | 2.0             |
| 36   | 2 \times 1200 | 2.2             | 2 \times 600 | 1.9             | 3 \times 150 | 1.8             | 3 \times 150 | 2.1             |
| 50   | 2 \times 1200 | 2.1             | 1 \times 600 | 2.0             | 1 \times 300 | 1.8             | 2 \times 150 | 1.6             |
| 100  | 2 \times 1200 | 2.0             | 3 \times 600 | 1.9             | 1 \times 300 | 1.8             | 2 \times 150 | 1.6             |
| 120  | 2 \times 1200 | 1.9             | 1 \times 600 | 2.0             | 3 \times 150 | 1.7             | 4 \times 150 | 1.8             |
| 126  | 2 \times 1200 | 1.8             | 1 \times 900 | 1.8             | 2 \times 300 | 1.7             | 1 \times 300 | 1.8             |
| 150  | 1 \times 1200 | 1.8             | 1 \times 900 | 1.7             | 1 \times 300 | 1.7             | 1 \times 300 | 1.8             |
| 180  | 2 \times 1200 | 2.0             | 2 \times 300 | 1.7             | 2 \times 60 | 1.7             | 2 \times 60 | 1.7             |
| 200  | 2 \times 1200 | 1.8             | 1 \times 600 | 1.7             | 1 \times 300 | 1.8             | 1 \times 300 | 1.8             |
| 230  | 2 \times 1200 | 1.8             | 1 \times 900 | 1.7             | 2 \times 300 | 1.7             | 1 \times 300 | 1.8             |
| 240  | 2 \times 1200 | 1.8             | 1 \times 900 | 1.7             | 1 \times 300 | 1.7             | 1 \times 300 | 1.8             |
| 270  | 2 \times 1200 | 1.8             | 1 \times 900 | 1.7             | 1 \times 300 | 1.7             | 1 \times 300 | 1.8             |
| 300  | 2 \times 1200 | 1.9             | 1 \times 600 | 2.0             | 1 \times 300 | 2.0             | 1 \times 300 | 1.9             |
| 360  | 2 \times 1200 | 1.8             | 1 \times 900 | 2.0             | 1 \times 300 | 2.0             | 1 \times 300 | 1.9             |

Note.—The number of frames per filter, the integration time (in seconds), and the mean FWHM for each observation (in arcseconds) are given.

\(^2\) Available at http://nedwww.ipac.caltech.edu.

\(^3\) The IRAF package is written and supported by the IRAF programming group at the National Optical Astronomy Observatory (NOAO) in Tucson, Arizona. NOAO is operated by the Association of Universities for Research in Astronomy, Inc., under cooperative agreement with the National Science Foundation.
and $\alpha$ and $\beta$ are the transformation coefficients for each filter.

A constant value associated with the sky background was subtracted using an interactive procedure that allows the user to select regions on the frame free of galaxies and bright stars. Errors in determining the sky background are, in fact, the dominant source of errors in the estimation of total magnitudes.

The most energetic cosmic-ray events were automatically masked using the cosmicrays task, and field stars were removed using the imedit task when necessary. Within the galaxy itself, care was taken to identify superposed stars. A final step in the basic reduction involved registration of all available frames for each galaxy and in each filter to within $0.1$ pixels. This step was performed by measuring centroids for foreground stars on the images and then performing geometric transformations using the geomap and geotran tasks in IRAF.

### 2.3. Errors

Apparent magnitudes for each galaxy were estimated in three concentric circular apertures. This was achieved in the $BVRI$ bands by using the phot routines in IRAF. Here we report the total apparent magnitudes, while in the Appendix we report apparent magnitudes at two other circular apertures, also in the $BVRI$ bands (see Table 7 in the Appendix).

An estimation of the errors in our photometry involves two parts: (1) the procedures to obtain instrumental magnitudes and (2) the uncertainty when such instrumental magnitudes are transformed to the standard system.

For item 1, notice that the magnitudes produced by the output of the IRAF routines (phot) have a small error that is internal to those procedures. Since we have also applied extinction corrections to the instrumental magnitudes in this step, our estimation...
of the errors is mainly concerned with these corrections and the estimation of the air mass. After a least-squares fitting, the associated errors of the slope for each principal extinction coefficient are $\delta(k_B) \sim 0.02$, $\delta(k_V) \sim 0.02$, $\delta(k_R) \sim 0.02$, and $\delta(k_I) \sim 0.015$. An additional error $\delta(\text{air mass}) \sim 0.005$ from the air-mass routines in IRAF was also considered.

For item 2, the zero point and first-order color terms are the most important to consider. After the transformation to the standard system by adopting our best-fit coefficients, the errors from the assumed relations for $\alpha$ were, respectively, 0.02, 0.04, 0.02, and 0.02 in $B$, $V$, $R$, and $I$ and 0.02, 0.03, 0.02, and 0.02 for $\beta$. To estimate the total error in each band, it is necessary to propagate the errors after considering the corresponding transformation equations. An estimate of the sky contribution is necessary for quoting the total uncertainties. This was achieved by estimating the total magnitudes for all galaxies before and after sky subtraction. Typical values $\delta(B) \sim 0.08$, $\delta(V) \sim 0.08$, $\delta(R) \sim 0.09$, and $\delta(I) \sim 0.1$ are obtained. Total typical uncertainties are 0.1, 0.12, 0.12, and 0.15 in the $B$, $V$, $R$, and $I$ bands, respectively.

The estimated total magnitudes in this work were compared with other external estimations when available in the literature. This has been done for (1) the standard stars and (2) the isolated spiral galaxies.

2.4. Standard Stars

For the standard stars, a comparison of our CCD magnitudes with those reported in Landolt (1992) for stars in the field of PG 0231+051 and the Dipper asterism star cluster M67 (Chevalier & Ilovaisky 1991) is shown in Figure 1.

Figure 1 shows no significant deviations between our CCD magnitudes and those reported for the standard stars. A linear fit to this plot indicates $\sigma \sim 0.005$ as the typical internal error for our magnitude estimations.

2.5. Isolated Galaxies

Figure 2 shows a comparison of the estimated magnitudes for the isolated galaxies in the $B$, $V$, and $I$ bands versus the available total magnitudes in NED and the aperture photometry in the HyperLeda databases. Discrepant cases such as CIG 80, 168, 188, 434, and 691 in the different bands are emphasized in the figure.

We find a reasonable agreement with the available values from the literature, except for a few discrepant cases shown in the figure. HyperLeda reports detailed aperture photometry in the $B$ band for CIG 80. From a plot of the available data, the reported value should correspond to an aperture size $\log A \sim 2$, while our magnitude corresponds to $\log A = 1.58$. The corresponding magnitude for an aperture similar to ours is 11.60 mag, in complete agreement with our estimation.

HyperLeda does not report any aperture photometry in the $B$ band for CIG 168. A detailed aperture photometry in the $V$ and $I$ (Cousins) bands is found instead. The $V$-band value in HyperLeda corresponds to $\log A = 1.44$, while ours is $\log A = 1.50$. An extrapolation of the available $V$ and $I$ magnitudes to our aperture size is consistent with our photometry. This makes us confident that our $B$-band magnitude is well estimated and suggests that the $B$-band magnitude reported in HyperLeda should correspond to a smaller $\log A$ value.

In the case of CIG 188, both HyperLeda and NED report a homogenized magnitude from previously published data, assuming standard Johnson $UBVRI$ filters. Note, however, that the NED magnitude is $14.10 \pm 0.75$ with a large error bar. Given the absence of detailed aperture photometry and the diffuse nature of this galaxy (see Fig. 4.19), we suggest that the observed discrepancy is explained by the different aperture sizes.

HyperLeda reports a couple of aperture data points for CIG 434 (corresponding to $\log A = 1.12$ and 1.3; see Gallagher & Hunter 1986). By assuming a linear curve of growth, an extrapolation to $\log A = 1.5$ (our aperture size) yields a magnitude value consistent with our data. NED reports a homogenized magnitude from previously published data, assuming standard Johnson $UBVRI$ filters.

