The Astrophysical Journal Supplement Series, 170:33–70, 2007 May

MARKARIAN GALAXIES. I. THE OPTICAL DATABASE AND ATLAS

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Received 2006 March 17; accepted 2006 October 24

ABSTRACT

A database for the entire Markarian catalog is presented that combines extensive new measurements of their optical parameters with a literature and database search. The measurements were made using images extracted from the STScI Digitized Sky Survey (DSS) of F_{pg}(red) and J_{pg}(blue) band photographic sky survey plates obtained by the Palomar and UK Schmidt telescopes. We provide accurate coordinates, morphological type, spectral and activity classes, red and blue apparent magnitudes, apparent diameters, axial ratios, and position angles, as well as number counts of neighboring objects in a circle of radius 50 kpc. Special attention was paid to the individual descriptions of the galaxies in the original Markarian lists, which clarified many cases of misidentifications of the objects, particularly among interacting systems, larger galaxies with knots of star formation, possible stars, and cases of stars projected on galaxies. The total number of individual Markarian objects in the database is now 1544. We also include redshifts that are now available for 1524 objects with UV-excess radiation, as well as galactic color excess $E(B-V)$ values and their 2MASS or DENIS infrared magnitudes. The database also includes extensive notes that summarize information about the membership of Markarian galaxies in different systems of galaxies and about new and revised activity classes and redshifts. An atlas of several interesting subclasses of Markarian galaxies is also presented.

Subject headings: astronomical data bases: miscellaneous — atlases — galaxies: active — galaxies: interactions — galaxies: starburst

Online material: extended figures, extended figure set, machine-readable table

1. INTRODUCTION

The analysis of catalogs of galaxies has become more and more important for cosmological studies. In order to extract information from galaxy catalogs that is both reliable and useful, they must be as complete and representative as possible in order to control selection effects. In this data paper we describe the properties of the Markarian galaxies, which were identified because of their UV excess. By using the Markarian galaxies as tracers and statistically comparing their properties to a control sample of "normal field galaxies" (A. Petrosian et al. 2007, in preparation), we can investigate a number of problems: morphological classification, distribution of linear diameters, nuclear activity, etc.

The morphological classification of galaxies has long been regarded as an important step toward understanding galaxy formation and evolution (e.g., van den Bergh 1997). There is considerable evidence that the morphological classification directly reflects the physical properties of galaxies (e.g., Roberts & Hayes 1994). Markarian objects can reveal important clues in these investigations since they span a wide luminosity range between -25 and -13 mag and have a very broad range of morphological structure as well as different stages of activity from QSOs to blue compact dwarfs (BCDs).

The luminosity function (LF) of the galaxies is an important constraint for models of cosmic structure formation and is fundamental to observational cosmology. The dependence of the LF on observable parameters such as morphology, color, etc. provides further information for the models. Wide-angle surveys at relatively bright apparent magnitudes allow the most detailed investigations of individual galaxy properties and remain the best approach for measuring the local LF and its variation from one part of the universe to other (e.g., Ellis 1997; Cross et al. 2001). The Markarian survey is one of the well-known wide-angle surveys, and it has previously been used to study this particular subject (e.g., Huchra 1977). We shall rederive the LF using our updated properties and improved statistics.

The statistical distribution of linear diameters is essential both for an understanding of galaxy structure and formation and also as a tool to probe the cosmological models. Growing interest in the diameter distribution function has been motivated by several problems related to studies of large-scale structure such as the determination of the optical dipole (e.g., Lynden-Bell et al. 1989), estimates of cluster distances from diameter information only (e.g., Lahav & Gull 1989), the reconstruction of the density field from diameter-limited catalogs (Maia & da Costa 1990; Dressler 1991; Bardelli et al. 1991; Hudson & Lynden-Bell 1991), determination of local redshift-distance law (e.g., Segal & Nicoll 1997), and in combination with other parameters as a tool for the independent check on the value of the Hubble constant (e.g., Ekholm et al. 1999; Russell 2002). Reflecting the different nature of the Markarian objects, their linear diameters cover broad range of values starting from a few kpc (BCDs) up to a hundred kpc (giant or merging galaxies). Different classes of Markarian objects with different diameter distributions can be useful to study these problems.

Large amounts of observational data have been accumulated in all spectral ranges supporting unified models of AGNs, particularly of Seyfert galaxies (e.g., Hines & Wills 1993; Goodrich et al. 1994; Evans et al. 1993; Tran 1995; Veilleux et al. 1997). The

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standard unification scheme postulates that the viewing angle of the circumnuclear torus of dust and gas is the only parameter of importance in determining the appearance of *all* types of Seyfert galaxies. Some papers, however, present results suggesting that not only the orientation of the circumnuclear torus relative to the line of sight, but also torus orientation relative to the host galaxy and host galaxy inclination may be important in AGN classification (e.g., Maiolino & Rieke 1995; Schmitt & Kinney 1996; Schmitt et al. 1997; Simcoe et al. 1997). The galaxy inclination effect may also be crucial for understanding the role of circumnuclear starbursts in AGN phenomena (e.g., Cid Fernandes & Terlevich 1995; Gonzalez Delgado et al. 2001). Since many Markarian galaxies contain AGNs and many more have starburst nuclei, information about their inclination can be important to study these problems.

Various cosmological scenarios related to the origin and evolution of large-scale cosmic systems (clusters and superclusters) predict different distributions for the angular momentum of galaxies, i.e., of the galaxy orientations, which are represented as different forms for the alignment of the galaxies within the systems. A random distribution of the rotation axes of the galaxies is expected in the framework of the major classical evolutionary scenarios of the systems (e.g., Shandarin 1974). On the other hand, fragmentation scenarios (e.g., Ozernoy 1978; Doroshenko et al. 1978) would suggest coherence in the alignments of galaxy orientations. The study of galaxy orientations therefore has the potential of yielding important information on the formation and evolution of the cosmic structures. Previous results of such studies are controversial. Studies have shown that there are coherent alignments of galaxy orientations in some clusters and superclusters, and no coherent alignment in several others (e.g., Aryal & Saurer 2004). Any alignment of galaxy orientations in these systems may also depend on the structure of the clusters and superclusters (e.g., Kashikawa & Okamura 1992) as well as the morphology of the galaxies (e.g., Wu et al. 1997; Aryal & Saurer 2005). No previous study has investigated whether there is also any correlation of galactic nuclear activity with alignments of galaxy orientations. Since Markarian galaxies are objects with different levels of activity and more than 30% of Markarian objects are members of clusters of galaxies (Petrosian & Turatto 1986a, 1986b), this sample will be valuable for such a study. Galaxies position angle information is crucial for such a study (e.g., Hawley & Peebles 1975; Jaaniste & Saar 1978).

The literature describing the influence of local environments on active and star-forming galaxies in the production of AGNs, starburst, and H II nuclei has become voluminous. Kennicutt (1990), Heckman (1990), and Schweizer (1990) reviewed the status of understanding of the relation between galaxy interaction and activity or enhanced star formation in galaxies. Recent studies add more data on the subject (e.g., Hashimoto et al. 1998; Iglesias-Paramo & Vilchez 1999). Data at different wavelengths provide evidence that close environments and interactions may trigger activity or bursts of star formation in the nuclei of galaxies. Nevertheless, the results of different investigations depend strongly on the adopted tracers of the activity and star formation (optical, IR, radio, etc.) and also very strongly on the samples on which the analyses were performed (e.g., Leech et al. 1994; Vilchez & Iglesias-Paramo 1998; Allam et al. 1999; Krongold et al. 2002). The UV excess radiation of Markarian objects mostly originates from AGNs or enhanced star-forming regions, and many of these objects are in close interaction or in the dense galactic environment. The study of such systems can help address these problems.

In summary, we have an extensive list of scientific problems that can be studied using the various parameters of Markarian galaxies. This paper describes a new database for 1544 Markarian objects containing the following new measurements: accurate optical positions, morphological classes, apparent magnitudes (red and blue), diameters, axial ratios and position angles, and counts of neighbor galaxies within 50 kpc radius based on the galaxy redshift and assuming a value for the Hubble constant of $H_0 = 75\ \mathrm{km\ s^{-1}\ Mpc^{-1}}$. We also provide extensive notes indicating isolation or the membership of Markarian galaxies in clusters, groups, triplets, or pairs of galaxies. In addition, we have compiled from the literature updated spectral and activity classes as well as new and revised determinations of redshifts that were required for distance estimates for all galaxies. At the request of an anonymous referee, we have also included the corresponding near-IR magnitudes for all the galaxies from the 2MASS or DENIS surveys and Galactic $E(B-V)$ values. This will facilitate comparison of the optical and near-IR properties of galaxy subsets.

In § 2 of this paper we describe the Markarian survey and some results. It also describes used observational material and the generation of the database. The database itself and related notes are described in § 3. In § 4 an atlas of several interesting subclasses of Markarian galaxies is presented. Future papers in this series will describe the statistical analyses that are already underway addressing some of the interesting problems described in this introduction. In particular, two studies addressing the problem of origin and evolution of the clusters of galaxies containing Markarian objects, and the influence of local environment on barred spiral Markarian galaxies, will be presented soon.

2. THE DATA

2.1. *The Markarian Survey*

The First Byurakan Spectral Sky Survey (FBS), also commonly known as the "Markarian Survey," was initiated in 1964. It was the first systematic objective-prism search for galaxies with strong ultraviolet (UV) continuum emission. The observations were carried out with the Byurakan Observatory (Armenia) 1 m Schmidt telescope equipped with a low-dispersion (1800 Å $\mathrm{mm^{-1}}$ at Hγ), 1.5° objective prism. This low-dispersion objective prism was mostly used with Kodak IIa-F plates to detect galaxies with excess UV radiation. The survey consisted of 1133 fields (each $4^\circ \times 4^\circ$ in size) and covered 17,008 $\mathrm{deg^2}$ north of -15° declination, excluding regions within 15°–20° of the Galactic plane. It was completed in 1978 and published in a series of 15 papers including 1500 UV-excess objects (Markarian et al. 1981 and references therein). Later Markarian at al (1989) added 15 new objects detected on the original plates, bringing the total number of Markarian objects to 1515. A list of 40 anomalous galaxies brighter than 13th magnitude was published earlier (Markarian 1963). These galaxies are not included in the database.

In the series of 15 original papers (Markarian et al. 1981 and references therein) the descriptions for individual Markarian galaxies and often their neighbor(s) are noted, and in several cases these neighbors were also described as UV-excess objects with appropriate spectral classes, but surprisingly these objects were not included in the UV-excess objects lists. These "missing" objects were included in the present database under the individual Markarian name. Similarly, several Markarian galaxies had more than one component described as a UV-excess object. We separate all these components as isolated Markarian objects and include them in this database by adding letters (a, b) to the name of the main Markarian object. This brings the total number of Markarian objects that are included in the present database to 1544.