For CIG 691, HyperLeda reports a $B$-band magnitude of $13.33 \pm 0.562$, while NED reports a magnitude of $12.60 \pm 0.5$, which is significantly closer to our reported value. Even more, the only aperture data point in HyperLeda suggests that the reported value corresponds to a smaller aperture size than ours.

Finally, the internal accuracy of our photometry was evaluated by comparing the total magnitudes derived from individual exposures. We find rms differences between individual measurements of $\delta(B) \sim 0.06$, $\delta(V) \sim 0.06$, $\delta(R) \sim 0.05$, and $\delta(I) \sim 0.05$. Additional magnitudes at two other concentric circular apertures in $B$, $V$, $R$, and $I$ for all the isolated galaxies in this study are reported in the Appendix.

3. Magnitudes and Colors

The estimated apparent magnitudes and the colors of the galaxies in the sample are presented in Table 3. Entries are as follows: Column (1) gives the CIG number, column (2) gives the logarithmic aperture size in 0.1 units according to the HyperLeda convention, and columns (3)–(6) give the observed integrated apparent magnitudes in the $B$, $V$, $R$, and $I$ bands. Finally, columns (7)–(9) give the observed $(B-V)$, $(B-R)$, and $(B-I)$ color indices. Total typical uncertainties in our photometry are 0.10, 0.12, 0.11, and 0.16 for the $B$, $V$, $R$, and $I$ bands, respectively.

The $(B-V)$-corrected colors span the range of $0.2$–$1.3$ mag. This is comparable to that reported in other samples of noninteracting galaxies (e.g., de Jong 1996; Verheijen 1997). We emphasize important differences in blue Galactic absorption values between Burstein & Heiles (1982) and Schlegel et al. (1998) for CIG 103 (1.485 vs. 0.440 mag), CIG 138 (1.95 vs. 0.65 mag), and CIG 144 (2.135 vs. 0.510 mag).
The fraction of dust seems to be larger for bigger galaxies, according to empirical (e.g., Giovanelli et al. 1995; Wang & Heckman 1996; Tully et al. 1998) and theoretical (e.g., Shustov et al. 1997) arguments. Therefore, the internal extinction correction should depend not only on inclination but also on galaxy scale:

\[ A_i(k) = \frac{C_{13}k}{a/b} \log \left( \frac{a}{b} \right) \]

where \( a/b \) is the major-to-minor axis ratio and \( C_{13k} \) is a scale-dependent coefficient in the given passband \( k \). From an empirical analysis, Tully et al. (1998) inferred the coefficients \( C_{13k} \) in the BRIK bands as a function of the galaxy maximum circular velocity. From their data (given in Tully & Pierce 2000) we have carried out linear correlations of these coefficients with the corresponding magnitudes not corrected for internal extinction:

\[
\begin{align*}
\gamma_B \text{(mag)} &= -6.30 - 0.40M_B, \quad M_B < -16.7, \\
\gamma_R \text{(mag)} &= -4.20 - 0.26M_R, \quad M_R < -17.7, \\
\gamma_I \text{(mag)} &= -3.40 - 0.20M_I, \quad M_I < -18.0, \\
\gamma_K \text{(mag)} &= -0.85 - 0.05M_K, \quad M_K < -19.7. \\
\end{align*}
\]

(3)

For values of the magnitudes larger than the limits given in equation (3), \( \gamma_k \) is assumed to be 0 (no extinction correction). For band \( V \), the line coefficients of \( \gamma_V \) were obtained by a simple interpolation of those in bands \( B, R, I \), and \( K \): \( \gamma_V \text{(mag)} = -4.67 - 0.29M_V, \quad M_V < -17.5 \). The \( a/b \) ratios estimated at the \( B \)-band 25 mag arcsec\(^{-2} \) isophote were taken from the HyperLeda database.

Table 4 shows foreground- and internal-extinction-corrected color indices and absolute magnitudes. Corrections are based on data generated from the dust galaxy maps given in Schlegel et al. (1998) and available in NED. Entries are as follows: Column (1) gives the identification CIG number, and columns (2)–(4) give the corrected \( (B-V), (B-R), \) and \( (B-I) \) color indices. Finally, columns (5)–(8) report the corrected absolute magnitudes in the \( B, V, R, \) and \( I \) bands. A Hubble constant value of 70 km s\(^{-1} \) Mpc\(^{-1} \) was adopted.

A more physical correction applied to the luminosities yields a \( B \)-band luminosity range \((-18.1 \leq M_B \leq -22.25) \), indicating no faint spirals in this sample, except for the case of CIG 434.

In Figure 3 we plot different color-magnitude diagrams \([M_B \text{ vs. } (B-V), (B-R), \text{ and } (B-I) \text{ colors}] \) for our sample of

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**Fig. 2.**—Comparison between our total \( B, V, \) and \( I \) magnitudes and the available photometry of similar apertures from the HyperLeda database. Discrepant cases like CIG 80, 168, 188, 434, and 691 are indicated. [See the electronic edition of the Journal for a color version of this figure.]
isolated galaxies. There is a mild correlation of colors with magnitude, although the sample is still small. In fact, a significant dependence of color on luminosity for normal isolated disk galaxies is not expected (e.g., Avila-Reese & Firmani 2000). The dependence that several papers reported in the past was mainly due to the dependence of internal extinction on luminosity (or circular velocity; Tully et al. 1998), which we take into account due to the dependence of internal extinction on luminosity (or dependence that several papers reported in the past was mainly the dependence of color on luminosity for normal isolated disk galaxies). There is a mild correlation of colors with magnitude, although the sample is still small. In fact, a significant dependence of color on luminosity for normal isolated disk galaxies is not expected (e.g., Avila-Reese & Firmani 2000). The dependence that several papers reported in the past was mainly due to the dependence of internal extinction on luminosity (or circular velocity; Tully et al. 1998), which we take into account accordingly here.

4. OPTICAL AND NIR MORPHOLOGY

In order to discuss the optical morphology (that could be modified by the presence of bars, rings, etc., or external factors) and its relationship to the global photometric properties, the images for each isolated galaxy are presented in the form of a mosaic in Figure Set 4, including, from top left to bottom right, (1) a gray-scale $R$-band image displayed at full intensity to look for faint external details; (2) an $R$-band sharp-filtered image to look for internal structure in the form of star-forming regions and/or structure embedded in dusty regions (the filtering/enhancing techniques [Sofue 1993] allow the subtraction of the diffuse background in a convenient way for discussing the different morphological details; (3) a $B$ index map to visualize the spatial distribution of the SF (light gray is for blue colors, while dark gray is for red colors); (4) a composed (sharp-filtered) NIR $JHK$ image which is a combination of the archive $J$, $H$, and $K$-band images from 2MASS (Skrutskie et al. 2006) to complement the structural and morphological analysis; and finally, at the far right, (5) the ellipticity $e$ and position angle (P.A.) radial profiles from the $I$ and composed $JHK$ images to provide evidence of the presence of bars and other structural details.

We identify a bar signature if the ellipticity radial profile $e$ rises to a maximum $e_{\text{max}}$ required to be above that of the outer disk, while the P.A. radial profile shows a plateau (within ±20°) along the bar (Wozniak et al. 1995).
All the images are oriented according to the standard (north-east) astronomical convention. The NIR images are approximately at the same scale as the optical images. For the sake of not crowding, the major diameter (in arcminutes) of the optical images is specified in the caption for each galaxy. In some cases, not all the foreground stars in each field have been removed.

In addition, we use the fact that the median value of the $(B - V)$ color declines systematically as the morphological type $T$ increases along the morphological sequence. Median integrated total $(B - V)$ colors of galaxies according to morphological class are given by Roberts & Haynes (1994). The UGC and the Local Supercluster samples in Roberts & Haynes (1994) are rather inhomogeneous in terms of environment, but the interacting objects were excluded from their analysis. The median colors of these samples are used as a reference in the following discussion.

4.1. Comments on Individual Objects

**CIG 1**: The galaxy was classified as SABbc (NED). The $R$-band and sharp-filtered images show a conspicuous fanlike structure at the end of the arms resembling a tidally disturbed galaxy. The optical images show three sharp-defined arms and a bar also visible in the composed image. We classify this galaxy as SBbc. The total $(B - V)$ color is representative of Sc types.

**CIG 4**: The galaxy was classified as Sc (NED). The gray-scale $R$-band image shows an inclined galaxy through a series of dust lanes. The optical $R$-band sharp-filtered and the $(B - I)$ color map images show two multiple and knotty arms and a strongly reddened central region. The composed $JHK$ image shows two main arms and an elongated central barlike region. We classify...
this galaxy as SABc. The total $(B - V)$ color is strongly reddened and not representative of Sc types. The photometric $(I$- and $JHK$-band $(\epsilon$ and P.A.) profiles show evidence of a bar in this galaxy.

**CIG 33:** This galaxy was classified as SAB(rs)cd (NED). The gray-scale $R$-band image shows a faint outer arm in the east, emphasizing its asymmetric appearance. Its internal $S$-shaped structure surrounded by a series of dust lanes and two prominent blobs to the north and southeast of the inner spiral arms is also apparent. The $B - I$ color index map shows a ringlike structure. The $JHK$-band image clearly shows an inner barred structure from which two arms emerge. We classify this galaxy as SB(rs)c. The total $(B - V)$ color is representative of Sc types. The photometric $I$- and $JHK$-band $(\epsilon$ and P.A.) profiles show evidence of a bar in this galaxy.

**CIG 53:** The galaxy was classified as a SB(rs)c (NED). The gray-scale $R$-band and the sharp-filtered images show knotty features along multiple arms, a prominent bar encircled by a ring elongated in the direction perpendicular to the bar, and the presence of strong dusty structures. The $B - I$ color map permits us to see a red central region and blue arms. The $JHK$-band image confirms the barred and ringed structures and traces of the arms. We classify this galaxy as SB(r)bc. The $(B - V)$ color is representative of Sbc types. The photometric $I$- and $JHK$-band $(\epsilon$ and P.A.) profiles show evidence of a bar in this galaxy.

**CIG 56:** The galaxy was classified as a SB(rs)b (NED). The gray-scale $R$-band image shows a barred galaxy with two dominant arms and a third faint arm to the northwest. At the outskirts, the two arms become diffuse. The sharp-filtered image and $(B - I)$ color map show a blue ring elongated in the direction of a red bar. The $JHK$ composed image shows a prominent bar and two dominant arms. We classify this galaxy as SB(r)b. The $(B - V)$ color is representative of Sb types. The photometric $I$- and $JHK$-band $(\epsilon$ and P.A.) profiles show evidence of a bar in this galaxy.

**CIG 68:** The galaxy was classified as SAB(rs)a (NED). The gray-scale $R$-band image shows a central elongated structure from which two arms emerge, while the sharp-filtered image shows traces of a bar. The $(B - I)$ color map shows a bluer ring elongated...
in the direction of the bar and an adjacent dust lane. The composed $JHK$ image shows a prominent bar and two arms. We classify this galaxy as SBr(r)a. The $(B - V)$ color is representative of Sa types. The photometric $I$- and $JHK$-band $(\epsilon$ and P.A.) profiles show evidence of a bar in this galaxy.

**CIG 80:** The major axis of this galaxy is longer than our CCD frame. However, we comment on the structure found within 4.3′. The galaxy was classified as SA(s)b (NED). The gray-scale $R$-band and sharp-filtered images show a multiarmed and strongly asymmetric pattern enhanced by the presence of dust lanes, resembling a strongly perturbed system. The $(B - I)$ color map shows an inner ring and bluer arms. The composed $JHK$ image shows a barlike structure from which two prominent arms seem to emerge and confirms the red nature of a ring oriented in the direction of the bar. We classify this galaxy as SBr(r)b. The $(B - V)$ color is consistent with Sab types. The photometric $(\epsilon$ and P.A.) profiles show weak evidence of a bar within the inner 25′′ of this galaxy. We noticed that this galaxy might not necessarily be isolated, because it appears in the LEDA database as part of a group.

**CIG 103:** The galaxy was classified as SAB(rs)ce (NED). This is another example of an apparently multiarmed galaxy seen through a series of strong dust lanes as shown in our $R$-band, sharp-filtered, and $B - I$ color map images. The color map also shows an elongated red central region apparently encircled by a pseudoring along the direction of a bar. The composed $JHK$ image shows evidence of a weak bar from which two arms emerge. We classify this galaxy as SBr(r)c. The $(B - V)$ color is consistent with Sc types. The photometric $(\epsilon$ and P.A.) profiles show weak evidence of a bar or an elongated structure within the inner 15′′ of this inclined galaxy.

**CIG 116:** The galaxy was classified as RSB(s)a (NED). All our images show this galaxy with two inner well-defined arms making an S-shaped structure. These arms become diffuse as they wind out, giving the appearance of an external ring oriented almost perpendicular to the bar. The internal structure is seen through strong dust lanes. The composed $JHK$ image shows the presence of a bar and two inner dominant arms. We classify this galaxy as RSB(s)a. The $(B - V)$ color is consistent with Sa types. The photometric $(\epsilon$ and P.A.) profiles show evidence of a bar in this galaxy.

**CIG 123:** This galaxy is classified as SBr(rs)bc (NED). From the global distribution of optical light, this galaxy appears asymmetric. Our images show an apparently multiple set of faint southern arms and a strong southern dust lane. The red central region, including the bar, and the bluer ring and arms are emphasized in the $B - I$ color index map. The composed $JHK$ image clearly shows a strong bar and a ring oriented in the direction of the bar. We classify this galaxy as SBr(r)c. The $(B - V)$ color is consistent with Sbc types. The photometric $I$- and $JHK$-band $(\epsilon$ and P.A.) profiles show evidence of a bar in this galaxy.

**CIG 138:** This galaxy was classified as SB(s)d (NED). This is an inclined galaxy seen through a series of dust lanes, causing the arms to appear multiple in nature. The $(B - I)$ color index map clearly emphasizes the reddened nature of the light distribution. In contrast, the composed $JHK$ image shows mainly two arms and an elongated central structure resembling a bar. We classify this galaxy as SBc. The reddened $(B - V)$ color does not correspond to ScSd types. The photometric $I$- and $JHK$-band $(\epsilon$ and P.A.) profiles do not show evidence of a bar in this galaxy.

**CIG 139:** The galaxy was classified as SB(s)dm pec (NED). The $(B - I)$ color index map, however, shows a central reddened region and an outer bluer region similar to what is observed in spirals. There are no archived $JHK$ images for this galaxy. We preserve NED’s classification in this case. Note that the obtained $(B - V)$ color is representative of Sm/Irr types. The photometric $I$-band $(\epsilon$ and P.A.) profiles do not show evidence of a bar.

**CIG 144:** The galaxy was classified as Sb (NED). This is an edge-on galaxy showing a peanut-shaped bulge in the sharp-filtered image. However, the $B - I$ color index image and the composed $JHK$ image show a different structure. We classify this galaxy as SBbc. The reddened $(B - V)$ color corresponds more to Sa types. The photometric $I$- and $JHK$-band $(\epsilon$ and P.A.) profiles are consistent with the presence of a bar in the inner 30′′ of this inclined galaxy.