In the course of the Markarian survey, more than 200 Seyfert galaxies, and hundreds of starburst, blue compact, and H II galaxies were discovered. The FBS remains perhaps the best-known source of such objects in the local universe. During the past 30 years, hundreds of research articles have appeared that contain detailed observational data and studies of Markarian objects (e.g., Huchra 1977; Keel & van Soest 1992; Mazzarella & Boroson 1993; Bicay et al. 1995). Extensive compilations of optical data and literature references for the Markarian galaxies were presented in two catalogs (Mazzarella & Balzano 1986, hereafter MB86; Markarian et al. 1989, hereafter M+89). Both catalogs have greatly contributed to the study of Markarian galaxies, but there still remained a significant incompleteness in the availability of many fundamental parameters such as magnitudes, diameters and morphologies. Today, the availability of the high-quality observations from the photographic sky surveys allows us to measure additional optical parameters such as morphology, apparent magnitude, size, and axial ratio of the galaxies in a more accurate and homogeneous way, and also to extract quantitative data about their local environment. This high accuracy and homogeneous information can be important and valuable not only for the study of the sample of Markarian galaxies, but also for comparative studies of the properties of the different samples of active and star-forming as well as normal galaxies. The data gathered in this database were measured and compiled with the goal of obtaining a complete, homogeneous set of optical parameters for the Markarian objects for statistical studies. Eventually, we expect that some of these parameters objects could be improved by data mining of the Sloan Digital Sky Survey (SDSS), but even when completed, however, the SDSS survey footprint will only cover about 70% of the Markarian survey area. The currently available Data Release 5 (DR5) of SDSS contains photometric data for 946 and photometric plus spectral information for 455 Markarian objects. It should also be noted that we do not use the SDSS magnitudes published in the DR5 catalog because of potential saturation of the CCDs for the brighter galaxies and the difficulties in measuring extended galaxies by the automated pipeline processing that often break up into multiple objects. In the future we expect that photometric measurements of these galaxies will become available following reprocessing from the image data.

2.2. *Compiled Parameters for Markarian Galaxies*

2.2.1. *Redshifts*

In this database, heliocentric redshifts for 1524 of 1544 Markarian objects have been collected from the literature, the NASA Extragalactic Database (NED), and the 455 Markarian galaxies observed spectrally in the SDSS 5th Data Release. Of the 20 objects without redshifts, 4 are galaxies (Mrk 1017, 1254, 1265 and 1327), 5 are components of the galaxies (Mrk 256b, 456a, 489a, 861a, and 913b), and the remaining 11 are galaxies with projected galactic stars. For these 11 cases the spectra of the projected stars had previously been observed and the UV-excess identified with the stars rather than the galaxies. In many cases when more than one redshift measurements are available, the more accurate H I 21 cm or the latest published value is given. Redshifts for the UV-excess components of the galaxies with multicomponent structure are mostly from the papers relating to their detailed spectroscopic study. References for these determinations are provided in the notes to the database. Redshift information for some misclassified or not correctly identified objects are described in the same section of the notes.

2.2.2. *FBS Spectral Classification*

Markarian (1967; MB86; M+89) assigned a spectral classification for each UV excess galaxy that describes the degree of condensation of the UV emission as well as its intensity. Emission regions are classified as "stellar" *s* or "diffuse" *d* if the half-width of the emission region on the Schmidt plates is of the order of 2″ or 6″–8″, respectively. The intermediate types *sd* and *ds* were also used. A number between 1 and 3 was used to indicate the relative intensity of the UV emission with 1 being the strongest UV excess. The existence of emission lines in the spectra was identified by "*e*," with "*e*:" indicating doubtful cases. In the database, spectral classes for Markarian galaxies are presented according to M+89.

2.2.3. *Activity Class*

In the database, we use the following classes to describe the activity: Seyfert class 1–2, LINERs as Seyfert class 3, QSO, BL Lacertae, SB (starburst nuclei), and H II objects (spectra similar to H II regions), as well as galactic stars. Galaxies with Wolf-Rayet spectra are described in the database as WR activity class objects (e.g., Schaerer et al. 1999). We should note that in the literature there is an overlap of SB and H II classifications. Many objects previously defined as H II have later been classified as SB and vice versa (e.g., Balzano 1983; Telesco et al. 1993). There are probably many more SB and H II objects among the Markarian galaxies that have narrow emission line spectra but for which detailed spectral information is not available yet. If there is not sufficient spectral information for classification of the galaxies, a description of the spectra of the galaxy as *e* (emission), *a* (absorption), or *e, a* (emission, absorption) is presented. All objects with new determinations of the activity classes and objects whose activity classes have been revised since M+89 are mentioned in the notes to the database.

2.3. *Measured Parameters for Markarian Galaxies*

2.3.1. *Observational Material and Images of Markarian galaxies*

Central to this project was the availability of the digitized sky survey (DSS) images obtained in support of the construction of the *HST* Guide Star Catalogues (Lasker et al. 1990; McLean et al. 1998), The GSC is based on Palomar Schmidt plates for the northern sky and the SERC UK Schmidt plates for the southern sky. Approximately 80% of the Markarian galaxies are located on the northern sky survey plates and 20% on the southern plates. Five different sets of survey plates were used in this project.

For the morphological classification, we primarily used the northern "Quick-V" (QV) survey, and the southern "Equatorial-J" (EJ) surveys. The QV plates are 20 minute *V*-band exposures on IIaD emulsion with Wratten number 12 gelatin or 3 mm Schott GG495 glass filter giving a central wavelength of 5700 Å. The EJ plates are ∼60 minute *J*-band exposures on IIIaJ emulsion with a Scott GG395 glass filter giving an effective wavelength of ∼4800 Å. We find the QV and EJ survey plates to be superior to the original Palomar Observatory Sky Survey (POSS-I) survey plates for our purpose of classifying the morphologies of the Markarian galaxies. This is because the central regions of the galaxies are frequently much less saturated on the QV, and additionally, more structure can be resolved with the medium grain QV and fine grain EJ emulsions compared to the coarse grain 103a POSS-I emulsions. The magnitudes and diameter measurement were computed from the POSS-II J_{pg} and F_{pg} surveys and the UKSTU EJ and ER surveys. The Palomar Sky Survey (Reid et al. 1991) has been taken in three passbands; blue (IIIa-J emulsion and GC395 filter: $\lambda_{\rm eff} \sim 4800$ Å); red (IIIa-F emulsion and RG610 filter: $\lambda_{\rm eff} \sim 6500$ Å); and near-infrared (INV emulsion and RG9 filter: $\lambda_{\rm eff} \sim 8500$ Å). The UKSTU ER is a IIIa-F emulsion with OG590 filter giving an effective wavelength of

~6300 Å. The mean limiting magnitude for the POSS-II plates are $J_{pg} = 22.5 \pm 0.4$ and $F_{pg} = 20.8 \pm 0.4$ (Reid et al. 1991).

All the plates were digitized at the Space Telescope Science Institute (STScI) using Perkin-Elmer PDS 2020G scanning microdensitometers with various modifications as described by Lasker et al. (1990). The QV and EJ plates were scanned at a resolution of 1.7″ pixel^{-1}. The POSS-II and UKSTU-ER plates were scanned at a resolution of 1.0″ pixel^{-1}. These images have better resolution and fidelity compared to the earlier POSS-I surveys on which many previous studies were based.

Using the positions published by MB86, $14.25' \times 14.25'$ images centered on each Markarian galaxy were extracted from the QV and EJ images in the DSS. These images were visually compared to the finding charts published by Markarian and his coworkers (Markarian et al. 1981 and references therein) to locate significant positional discrepancies. The finding charts published by Markarian and his coworkers are copies of the POSS E plates covering a $16' \times 16'$ fields. Using these images, the accurate coordinates of Markarian galaxies were measured and their morphologies were determined.

Using the accurate optical positions of Markarian galaxies, $10' \times 10'$ regions centered on each Markarian galaxy were extracted from the POSS-II J, POSS-II F, and UKSTU-ER images. Using these images, the morphologies of Markarian galaxies were checked using the outer region structure. We then measured each object's blue and red apparent magnitude, major and minor diameters, and position angles, as well as determining the apparent number of neighboring galaxies within a 50 kpc radius based on the published redshift.

2.3.2. *The Coordinates*

The original Markarian lists contain positions accurate to about 2′–3′ in right accession and declination. In both the MB86 and M+89 catalogs, the sources of accurate coordinates of Markarian galaxies are Peterson (1973), Kojoian et al. (1978, 1981a, 1981b, 1982, 1984), and Foltz et al. (1980, 1981). In these articles the accuracy of the position measurements is reported to be a few arcseconds.

Finding charts of the Markarian galaxies and descriptions of individual objects were the primary sources to build the list of the objects for measurement. Positions of stellar objects are typically located to better than 0.5″ using either a 2D Gaussian fit or the intensity-weighted moments of the object pixels. The actual positions of the extended objects are somewhat more poorly determined because of their more complex morphologies and difficulty of locating the image centroid of the objects. For such objects and also for the objects with multiple UV-excess sources in the common envelopes we visualized the images of the Markarian objects using the Aladin interactive software sky atlas and checked or measured carefully the positions (using the peak intensity) for diffuse objects or multiple UV-excess components in the common envelopes. In these cases the positions may be uncertain to 1″. Once again, note that multiple components have been renamed by adding a letter to the original Markarian name. All coordinates are in the *HST* Guide Star Selection J2000.0 System.

2.3.3. *The Morphology*

The descriptions in the original lists of Markarian galaxies indicate that a large fraction are morphologically peculiar. However, these descriptions were often in error because they were limited by the sensitivity of the Palomar Observatory Sky Survey (POSS-I) prints on which galaxies images were inspected. Only about 30% of the sample objects (preferentially the closer and brighter galaxies) had previously published morphological descriptions (MB86; M+89; Huchra 1977; de Vaucouleurs et al. 1976, hereafter RC2; Nilson 1973). The current database presents complete and homogeneous data for the morphologies of Markarian galaxies.

The northern QV survey plates were originally intended for the measurement of stellar objects between 12th and 19th magnitude; however, since they are of shorter exposure than typical survey plates the nuclei of many galaxies are not saturated. These plates are suitable for examining the morphology of the central structure of many brighter galaxies. This is especially true for Markarian galaxies, which are typically between 14th and 17th magnitude. Furthermore, the uniformity of the survey plates makes them useful for examining the structural features of the galaxies. For the morphological study of Markarian galaxies, especially the structure of the outer regions, the J_{pg} and F_{pg} plates were used as supplementary material. By using both digital images and isophotal maps, which were constructed to display the large dynamic range of the images, we classified the Markarian galaxies using the modified Hubble sequence (E-S0-Sa-Sb-Sc-Sd-Sm-Im) and the extension to blue compact dwarf galaxies (BCDs; Sandage & Binggeli 1984).

Markarian irregular galaxies usually contain at least one giant star-forming region, which is the main source of the excess UV radiation. Sandage & Binggeli (1984) designate giant H II regions in irregular galaxies as BCDs. We have expanded this approach by classifying such galaxies using the composite notation Im/BCD when the underlying Im system is dominant and by BCD/Im when the BCD component (often with several knots) dominates. It is important to note that this approach is morphological only. According to several recent studies (e.g., Papaderos et al. 1996; Doublier et al. 1997), the underlying component of a BCD is structurally different from that of an Im galaxy.