**CIG 151:** The galaxy was classified as SAdm (NED). This is an inclined and apparently multiarmed spiral galaxy. The central region appears elongated in the sharp-filtered image and red in the $B - I$ color map. The composed $JHK$ image suggests a bar structure and two adjacent arms. We classify this galaxy as SABbc. The $(B - V)$ color corresponds to Sc types. The photometric $I$- and $JHK$-band $(\epsilon$ and P.A.) profiles show weak evidence of a bar in this inclined galaxy.

**CIG 154:** The galaxy was classified as SBcd (NED). This apparently disturbed galaxy shows an elongated and reddened central region. The winding of the inner arms suggests a ring oriented in the direction of the bar. The inner arms appear bifurcated at various places, and faint outer arms are also perceived. The composed $JHK$ image shows a bar and a ring. We classify this galaxy as SB(r)cd. The $(B - V)$ color corresponds to ScdSd types. The photometric $I$- and $JHK$-band $(\epsilon$ and P.A.) profiles show evidence of a bar in the inner 10′′ and of a ring at about 12′′ in this galaxy.

**CIG 168:** The galaxy was classified as SAB(sbc) (NED). It appears moderately flocculent in the optical images with an elongated and red central region. The composed $JHK$ image also suggests an elongated central structure and only two prominent arms. The $(B - V)$ color corresponds to ScdSd types. We classify this galaxy as SAB(s)cd. The photometric $I$- and $JHK$-band $(\epsilon$ and P.A.) profiles do not show evidence of a bar.

**CIG 175:** The galaxy was classified as SA(s)a pec (NED). The optical images show traces of diffuse and faint armlike features and a prominent central region. The knotty appearance in the central part may be either intrinsic or caused by some coincident field stars not appearing in the composed $JHK$ image. The $(B - V)$ color corresponds to Sm/Im types. We classify this galaxy as Sa pec. The photometric $I$- and $JHK$-band $(\epsilon$ and P.A.) profiles are consistent with smooth precessing armlike features.

**CIG 180:** The galaxy was classified as SA(rs)c (NED). The optical images show a multiple set of tightly wound arms and a reddened central region apparently encircled by an inner ring. In contrast, the composed $JHK$ image shows a prominent central region and traces of the adjacent disk. We classify this galaxy as SA(r)b. This is an interesting case of a nonbarred spiral with a symmetric inner ring that also shows hints of a circumnuclear ring. The $(B - V)$ color corresponds to SabSb types. The photometric $I$- and $JHK$-band $(\epsilon$ and P.A.) profiles show weak evidence of a central ring within the inner 10′′ and emphasize, in contrast with the optical image, the smooth nature of the central NIR structure in this galaxy.

**CIG 188:** The galaxy was classified as SAB(s)d (NED). This galaxy shows multiple arms in the optical images. The sharp-filtered image allows us to see a central bar structure that is red in the $B - I$ color map. The low signal in the composed $JHK$ image does not permit us to appreciate the central bar, but the photometric $I$- and $JHK$-band $(\epsilon$ and P.A.) profiles confirm the presence of a central bar. The total $(B - V)$ color is representative of SdSd types. We classify this galaxy as SB(s)d.
CIG 208: The galaxy was classified as Sb (NED). This is a highly inclined galaxy. The sharp-filtered and color index images show the central region resembling a long bar and the outer arms. The total \((B-V)\) color is representative of ScdSd types. The photometric \(I\)- and \(JHK\)-band \((\epsilon \text{ and P.A.})\) profiles also resemble a bar within the inner 25\(^\circ\). We classify this galaxy as SABcd.

CIG 213: The galaxy was classified as S0 (NED). We use the \(B\)-band image to show a bar surrounded by an almost circular ring oriented in the direction of the P.A. of the bar. The total \((B-V)\) color is representative of E0 types. We classify this galaxy as RSB0. The photometric \(B\)- and \(JHK\)-band \((\epsilon \text{ and P.A.})\) profiles confirm a bar within the inner 15\(^\circ\).

CIG 224: The galaxy was classified as SB(r)s(d) (NED). The optical images show a galaxy of flocculent appearance with an outer pseudoring and evidence of a bar. The composed \(JHK\) image is of low signal but still shows an elongated central region. The total \((B-V)\) color is representative of SdSm types. We classify this galaxy as RSBD. The photometric \(I\)- and \(JHK\)-band \((\epsilon \text{ and P.A.})\) profiles show a bar within the inner 15\(^\circ\).

CIG 237: The galaxy was classified as Sc (NED). This is an edge-on galaxy. The total \((B-V)\) color is representative of Scd types. Based on the observed prominence of the bulge region in the optical and composed \(JHK\) images, we assume Sc classification.

CIG 309: The galaxy was classified as SA(r)ab (NED). The optical and \(JHK\) images show an inner and outer ring. The optical images show an intermediate region of strongly wound and knotty arms. The total \((B-V)\) color is representative of S0Sa types. We classify this galaxy as RS(r)a. The smooth behavior of the photometric \(I\)- and \(JHK\)-band \((\epsilon \text{ and P.A.})\) is consistent with an early-type galaxy.

CIG 314: The galaxy was classified as SAB(rs)c (NED). This is a multiarmed knotty spiral showing a red central region. The composed \(JHK\) image barely shows part of two arms emanating from an elongated central region. The photometric \(I\)- and \(JHK\)-band \((\epsilon \text{ and P.A.})\) profiles show evidence of a weak bar. The total \((B-V)\) color is representative of ScdSd types. We classify this galaxy as SAB(rs)c.

CIG 434: The galaxy was classified as Im (NED). The optical images show a Magellanic-type irregular with an elongated and red region resembling a bar. There are no detected images available in the 2MASS survey. The total \((B-V)\) color is representative of Im types. We keep the Im classification. The photometric \(I\)- and \(JHK\)-band \((\epsilon \text{ and P.A.})\) profiles show evidence of a bar.

CIG 472: The galaxy was classified as SAB(rs)c (NED). The optical images show a pattern of two arms that become bifurcated at the outer regions. In contrast, the composed \(JHK\) image shows a single prominent northern arm extending to the south. The total \((B-V)\) color is representative of ScdSd types. The photometric \(I\)- and \(JHK\)-band \((\epsilon \text{ and P.A.})\) profiles show evidence of a bar. We classify this galaxy as SAB(rs)c.

CIG 518: The galaxy was classified as SA(s)c (NED). The optical images show a pattern of two arms that become bifurcated at the outer regions and a red elongated central region. In contrast, the composed \(JHK\) image shows only two prominent arms that appear to enclose an elongated central region. The photometric \(I\)- and \(JHK\)-band \((\epsilon \text{ and P.A.})\) profiles show evidence of a bar. The total \((B-V)\) color is representative of SbSc types. We classify this galaxy as SB(s)bc.

CIG 528: The galaxy was classified as SAbc (NED). The optical images show a spiral pattern with two faint, thin outer arms to the northeast and southwest resembling tidal tails. The composed \(JHK\) image shows only part of two central arms. The total \((B-V)\) color is representative of ScdSd types. The photometric \(I\)- and \(JHK\)-band \((\epsilon \text{ and P.A.})\) profiles do not show evidence of a bar. We classify this galaxy as SA(rs)c.
to Sb types. The photometric $I$- and $JHK$-band ($\epsilon$ and P.A.) profiles show evidence of a bar in the inner 15% of this galaxy.

**CIG 935:** The galaxy was classified as SAB(rs)cd (NED). The optical images show a multiarmed spiral pattern with an elongated central region. In contrast, the composed $JHK$ image shows traces of a two-armed central pattern. The photometric $I$- and $JHK$-band ($\epsilon$ and P.A.) profiles show weak evidence of a bar. The $(B - V)$ color corresponds to SbcSc types. We classify this galaxy as SAB(rs)cd.

**CIG 976:** The galaxy was classified as SbcSc (NED). The photometric $I$- and $JHK$-band ($\epsilon$ and P.A.) profiles show weak evidence of a bar. The $(B - V)$ color corresponds to SbcSc types. We classify this galaxy as SbcSc.