In several cases (Mrk 59, 71, 86b, 94, 256b, 404, 489b, 1039, 1236, 1315, and 1379a) the Markarian object is actually a giant H II complex in the large galaxy. These cases are noted in the catalog as an H II region. Close interacting systems or mergers are classified as separate classes of the objects.

In Figure 1, as examples, images of each morphological type galaxies are shown both in gray scale and contour plots. The field size (and thus magnification) was selected individually for each galaxy to clearly illustrate its individual morphological structure. The contour levels are in arbitrary units. The lowest contour level was chosen at the about 3 σ level of the local background. The contour interval is constant, but different in each case; usually it is between 10%–30% of the local background. The interval was chosen in order to best illustrate both the inner and outer structure of the galaxy.

The morphological structures of "peculiar" Markarian galaxies are better studied (e.g., Petrosian et al. 1978; Mazzarella & Boroson 1993) than the morphologies of "ordinary" Markarian objects, for which the most valuable research was carried out by Huchra (1977). Prior to this study, the HYPERLEDA (Leon-Meudon Extragalactic Database) database contained the published morphological classes of 675 Markarian galaxies. These were collected from various publications and often are incorrectly defined or not complete. Figure 2 illustrates several examples that are misclassified in the HYPERLEDA compilation due to its inhomogeneous nature. The total number of misclassified cases in HYPERLEDA is around 100.

Figure 3 illustrates the distribution of the object morphologies derived from our homogeneous classification compared with the subsample available within HYPERLEDA.

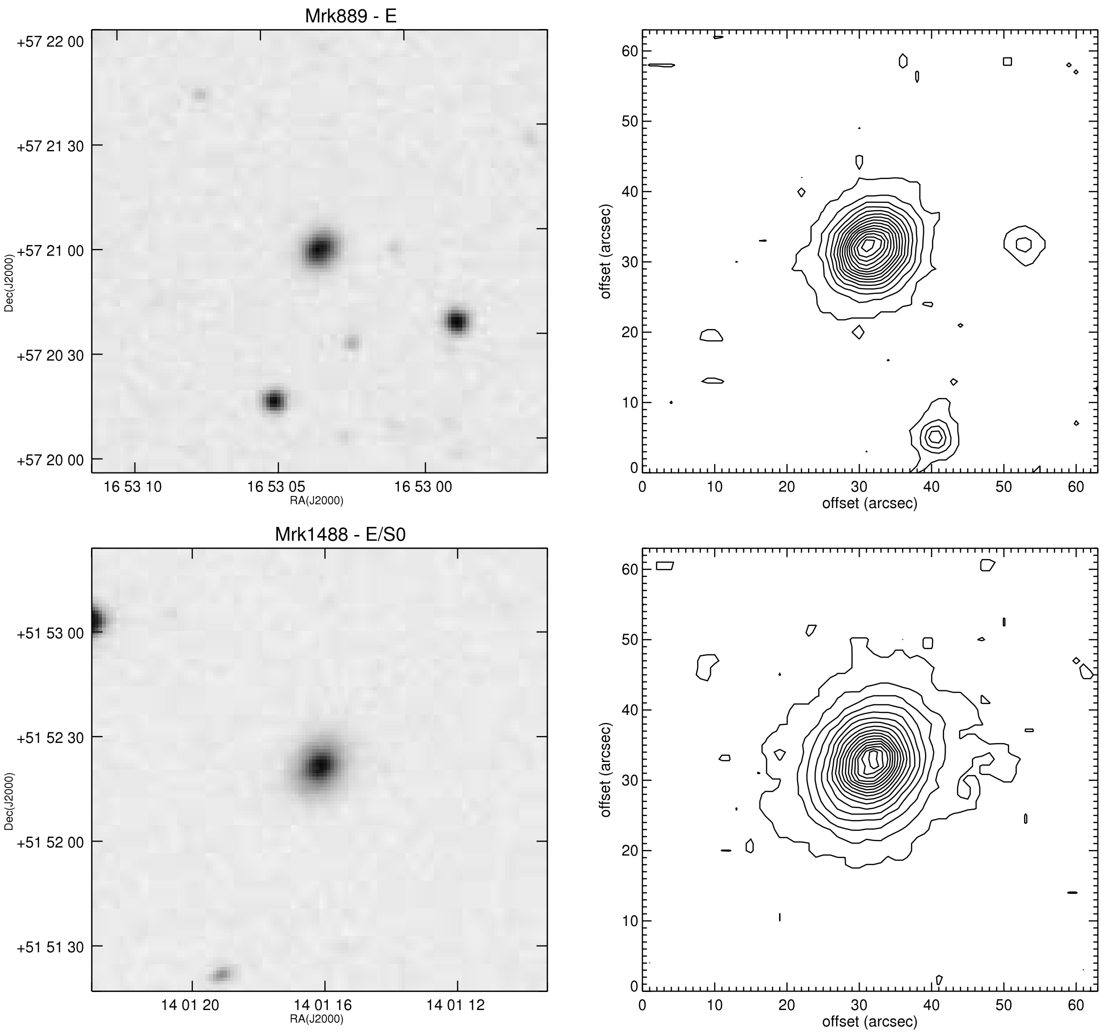


Fig. 1.—Examples of different morphological type Markarian objects. North is up, and east is to the left. The magnification was selected individually for each galaxy to clearly illustrate its individual morphological structure. The contour levels are in arbitrary units. The lowest contour level was chosen at the about 3 σ level of the local background. The contour interval is constant but different in each case; usually it is between 10% and 30% of the local background. The interval was chosen in order to best illustrate both inner and outer structure of the galaxy. Contour plot axes are labeled in arcseconds.