**CIG 983:** The galaxy was classified as SAB(rs)cd (NED). The optical images show a multiarmed spiral pattern with a slightly elongated central region. The sharp-filtered image shows only a two-armed pattern and a slightly elongated central region. The photometric $I$- and $JHK$-band ($\epsilon$ and P.A.) profiles show weak evidence of a bar. The $(B - V)$ color corresponds to SbcSc types. We classify this galaxy as SAB(rs)cd.

**CIG 1004:** The galaxy was classified as SB(s)c (NED). The optical images show a bar and a multiarmed spiral pattern. The composed $JHK$ image shows only a two-armed spiral pattern and a prominent large-scale bar. The photometric $I$- and $JHK$-band ($\epsilon$ and P.A.) profiles also show evidence of a large bar. The $(B - V)$ color corresponds to SbcSc types. We classify this galaxy as SB(s)c.

**CIG 1009:** The galaxy was classified as Sa (NED). The optical images show a set of tightly wound arms forming an inner ring. The composed $JHK$ image also shows a central-arm pattern. The photometric $I$- and $JHK$-band ($\epsilon$ and P.A.) profiles do not show evidence of a bar. The $(B - V)$ color corresponds to SbSb types. We classify this galaxy as Sa(ab).

**CIG 1023:** The galaxy was classified as SB(r)b (NED). The optical images show arms forming an outer ring. A bar is seen enclosed by an inner ring along the major axis of the bar. The arms appear to start at the end parts of the bar. The composed $JHK$ image shows the prominence of the bar. The $(B - V)$ color corresponds to SbSb types. We classify this galaxy as RSB(r)b.

### 4.2. Generalities of the Sample

Table 5 is a summary of the morphological results found in this work. Column (1) gives the original catalog number, column (2) gives the Hubble type as reported in NED, column (3) gives the Hubble type as estimated in this work, column (4) indicates the presence of bars/rings, column (5) indicates the presence of multiple arms from the optical ($BVR\text{I}$) images, and column (6) reports the bar ellipticity (corrected for inclination).

NED contains morphological information on subtypes for almost all of these isolated galaxies, except for some of the most inclined ones (CIG 144, 208, 237, 889, and 906). Of the galaxy sample, 42% are earlier than Sbc and 52% are of Sbc type or later. The catalog information concerning bars (confirmed and presumed) comprised 27 galaxies before this work, and we were able to add this information to 8 other galaxies. This indicates that up to 79.5% of the isolated galaxies in this subsample show evidence of barred structure: for 63.5% the evidence is clear (SB galaxies), and for 16% the bars are weak or suspected (SAB galaxies). The bar fraction is roughly the same for early and late types. We have measured the $I$-band and $JHK$ isophotal ellipticities associated with a bar and calculated the maximum ellipticity, $\epsilon_{\text{max}}$. This quantity (corrected by inclination) is related to a measure of bar strength, such as gravitational bar torque (Laurikainen et al. 2002). Column (6) in Table 5 gives the values of $\epsilon_{\text{max}}$ for our sample. Among barred galaxies, the average value of $\epsilon_{\text{max}}$ is 0.39 ± 0.4. If we include the values of $\epsilon_{\text{max}} = 0.39$, seven early-type galaxies and six late-type galaxies have $\epsilon_{\text{max}} \geq 0.4$, which is commonly considered as evidence of a strong bar. Similarly, the catalog information for rings in our sample previously comprised 16 galaxies; in this work, this information has been added to 8 other galaxies, now accounting for 55% of the sample.

Finally, we emphasize the finding of clear morphological signatures of disturbance at least in two galaxies, CIG 1 and CIG 80. The disturbance is revealed in the former case by the broad fan-like shape of the outer arms, while in the latter case it is revealed by the strong global asymmetric pattern of the multiple arms (see Figs. 4.1 and 4.6 and § 4.1).

### 5. PHYSICAL MORPHOLOGY

Physical morphology has appeared as an alternative way to classify galaxies, on the basis of physical properties rather than visual features (see Morgan & Osterbrock 1969; Abraham et al. 1996; Conselice 1997; Bershady et al. 2000, among others). C03 (and references therein) has provided a useful framework for classifying galaxies closely tied to underlying physical processes and properties. C03 argues that the major ongoing and past formation modes of galaxies can be distinguished using three model-independent structural (photometric) parameters, which allow for a robust classification system. These parameters are the concentration of stellar light ($C$), its asymmetric distribution ($A$), and a measure of its clumpiness ($S$).

Below we present the $C\text{AS}$ parameters measured at various passbands for our observed sample of isolated galaxies. The $C\text{AS}$ characterization of this set of isolated galaxies is also helpful as a comparative sample for interpreting similar results of other surveys that sample galaxies in a wide range of environments (e.g., C03; Hernández-Toledo et al. 2005, 2006). Next, we briefly review each of the $C\text{AS}$ parameters.

#### Concentration of light ($C$).

The concentration index $C$ is defined as the ratio of the 80% to 20% curve of growth radii ($r_{80\%}$, $r_{20\%}$), within 1.5 times the Petrosian inverted radius at $r(\text{f1} = 0.2)r(\text{f2})$ normalized by a logarithm, $C = 5 \log(r_{80\%}/r_{20\%})$ (for more details, see C03). The concentration is related to the galaxy light (or stellar mass) distributions.

#### Asymmetry ($A$).

The asymmetry index is the number computed when a galaxy is rotated $180^\circ$ from its center and then subtracted from its prerotated image, and the summation of the intensities of the absolute value residuals of this subtraction is compared with the original galaxy flux (for more details, see C03). This parameter is also measured within 1.5$r_{C}$.

#### Clumpiness ($S$).

Galaxies undergoing SF are very patchy and contain large amounts of light at high spatial frequency. To quantify this, the clumpiness index $S$ is defined as the ratio of the amount of light contained in high-frequency structures to the total amount of light in the galaxy within 1.5$r_{C}$ (C03). The $S$-parameter, because of its morphological nature, is sensitive to dust lanes and inclination (C03).

#### Measurement of $C\text{AS}$ parameters.

The measurement of the $C\text{AS}$ parameters for the isolated spiral galaxies was carried out in...
several steps: (1) close field and overlapping stars were removed from each image; (2) sky background was removed from the images; (3) the center of each galaxy was considered as the barycenter of the light distribution and the starting point for measurements; (4) the CAS parameters for all the spiral isolated galaxies were estimated directly, i.e., isolated galaxies were not influenced by light contamination from any other galaxy of similar size in the neighborhood (isolation criteria); and (5) galaxies with high inclination or axis ratios could introduce systematic biased trends with wavelength. Figure 5 shows the cumulative distribution function of the CAS parameters at the R-band by other authors upon request.

The CAS parameters and their errors (Table 6). The CAS values in the other bands for our observed isolated spirals will be provided by us upon request.

By sorting the sample into early- and late-type spirals (SaSb and SbcSm, respectively), the corresponding average and standard deviation values of the CAS parameters are \((C/R)/(SaSb) = 4.00 \pm 0.50\), \((A(R)/(SaSb) = 0.08 \pm 0.05\), \((S(R)/(SaSb) = 0.20 \pm 0.12\) and \((C(R)/(SbcSm) = 3.10 \pm 0.40\), \((A(R)/(SbcSm) = 0.19 \pm 0.10\), \((S(R)/(SbcSm) = 0.36 \pm 0.20\). Our mean values are consistent with those reported in C03 for the Frei et al. (1996) sample of noninteracting galaxies, except in the case of \((S(R))/(SbcSm). Note, however, that irregulars were included in the SbcSm class, while in C03 these galaxies are separated.