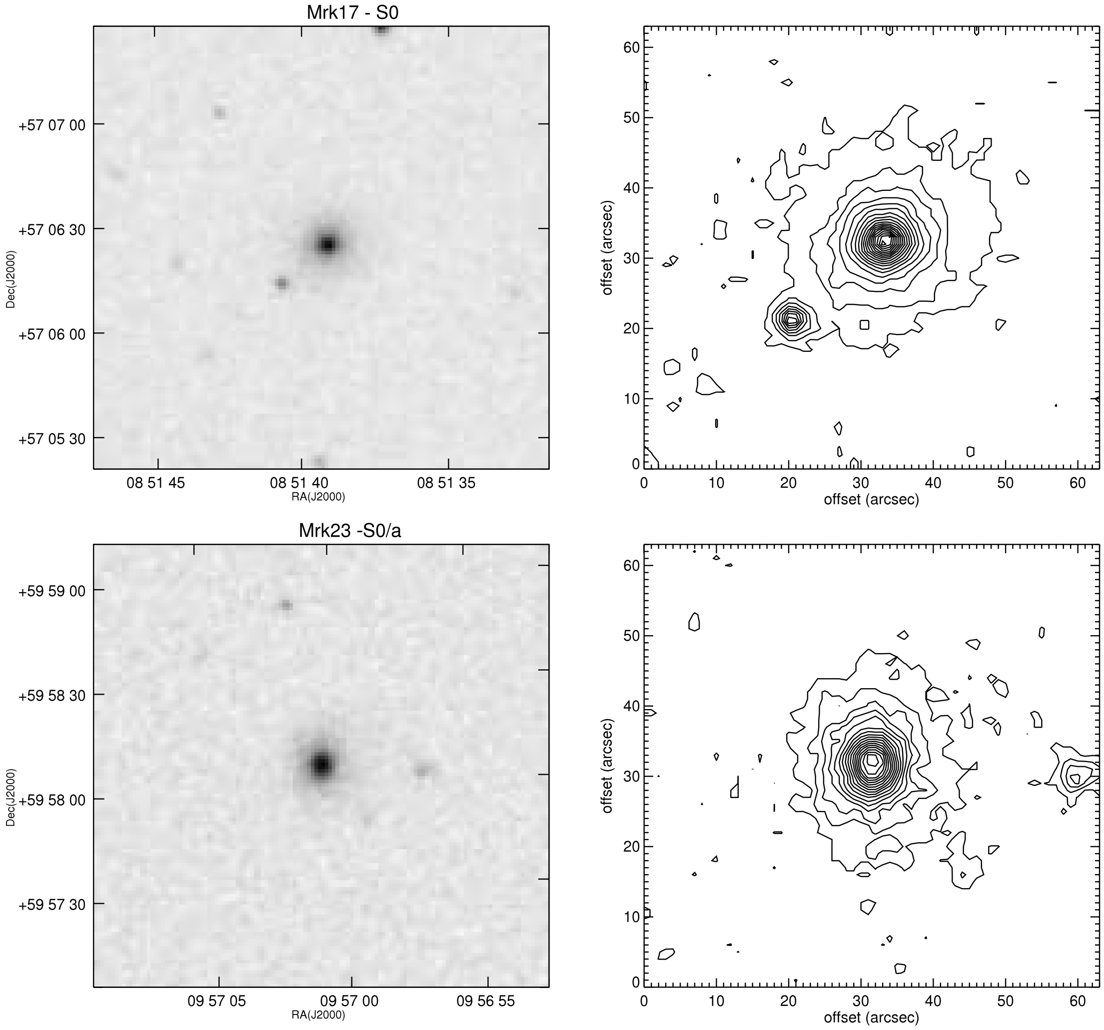


FIG. 1— *Continued*

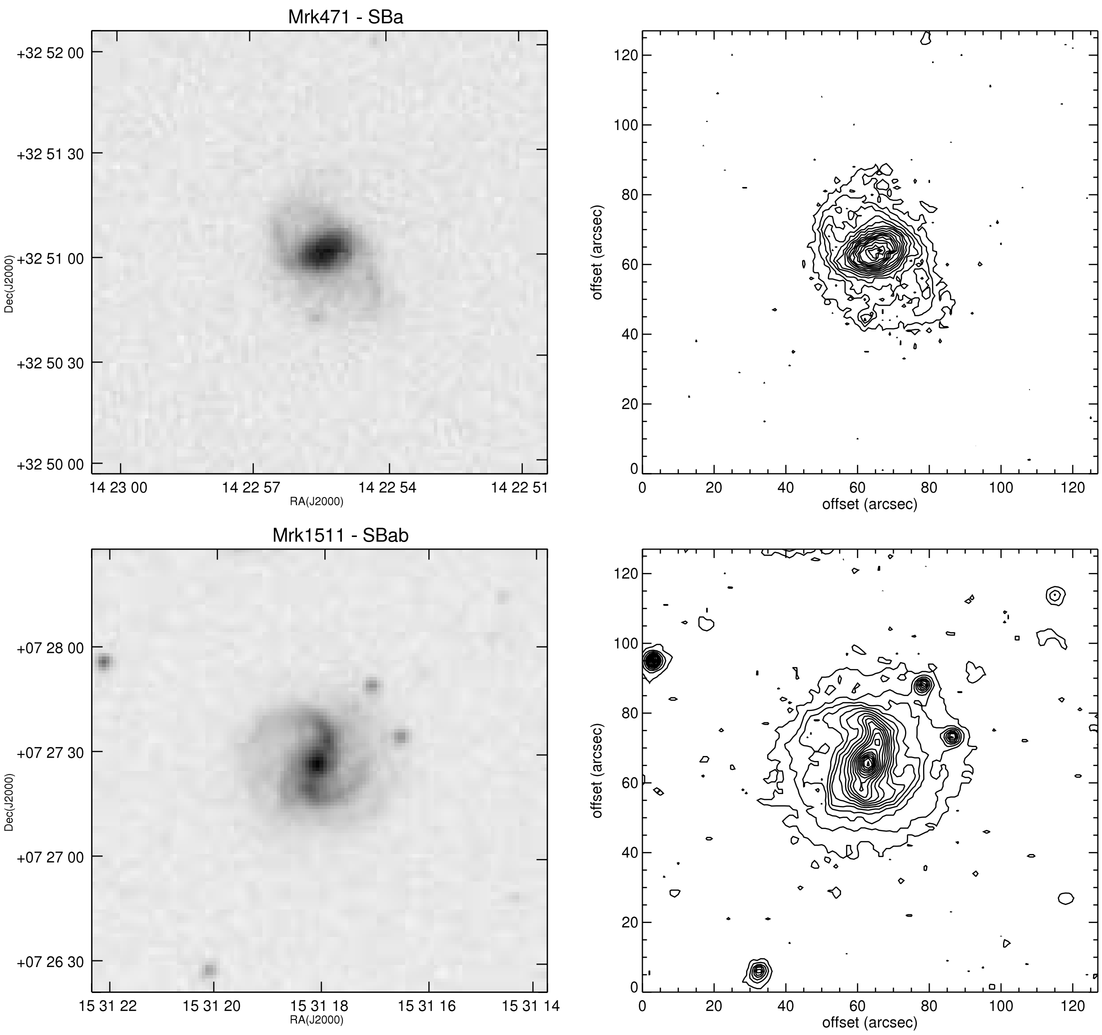
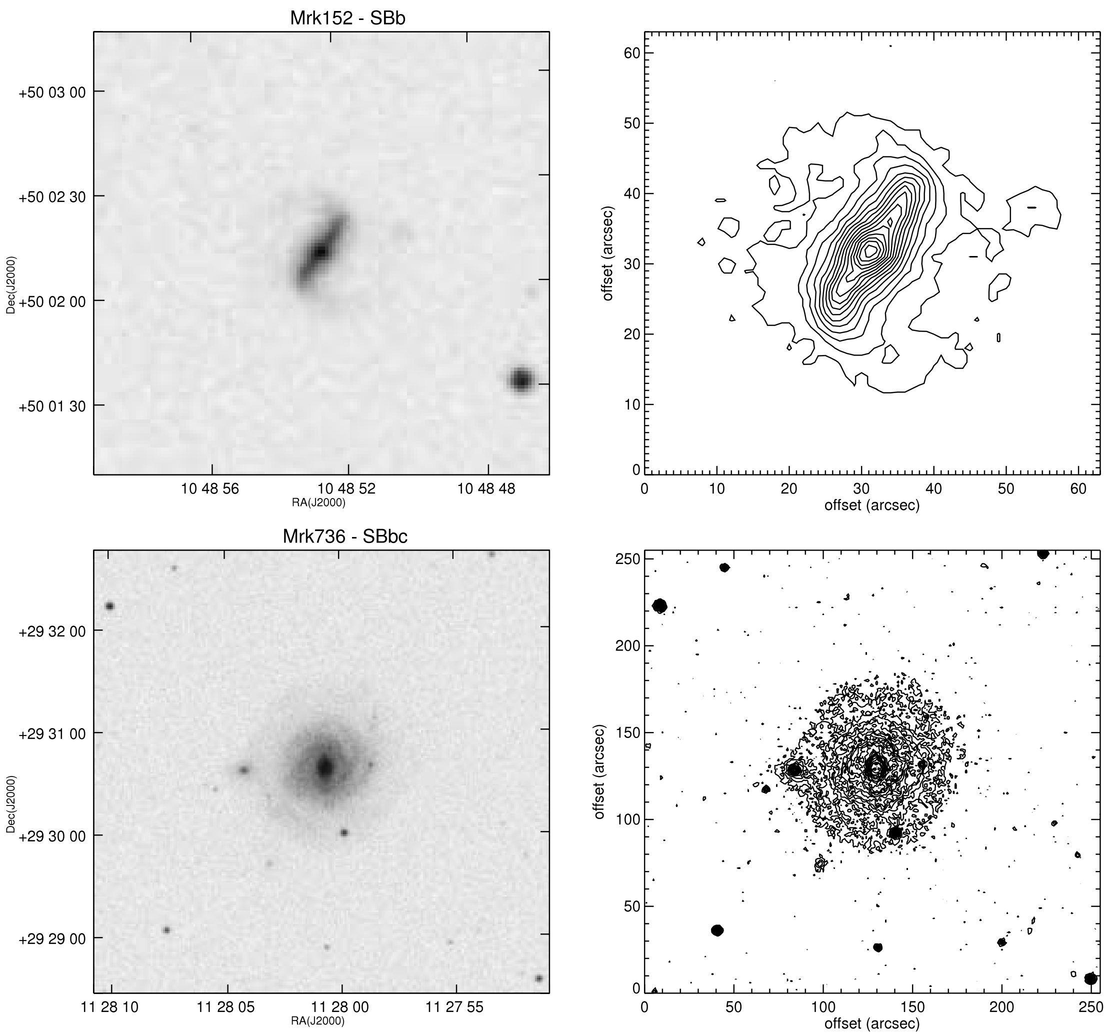


FIG. 1—*Continued*



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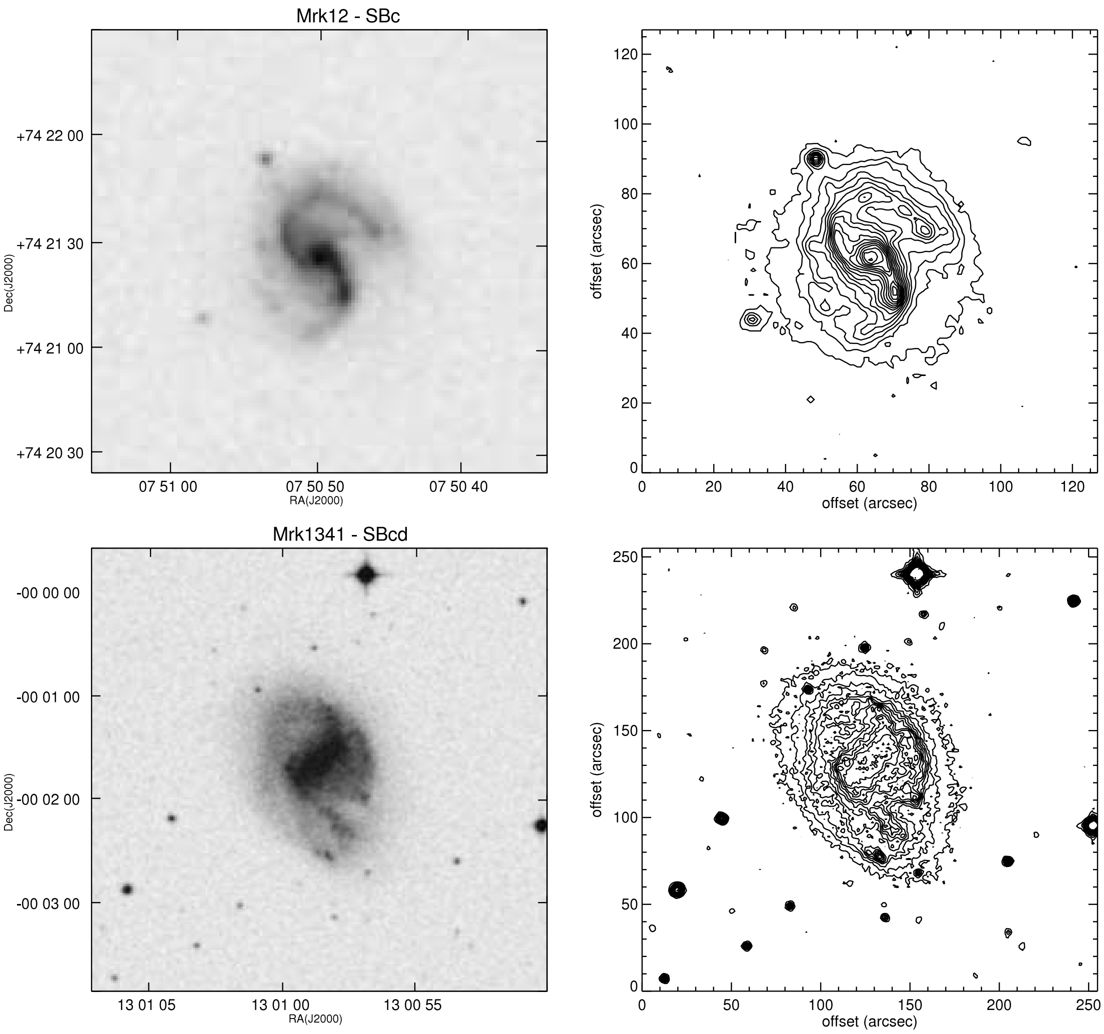

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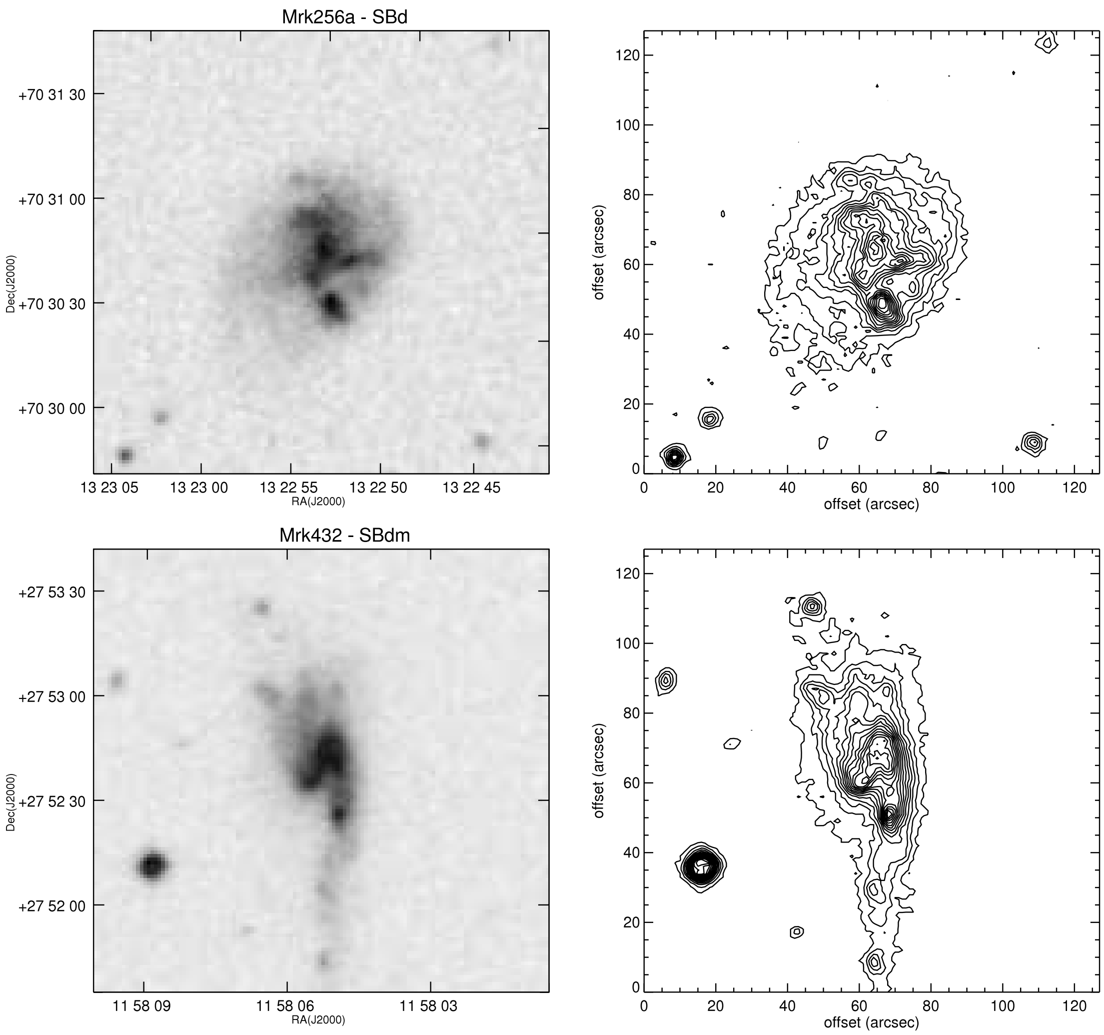

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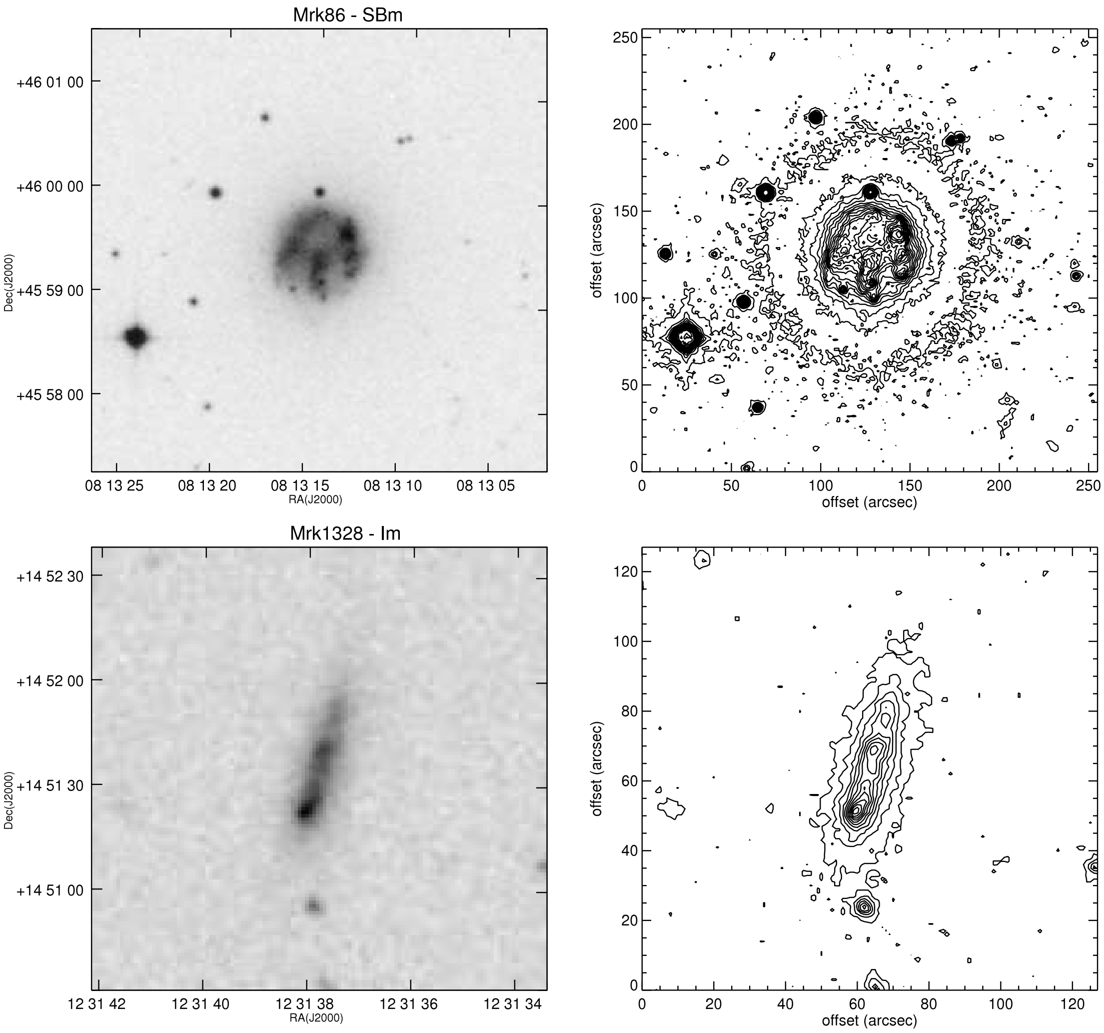

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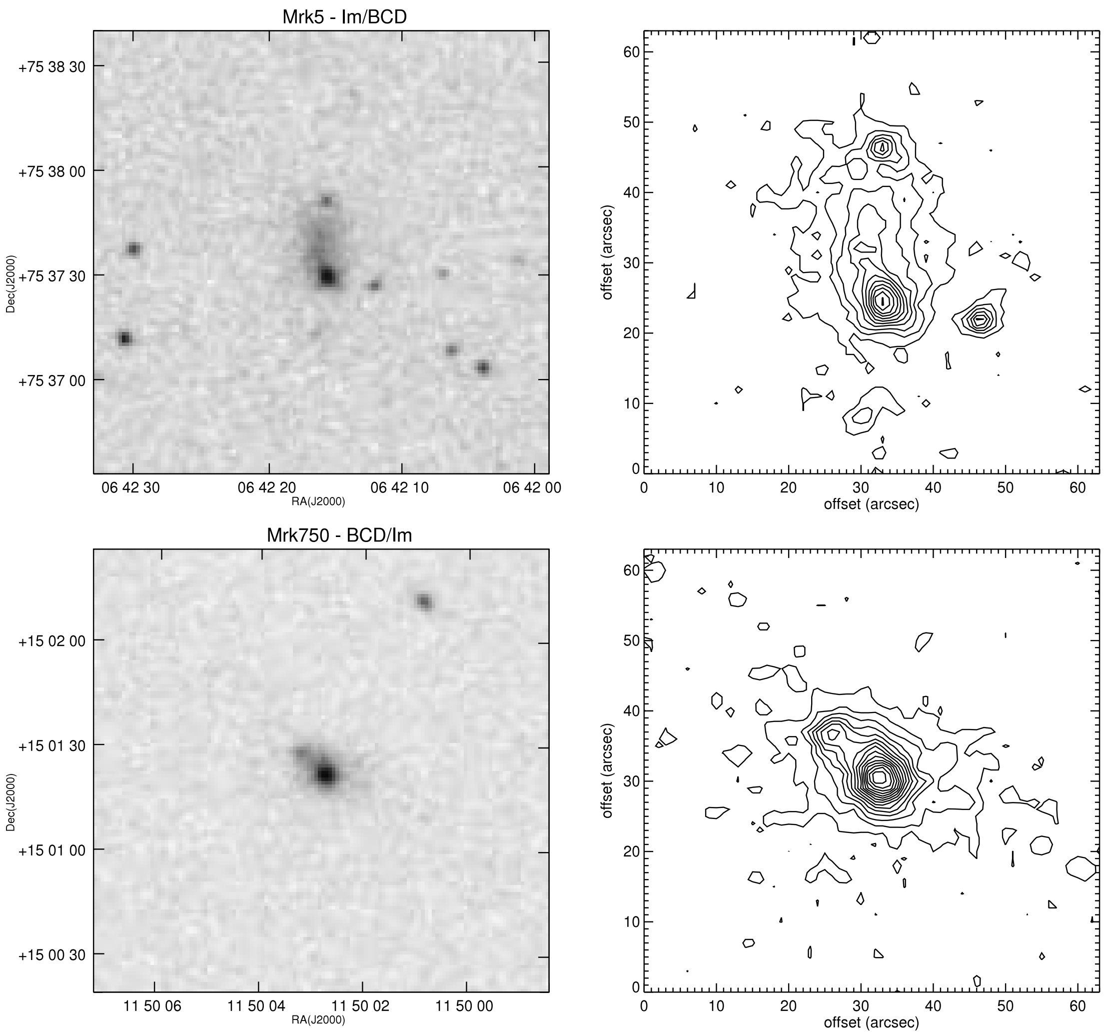

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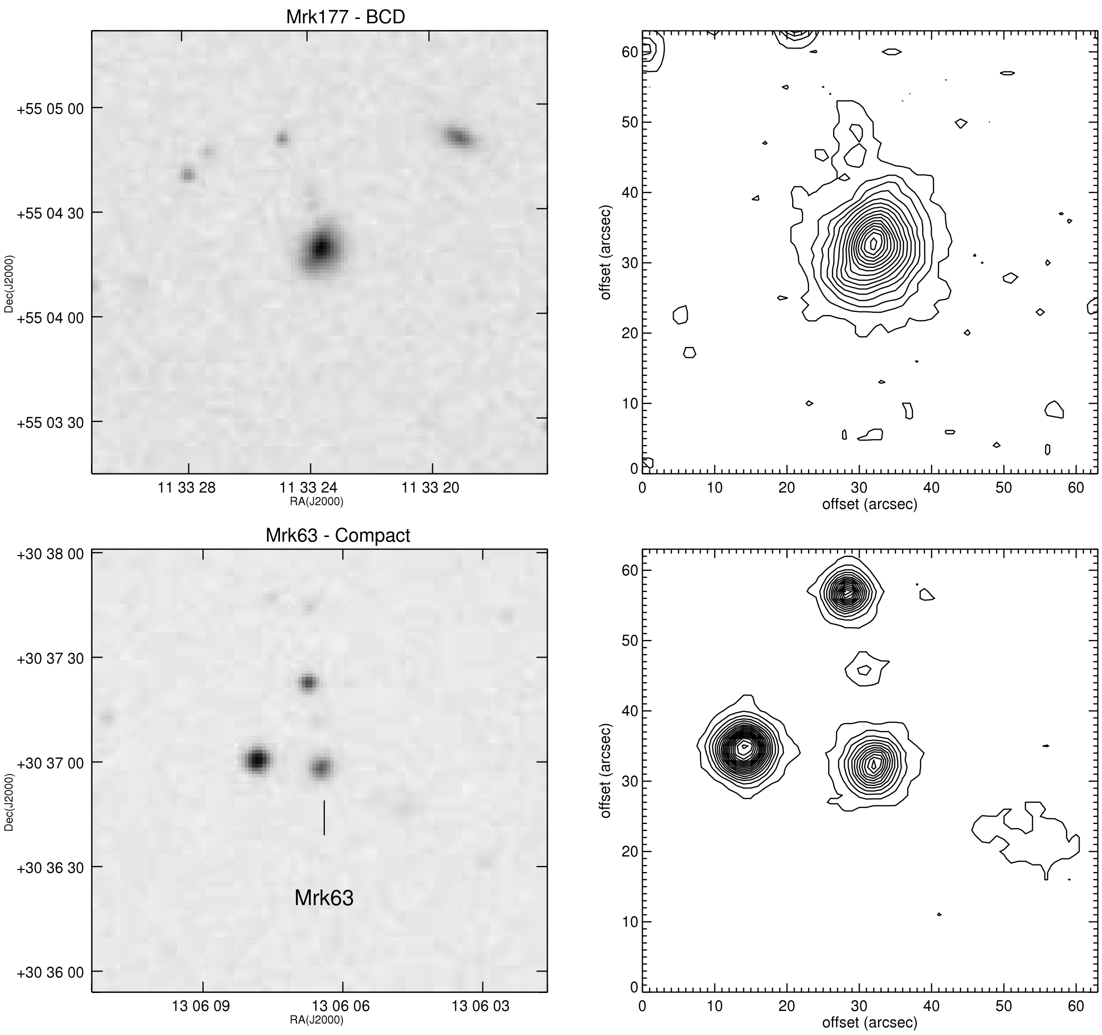