An interesting question is how the CAS parameters change with wavelength. Figure 5 shows the cumulative distribution function of the CAS parameters at the B, R, J, and K bands. This comparison lets us see visually that there are significant systematic

### TABLE 5

| CIG       | Type (NED) | Type (This Work) | Bars/Rings | Optical Arms | Bar Ellipticity \(\epsilon_{\text{max}}\) |
|-----------|------------|------------------|------------|--------------|----------------------------------|
| CIG 1     | SABbc      | SBbc             | B          | Multi        | 0.24                            |
| CIG 4     | SAbc       | SABc             | B          | Multi        | 0.19                            |
| CIG 116   | (RSB)s/a   | RS B(s)a         | B          | Multi        | 0.42                            |
| CIG 123   | SB(rg)b    | SB(rg)b          | B          | Multi        | 0.46                            |
| CIG 138   | SB(rg)d    | SB(rg)d          | B          | Multi        | 0.0                             |
| CIG 139   | SB(r)sm    | SB(r)sm          | B          | Multi        | 0.36                            |
| CIG 144   | SB         | SABb             | B          | Multi        | 0.38                            |
| CIG 151   | SBd        | SBd              | B          | Multi        | 0.80                            |
| CIG 150   | SBd        | SBd              | B          | Multi        | 0.36                            |
| CIG 158   | SAbc       | SAbc             | B          | Multi        | 0.20                            |
| CIG 175   | SA(r)abc   | SA(r)abc         | B          | Multi        | 0.20                            |
| CIG 180   | SB(r) 0    | SB(r) 0          | B          | Multi        | 0.31                            |
| CIG 188   | SBabc      | SBabc            | B          | Multi        | 0.31                            |
| CIG 208   | Sb         | SABc             | B          | Multi        | 0.19                            |
| CIG 213   | S0         | RSB0             | B          | Multi        | 0.40                            |
| CIG 224   | SB(rg)d    | SB(rg)d          | B          | Multi        | 0.40                            |
| CIG 309   | Sa(r)ab    | RSa(r)ab         | R          | Multi        | 0.44                            |
| CIG 314   | SAb(s)c    | SAb(s)c          | B          | Multi        | 0.20                            |
| CIG 434   | Im         | Im               | B          | Multi        | 0.80                            |
| CIG 472   | SAB(s)c    | SAB(s)c          | R          | Multi        | 0.31                            |
| CIG 518   | SA(s)c     | SB(s)c           | B          | Multi        | 0.20                            |
| CIG 528   | SAbc       | SAbc             | R          | Multi        | 0.31                            |
| CIG 549   | SAbc       | SAbc             | R          | Multi        | 0.31                            |
| CIG 604   | SB(r)abc   | SB(r)abc         | B          | Multi        | 0.44                            |
| CIG 619   | SB(r)cd    | SB(r)cd          | B          | Multi        | 0.53                            |
| CIG 710   | SA(s)c    | SB(s)c           | B          | Multi        | 0.53                            |
| CIG 889   | Sa         | SBa              | B          | Multi        | 0.20                            |
| CIG 906   | Sb         | Sb               | B          | Multi        | 0.47                            |
| CIG 911   | SBA        | SBA              | B          | Multi        | 0.47                            |
| CIG 976   | Sab        | Sab              | B          | Multi        | 0.30                            |
| CIG 987   | SAb(s)c    | SAb(s)c          | B          | Multi        | 0.60                            |
| CIG 1004  | SB(s)c    | SB(s)c           | B          | Multi        | 0.40                            |

5.1. CAS Results

Since CAS parameters are mostly reported in the R band by other authors, in order to compare we also present the R-band-calculated

\[ CAS \text{ parameters} \]
changes in the CAS parameters with wavelength. The concentration C becomes higher from bluer to redder bands, especially for those galaxies with low and intermediate values of C. In the case of both the asymmetry A and clumpiness S parameters, their values strongly decrease from bluer to redder bands, decreasing more as these parameters get larger.

In Figure 6 we plot the average and standard deviation values of the CAS parameters versus wavelength (color band) for our sample, sorted into early- and late-type spirals (SaSb [left panels] and SbcSm [right panels], respectively). The CAS parameters of later types show, on average, more dependence (and scatter) with wavelength than the early types. Among the CAS parameters, clumpiness is the most sensitive to wavelength.

6. DISCUSSION

6.1. Morphology, Bars, and Rings in Isolated Galaxies

The optical and IR emission in galaxies are dominated by different populations of stars and are subject to dust absorption at different levels. The structures that are dominated by older stellar populations are more prominent and less affected by extinction in the IR than in the optical. In the IR one observes a higher bar fraction than in the optical, as well as cases where the bulge appears more prominent, the spiral arms less flocculent, and the rings less prominent (Eskridge et al. 2000). The latter points toward an earlier type classification from the IR images than from optical ones. The same trends mentioned above are observed for our sample of isolated galaxies. It should be remarked that, in our attempt to describe the morphology of the observed galaxies, we also have made use of the $HK$ images from 2MASS.

The reclassification presented here (see Table 5) preserves the optically observed morphology but takes into account the NIR bar morphology. In general, previous results concerning the differences in morphology as passing from optical to NIR bands (Eskridge et al. 2000) agree with those seen in our subsample of isolated galaxies, although the fraction of isolated galaxies for which these differences become significant is actually small in our case ($\sim 15\%$).

Concerning bars in our isolated galaxies, they come in a variety of sizes, shapes, and color distributions, from apparently strong, to small ones confined to the central parts of galaxies, and up to oval-shaped bulges, suggesting a range of strengths, lengths, and mass distributions. We have shown that the fraction of galaxies in our sample with clear evidence of optical/IR bars (SB galaxies) is $63\%$, while $17\%$ more show some evidence of weak bars (SAB galaxies). These fractions are in agreement with estimates from larger samples of galaxies. For example, Eskridge et al. (2000) determined the fraction of strongly barred galaxies in the $H$ band for a sample of 186 spirals from different environments to be $56\%$, while another $16\%$ are weakly barred. For the same sample, the fraction of barred galaxies reported in the optical is almost a factor of 2 smaller than that in the NIR. We do not find such a strong difference with the passband in our sample of isolated galaxies. We also reported the presence of inner ($r$) and outer ($R$) rings when possible, but a detailed ring morphology (Buta 1986, 1995) was not attempted. The fraction of galaxies with rings in our sample is high, $55\%$.

Note that the observed fraction of bars and rings in the present paper can hardly be a bias of our observing procedure, since we simply selected objects according to their availability in the sky.

The high fractions of bars for the isolated galaxies found here, similar to the fractions observed in other environments, could suggest that interactions and the global effects of the group/cluster environment are not crucial for the formation/destruction of bars. How do bars form in isolated environments? It is known that the presence and evolution of bars in a Hubble time depends on the host galaxy structure, the dark matter halo structure, the disk-to-halo ratio, and the environment (e.g., Athanassoula 2003; Berentzen et al. 2006; Colin et al. 2006). High-resolution $N$-body simulations of isolated disks embedded in CDM halos show that extended strong bars almost always form, but they slow down as a result of angular momentum transport to the disk and halo (Debattista & Sellwood 2000; Athanassoula & Misiriotis 2002; Valenzuela & Klypin 2003); eventually, the bars may dissolve, forming a pseudobulge (e.g., Avila-Reese et al. 2005a; Berentzen et al. 2006).

The isolated environment may ensure the presence of dynamically cold disks that can form a variety of stellar bars. The observed bar fraction could also be a consequence of long-lived bars or, alternatively, of bars that recurrently form, self-destroy, and reappear due to gas accretion (Bournaud & Combes 2002; Gadotti & dos Anjos 2001). Constant gas accretion is a condition more viable in isolated environments than in groups or clusters.
Our data reveal no difference in the relative bar fraction of early- (SaSb) and late- (SbcSm) type galaxies. If any, among the barred galaxies, the late-type subsample contains a larger fraction of weakly barred (SAB) galaxies than the early-type subsample. Eskridge et al. (2000) also found that the fraction of barred galaxies almost does not depend on morphological type. It seems that, rather than the fractions, the properties of the bars (length, strength, surface brightness profile, etc.) are what change as a function of the morphology and/or environment (e.g., Erwin 2005 and references therein). For our sample, we have estimated the bar deprojected maximum ellipticity, $\epsilon_{\text{max}}$. We do not find significant differences in $\epsilon_{\text{max}}$ as a function of morphological type or of the $\text{CAS}$ parameters. Further analysis is necessary to infer the disk and bar properties and compare them with model predictions.