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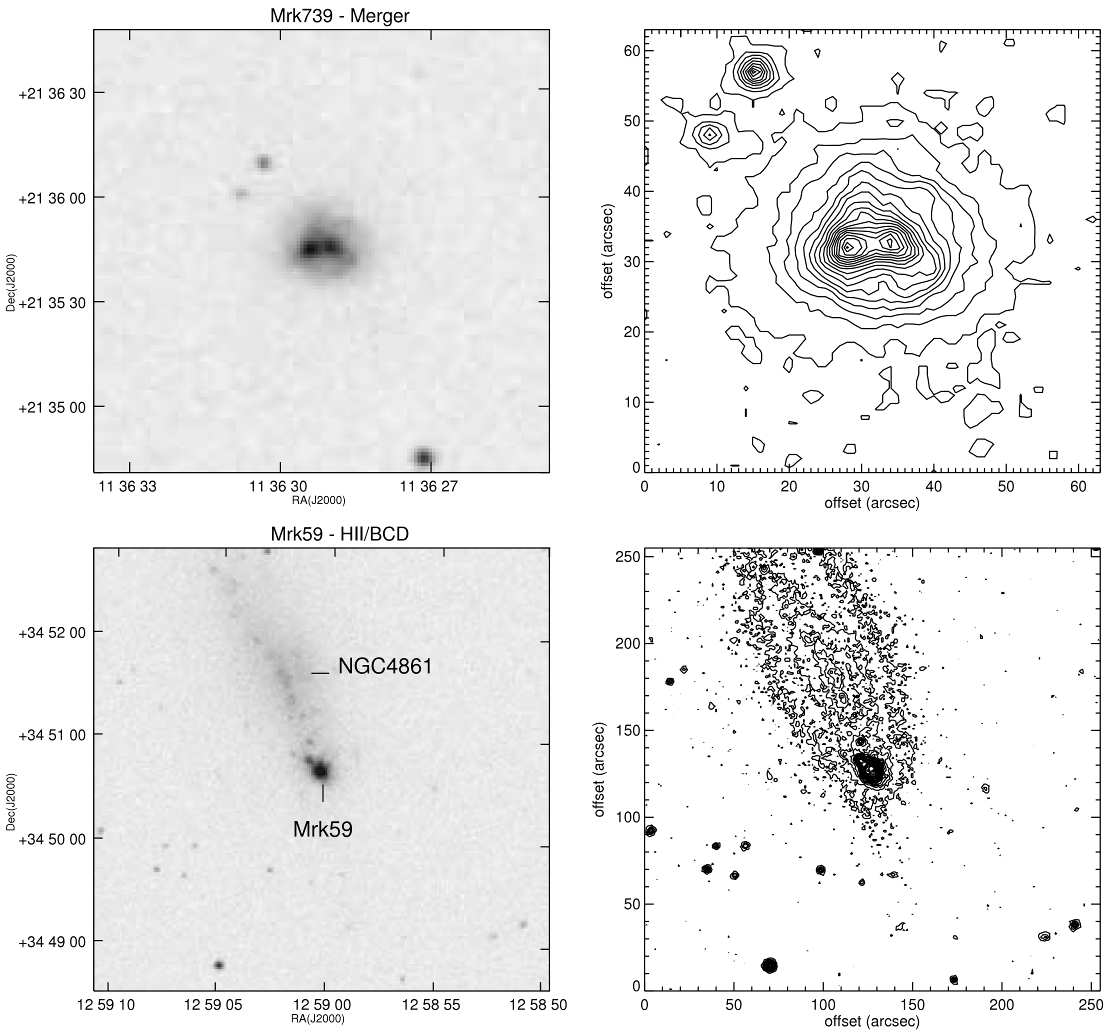


FIG. 1—*Continued*

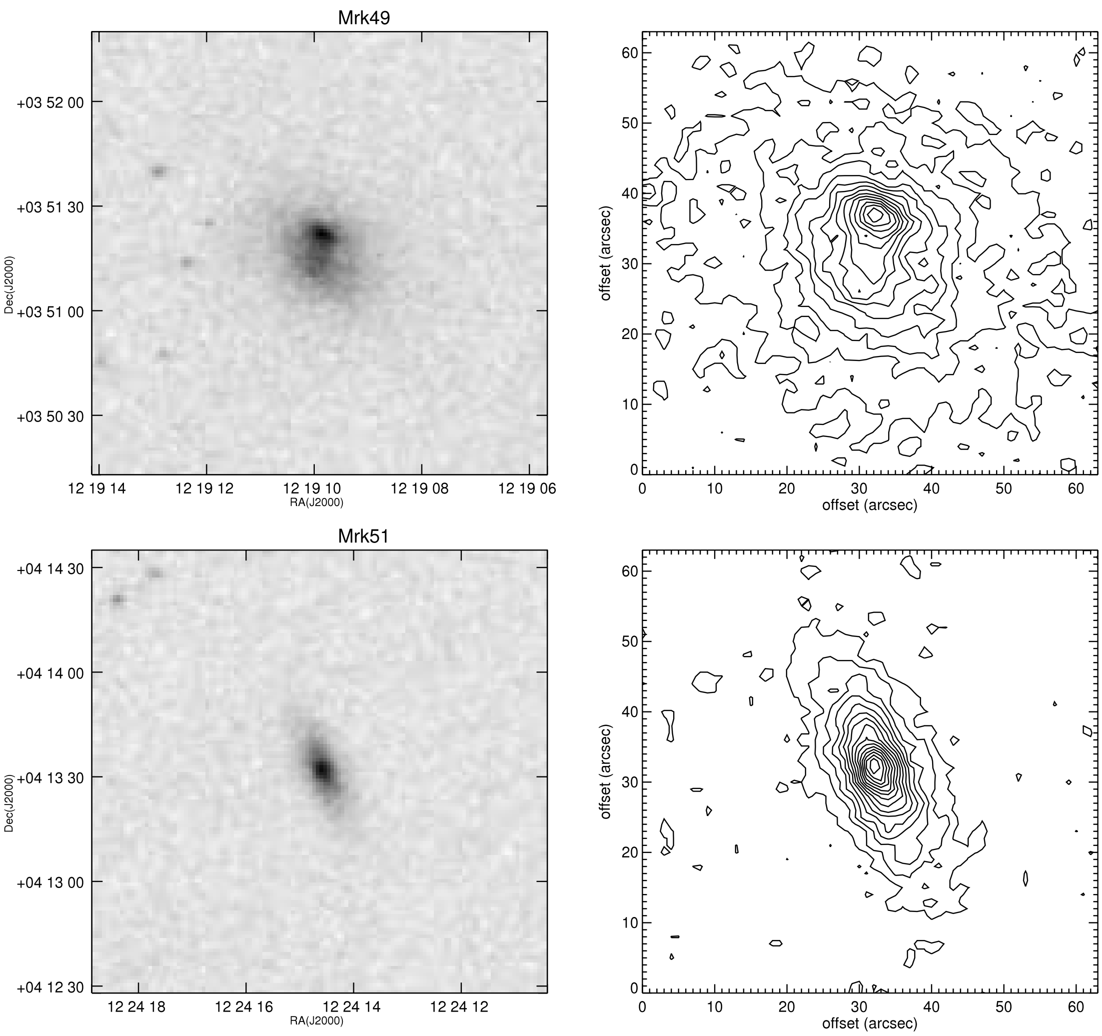


Fig. 2.—Examples of galaxies classified differently by HYPERLEDA and in this paper: Mrk 49 (elliptical cf. Im/BCD); Mrk 51 (elliptical cf. spiral); Mrk 1504 (elliptical cf. spiral); Mrk 314 (elliptical cf. merger); Mrk 84 (nonbarred cf. barred spiral); Mrk 161 (nonbarred cf. barred spiral); Mrk 647 (nonbarred cf. barred spiral); Mrk 1189 (nonbarred cf. barred spiral); Mrk 162 (compact cf. spiral); Mrk 1319 (compact cf. spiral); Mrk 750 (compact cf. BCD/Im); Mrk 194 (compact cf. merger). North is up, and east is to the left. The magnification was selected individually for each galaxy to clearly illustrate its individual morphological structure. Contour levels and axis labels are as in Fig. 1.