Another relevant topic is that of ring formation in isolated environments. Rings of SF are a common phenomenon in disk galaxies. Most rings form by gas accumulation at resonances, usually under the continuous action of gravity torques from a bar pattern, but sometimes in response to a mild tidal interaction with a nearby companion (Buta & Combes 1996; Buta 1999). In either case a resonance is a very special place in a galaxy where SF can be enhanced and may proceed either as a starburst or continuously over a period of time. Most of the observed rings in our galaxies are of the type encircling the end of the bars and elongated along the bar’s P.A. Singular cases of outer rings, inner rings, and a probable circumnuclear ring were detected. Contrary to bars, most of the observed rings in these isolated galaxies show bluer color distributions, suggesting that their stellar populations are more similar to those in their hosting disks than those in the bars. However, some of our composed $JHK$ images also show the prevalence of rings in the NIR. The existence of this old population of rings underlying star-forming rings suggests a strong coupling between the stellar and gaseous components in the resonance regions.

Finally, it should be mentioned that in all 44 of the isolated galaxies studied here, we did not find strong signatures of interactions or perturbations. However, in two cases (CIG 1 and CIG 80)
moderate morphological distortions can be seen, which could indicate some level of dynamical disturbance; however, these distortions could hardly be produced by strong interactions, as in the case of the isolated disturbed galaxies reported in Karachentsev et al. (2006, see Introduction). Satellite accretion could explain the distortions seen in CIG 1 and CIG 80. On the other hand, as mentioned above, bars and rings are axisymmetric structures that can be explained as a product of the internal secular evolution of disks. Interactions and perturbations may induce and amplify bar/ring formation but can also contribute to their fast dissolution. A larger sample is necessary in order to explore whether a fraction of isolated galaxies show evident signatures of interaction, which is a question of relevance, as mentioned in § 1.

6.2. Physical Morphology through the CAS Parameters

The CAS parameters have been used in alternative galaxy classification schemes (see § 5). The CAS parameters also allow the possibility of classifying galaxies according to their interaction state (C03; Hernández-Toledo et al. 2005, 2006), which is useful in high-redshift studies. In this sense, it is important to have a well-studied comparative sample of local isolated galaxies. In spite of the small number of galaxies in our current sample, we introduce below an indicative discussion of the measured CAS parameters in different color bands and of their trends with other galaxy properties.

Figure 7 shows the loci of the isolated SaSb and SbcSm galaxies in the projected planes of the $R$-band CAS space. Only the averages and their standard deviations are shown (crosses and solid error bars). The large boxes indicate the amplitude of variation of the CAS parameters (lower and upper limits) from the $B$, $V$, $R$, $I$, $J$, and $K$ bands. For comparison, the $R$-band averages and standard deviations of galaxies in interacting S+S pairs (Hernández-Toledo et al. 2005) and starburst and ultraluminous infrared galaxies (ULIRGs) (C03) are also plotted. Visually, the major difference between isolated spirals and interacting, starburst, and ULIRG spirals takes place in the $A$-$S$ plane.

6.2.1. Concentration

The quantitative measure of $C$ in our isolated spirals spans the range $3.0 \leq C(R) \leq 4.5$, in agreement with other works. The average and standard deviation values are $(C(R)) = 3.5 \pm 0.59$. It
is known that for lenticular and elliptical galaxies, the concentrations are typically larger than for spirals (e.g., C03; Hernández-Toledo et al. 2006). We have also found that $C$ systematically increases with the passband for almost every one of the isolated galaxies (Fig. 5). This is in agreement with previous finds that the scale lengths of spirals are smaller in the NIR bands than in the optical bands (e.g., de Jong 1996), which probably points to an inside-out galaxy formation scenario: bluer colors trace younger stellar populations, and if the disk is more extended in the optical than in the NIR, then the outer disk might be younger (more recently assembled) than the inner regions. Metallicity gradients would emulate such an effect, but it seems that this is not the case (de Jong 1996).

According to our current understanding of galaxy formation, disks generally form from the inside out within growing CDM halos (for a recent review, see Avila-Reese 2007). Their concentrations (or surface brightnesses) depend mainly on the spin parameter of the halo. CDM halos span a wide lognormal distribution of the spin parameter; hence, one also expects a wide range of concentrations for the disks. Most likely, the observed distribution of concentrations for isolated disk galaxies is not as wide as we would expect from theory. It should also be taken into account that internal secular processes after disk formation rearrange the mass (light) distribution, and that the presence of a large bulge in early-type spirals tends to increase their $C$-parameter with respect to galaxies with smaller bulges. A fair comparison of concentrations observed in isolated spirals with model predictions is certainly a promising avenue of research. In the case of ellipticals (and probably the bulges of early-type galaxies), theory suggests that they are more concentrated due to the violent and dissipative processes that are at the basis of their formation: major mergers of gaseous disks.

![Figure 7](image_url)
Concentration of light has been shown to correlate with properties of galaxies such as Hubble type, color, and surface brightness (Okamura et al. 1984; C03; see below). More recent studies have also shown that concentration of light correlates with internal scaling properties such as velocity dispersion, size, luminosity, and black hole mass (Graham et al. 2001).

### 6.2.2. Asymmetry

Concerning asymmetry, the method used here gives a simple quantitative measure of how a galaxy deviates from axisymmetry. The asymmetry parameter $A$ has been shown to be sensitive mainly to galaxy interactions and mergers but is also influenced by SF clumps, dust lanes, and projection effects. The quantitative measure of $A$ in the present sample of isolated galaxies roughly spans the range $0.0 \leq A(R) \leq 0.23$, the average and standard deviation being $\langle A(R) \rangle = 0.15 \pm 0.10$. The later types are slightly more asymmetric, on average, than the earlier types. The asymmetries reported here are definitively lower than those typical of interacting disk galaxies (see Fig. 7). The $A$-parameter decreases significantly as the passband is redder (Fig. 5). For interacting spirals, the same trend was observed, but to much less of an extent (Hernández-Toledo et al. 2005). This suggests that while the (high) asymmetry in interacting spirals is mainly of global/external origin, and hence is more or less the same in different bands, in the case of isolated spirals the (low) asymmetry is in part related to SF effects; this is why $A$ is so sensitive to the passband in which it is measured. The question of whether a disk of a spiral galaxy is intrinsically asymmetric is of great interest. Some studies have shown that important deviations from axisymmetry exist in the optical and other wavelengths (Rix & Zaritsky 1995; Richter...
However, systematic attempts to quantify asymmetry and other measures like the CAS parameters in several wavelengths for well-selected local samples of galaxies are either rare or missing in the literature.

### 6.2.3. Clumpiness

Galaxies undergoing SF are patchy, especially in the bluer bands, and an important fraction of light must be in high spatial frequency structures. This is quantified through the clumpiness parameter $S$. For our sample of isolated galaxies, $S(R)$ ranges roughly from 0.0 to 0.6, the average and standard deviation values being $\langle S(R) \rangle = 0.31 \pm 0.15$. The $S$-parameter is, on average, larger and more scattered in later types than in earlier types, as is seen in Figure 7 (see also below). It is well known indeed that late-type galaxies present more current SF activity than early-type galaxies. Although the parameter $S$ in our isolated galaxies is typically smaller than in interacting spirals, the differences are actually small and not as significant as in the case of the asymmetry parameter (Fig. 7). It is also interesting to note that the increase of the $S$-value as the passband is bluer in our isolated galaxies (Fig. 5) is much more significant than in the case of interacting galaxies (Hernández-Toledo et al. 2005).

### 6.2.4. Correlations

We next explore how the CAS parameters of isolated galaxies correlate with other properties and whether these correlations are sensitive to the passband. Figures 8 and 9 show the $B$, $R$, $J$, and $K$-band CAS parameters versus morphological type $T$ and corrected total $(B-I)$ color. Nearly edge-on galaxies (inclination $\geq 80^\circ$) are plotted with open circles. Given that $A$ and $S$ are

![Fig. 9. CAS parameters in the $B$, $R$, $J$, and $K$ bands vs. the corrected total $(B-I)$ color. Galaxies with inclinations larger than $80^\circ$ are shown with open circles.](image-url)
particularly sensitive to projection effects, it is important to visualize these galaxies, since they may be masking any trend.

After a visual inspection of Figures 8 and 9, the general conclusion is that any potential trend of the CAS parameters with $T$ and total $(B - I)$ color typically tends to be more robust in the redder bands. This emphasizes the merits of IR parameters, which are less contaminated from (transient) SF effects and better represent the basic structure of galaxies. We should note that the scatters in these trends, even for the $J$ band, are large. The images from 2MASS are, unfortunately, of low quality, especially in the $K$ band. Besides, for several of our galaxies, there are no images in this survey. Therefore, the $J$- and $K$-band data discussed here should be taken only as indicative.

Larger samples are needed in order to better quantify the dependencies shown in Figures 8 and 9 and infer from them clues to the physics of disk galaxies. Notwithstanding this, we present below a brief discussion of the observed trends.

According to Figures 8 and 9, while the concentration tends to be higher for earlier type and redder galaxies, the asymmetry and clumpiness tend to become smaller. The morphological type is led mainly by the bulge-to-disk ratio. The global color is also affected by this ratio. Therefore, it is expected that earlier types will be more concentrated and redder. However, the $C$-parameter and the global color are not too sensitive to the bulge-to-disk ratio for galaxies with intermediate-to-small values of this ratio (say, Sb types and later); therefore, in these cases, the measured $C$ and global color reflect mostly the pure disk concentration and color. Thus, that $C$ depends on $T$ for late types mainly implies a connection between the spiral arm properties and the disk concentration. The dependence of $C$ on color would mainly imply that less concentrated disks have a more constant SF history, probably because their gas surface densities are low.

Concerning asymmetry, the observed dependence on $T$ indicates that most of the asymmetry of our isolated spirals is associated with the natural flocculency in later type galaxies, as well as with SF, which is more active for later types (as is also evidenced by the trend of higher $S$-values as the types are later and the colors bluer; see above). In this interpretation, the effect of large-scale perturbations (e.g., interactions) is neglected. The $A$-parameter could be used as a first-approximation indicator of interaction signatures in isolated spirals. An automatic analysis of images in large samples of galaxies easily provides the $A$-parameter. An even more reliable test for interactions would be to produce the loci of the studied isolated spirals in the $A$-$S$ diagram, where maximum differences between isolated and interacting galaxies are revealed, as was seen above (Fig. 8; see also Hernández-Toledo et al. 2005). The adding of color information is also valuable, as evidenced by Figure 9.

7. SUMMARY AND CONCLUSIONS

We present results of our $BVRI$ CCD photometry for a set of 44 isolated galaxies selected from the CIG (Karachentseva 1973). We have shown that our derived parameters are generally in good agreement with the aperture photometry reported in the HyperLeda database and other individual photometric works. In addition, we present multiaperture photometry (Appendix) in order to facilitate further comparisons and contribute to the existing databases of aperture photometry (e.g., HyperLeda).

In a further step, we have analyzed the morphology of each of the galaxies based on our mosaic $R$-band and sharp-filtered $R$-band images, two-dimensional $(B - I)$ color maps, composed NIR $JHK$ images from the 2MASS archives, and photometric $e$ and P.A. radial profiles. A morphological reclassification of the galaxies has been presented with emphasis on structural features such as bars and rings and global disturbances.

The sample morphological types range from Sa to Sm, half of the galaxies being earlier than Sbc (SaSb) and the other half being Sbc or later (SbcSm). After our reclassification, we found that ~63% of the galaxies are clearly barred (SB), while ~17% more show some evidence of a weak bar (SAB). There is no significant difference in the bar fraction with morphological type. The average and standard deviation values of the $A$-band deprojected maximum ellipticity of the bars, $e_{\text{max}}$, is 0.39 ± 0.1. There is no trend of $e_{\text{max}}$ with morphological type and the concentration, asymmetry, and clumpiness (CAS) parameters. We have also found that 55% of the isolated galaxies in our sample show ring structures.

Finally, we have calculated the $BVRI$, $J$, and $K$-band CAS parameters for the sample. The CAS averages and standard deviations in the $R$ band for the SaSb and SbcSm subsamples are $(C(R)(\text{SaSb}) = 4.00 \pm 0.50$, $(A(R)(\text{SaSb}) = 0.08 \pm 0.05$, $(S(R))(\text{SaSb}) = 0.20 \pm 0.12$ and $(C(R))(\text{SbcSm}) = 3.10 \pm 0.40$, $(A(R))(\text{SbcSm}) = 0.19 \pm 0.10$, $(S(R))(\text{SbcSm}) = 0.36 \pm 0.20$, respectively. These values are in good agreement with previous results for noninteracting galaxies.

While $C$ systematically increases from bluer to redder bands, both $A$ and $S$ significantly decrease. The CAS parameters present more robust trends with the morphological type $T$ and the total $(B - I)$ color in the redder bands, suggesting that the basic structure of galaxies is revealed better in the IR and NIR bands. The $C$-parameter tends to be higher for earlier type and redder galaxies, while $A$ and $S$ tend to be smaller. The $A$-parameter could be an excellent way to detect candidates for isolated spirals with signs of interaction by means of an automatic analysis of images.

The loci of our isolated galaxies in the projected planes of the CAS space depend on the morphological type (and on the color). The major difference between the isolated and interacting starburst and ULIRG spirals takes place in the $A$-$S$ plane.

After the completion of this paper, a work by Taylor-Mager et al. (2007) with some aims and results similar to those presented here was posted in the arXiv database. Taylor-Mager et al. analyzed the CAS parameters for a sample of galaxies (mainly late types, including peculiars) as a function of wavelength, from UV to IR (0.15–0.85 μm), with the aim of exploring how the galaxy’s appearance changes with rest-frame wavelength. The result leads to a measure of the morphological $k$-correction for high-redshift galaxies. Their results complement well those presented here, and both are in qualitative agreement where comparison is possible. The building of well-defined samples of local isolated galaxies with uniform and detailed photometric information is of great relevance because it provides a fair database for comparison with model predictions, as well as with observed samples of galaxies in other environments and at higher redshifts (e.g., Jansen et al. 2000). In this paper we present a first step in the building of such a sample and discuss some preliminary results.

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Since the birth of galaxy photometry (Whitford 1936), the amount of photometric data has increased exponentially (Prugniel 1987). However, these data are inhomogeneous in both quality and format: photographic, photoelectric, or more recently, CCD observations. The data are usually presented as centered aperture photometry through circular or elliptical apertures or as photometric profiles. In order to take into account the continuously growing amount of photometric data and at the same time make different photometric data reports somehow comparable, we present in Table 7 our estimations of integrated magnitudes in two additional concentric circular apertures. Columns (2) and (7) give the logarithm of the aperture radius (in units of 0.1); see HyperLeda convention) for each isolated spiral galaxy. Columns (3)–(6) and (8)–(11) give their corresponding magnitudes in the $B$, $V$, $R$, and $I$ bands. The contribution of the sky to the errors in the magnitudes is relatively small at these apertures. Typical uncertainties in the magnitudes are 0.11, 0.12, 0.11, and 0.12 in the $B$, $V$, $R$, and $I$ bands, respectively.
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