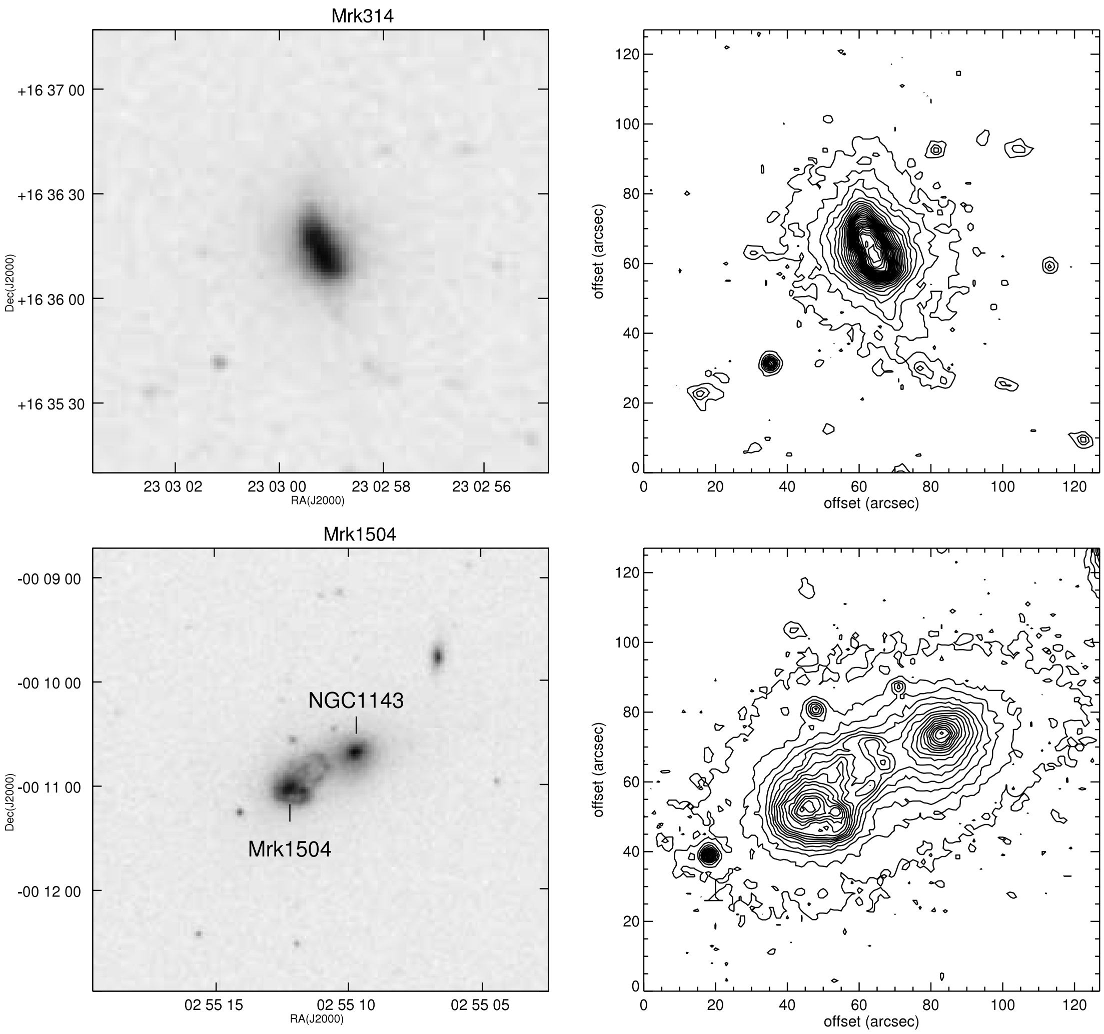


FIG. 2—*Continued*

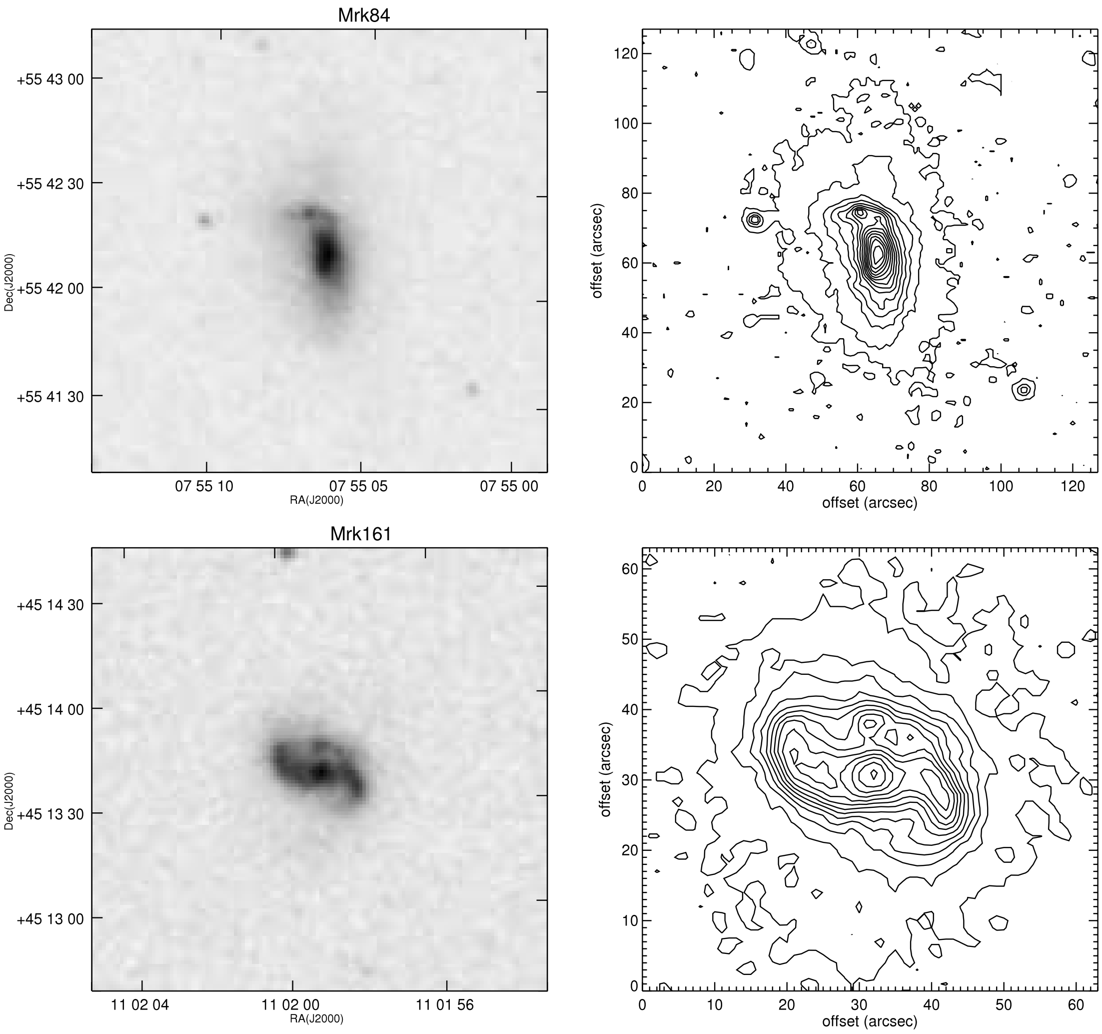


FIG. 2—*Continued*

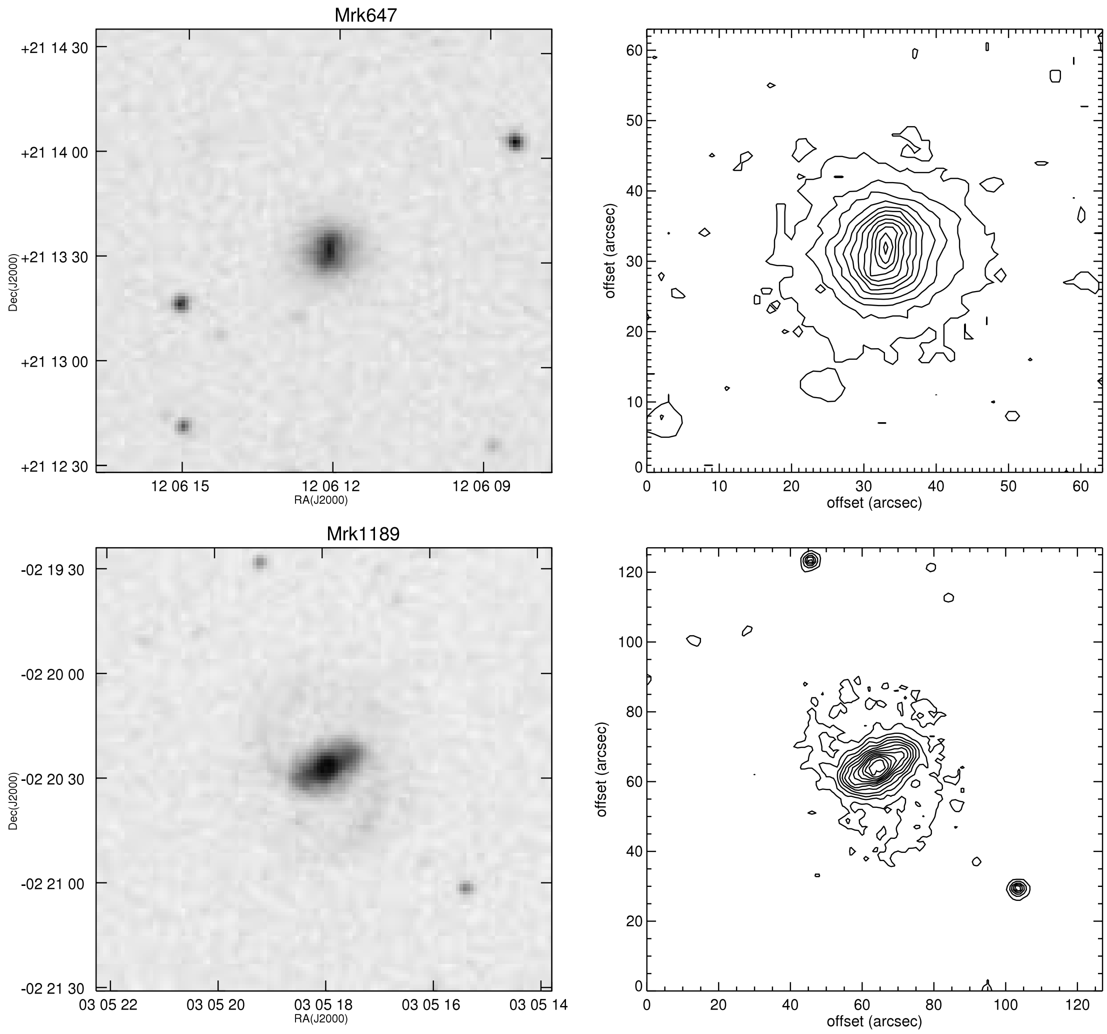


FIG. 2—*Continued*

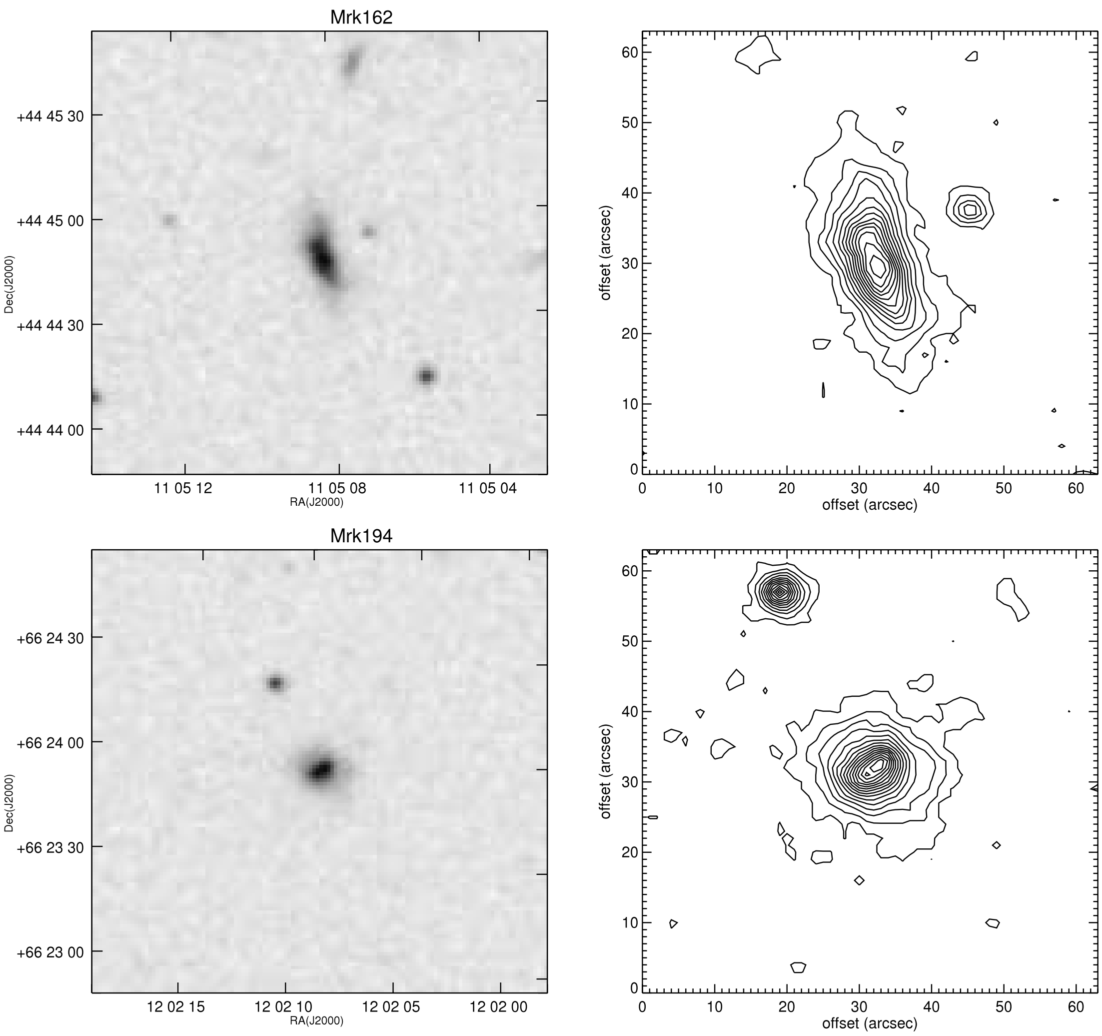


FIG. 2—*Continued*

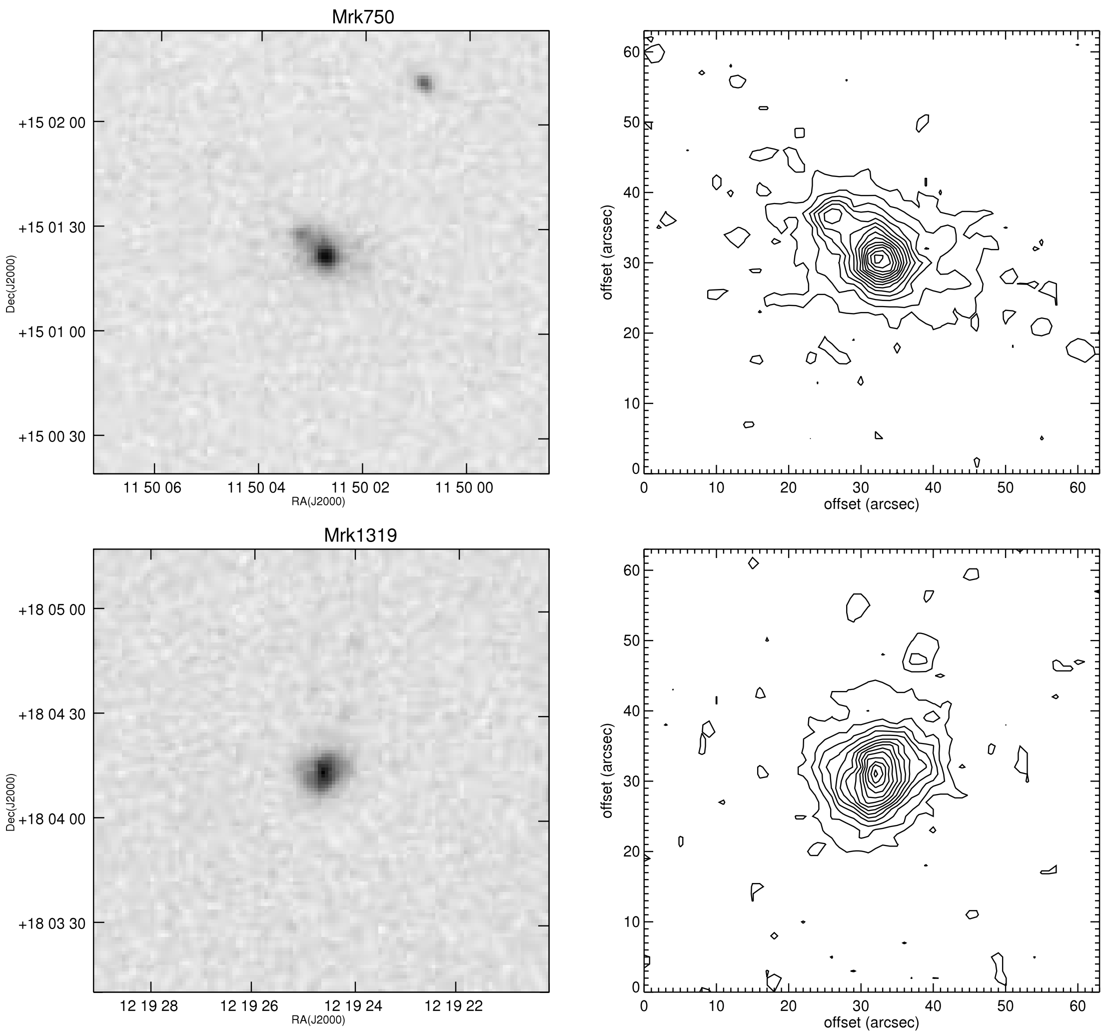


FIG. 2—*Continued*

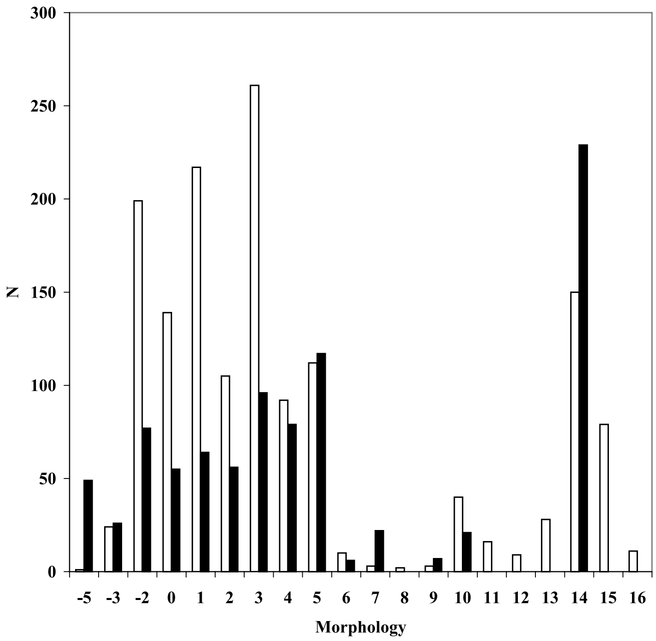


FIG. 3.—Bar graph showing change in morphological distribution between the HYPERLEDA sample (*white*) and our complete classification (*black*).

2.3.4. *Angular Diameters*

In both the original lists of Markarian galaxies and in M+89, the angular sizes of UV-excess objects were measured on red POSS-I charts and corresponded to the regions of the galaxies radiating in UV. In most cases, this was the main body of the galaxy, but in a number of cases it referred only to the nuclear region or some condensation in the galaxy. These diameters were eye estimates and so were not homogeneous or accurate.

The major and minor angular diameters of Markarian galaxies were measured in a homogeneous way from the blue and red images of the galaxies at the isophote corresponding to 3 times the background rms noise or 3 σ. Since the J_{pg} and F_{pg} plates have different limiting apparent magnitudes (Reid et al. 1991), it is necessary to reduce the measured diameters to a single uniform system. Taking into account that the mean linear diameter of the galaxy depends on its morphological type (e.g., Roberts & Hayes 1994), a reduction to a uniform system is performed separately for the samples of early (elliptical, S0 and S0/a galaxies) and late (spiral and irregular galaxies) as well as blue compact and compact type galaxies. Such a separation into subsamples was essential also for the Heidmann et al. (1972) procedure, which was used to determine the mean limiting galaxy surface brightness in our system.

Figure 4 compares the red and blue major diameters for the (*a*) early-type galaxies, (*b*) late-type galaxies, and (*c*) the BCD and compact galaxies. Using linear regression to determine the fits and correlation coefficients give us the following:

Early.—$D''(F) = (0.942 \pm 0.011)D''(J) + (0.634 \pm 0.488)$, $r = 0.978 \pm 0.011$, $N = 363$.

Late.—$D''(F) = (0.917 \pm 0.006)D''(J) + (1.515 \pm 0.333)$, $r = 0.985 \pm 0.006$, $N = 870$.

Compact.—$D''(F) = (0.858 \pm 0.019)D''(J) + (1.425 \pm 0.441)$, $r = 0.958 \pm 0.021$, $N = 178$.

In general, the 5%–8% larger blue diameters of Markarian galaxies in comparison to red diameters are due to a combination of both the deeper limiting magnitudes for the blue plates compared to the red plates (Reid et al. 1991), and the fact that the outer regions of many of these galaxies tends to be blue because of star formation in their disks. Using the method of Heidmann et al. (1972), we obtain two estimates of the limiting (3 σ) surface brightness from both the early-type (25.22 $\pm$ 0.38 mag arcsec^{-2}) and late-type (25.25 $\pm$ 0.59 mag arcsec^{-2}) galaxies. These are consistent with each other and we shall adopt a mean limiting surface brightness of $Bj = 25.2$ mag arcsec^{-2} for our measurements.

We used data from HYPERLEDA to verify the agreement of our diameter system with the standard $D(25)$ diameter system (Paturel et al. 1991, 1997). Once again, the comparison of our measured blue angular diameters with the HYPERLEDA angular diameters are done separately for early- and late-type Markarian galaxies. Before comparing the samples, we excluded the objects that are incorrect in HYERLEDA. Figure 5 compares HYPERLEDA $D(25)$ and our blue diameters for (*a*) early-type and (*b*) late-type Markarian galaxies. The dependence between two diameters can be fitted in with the linear regression, which has following form and coefficient of correlation:

Early.—$D''(25) = (0.870 \pm 0.016)D''(J) + (1.910 \pm 0.747)$, $r = 0.956 \pm 0.018$, $N = 277$.

Late.—$D''(25) = (0.923 \pm 0.008)D''(J) + (1.345 \pm 0.477)$, $r = 0.980 \pm 0.008$, $N = 584$.

Our measured blue diameters are typically larger than HYPERLEDA blue $D(25)$ diameters. This is due to the deeper mean limiting galaxy surface brightness in our system.

2.3.5. *Axial Ratios*

Several authors (e.g., Smith 1985) emphasized that the Markarian survey may be biased against discovering objects with even quite small amounts of dust extinction. Other authors stress the importance of a bias against discovering of the UV excess galaxies, as a function of the inclination of the galaxy with respect to the observer (Joeveer 1986). In this respect determination of inclination for large number of Markarian objects is crucial.

The major and minor angular diameters of Markarian galaxies were measured in both bandpasses in a homogeneous way with respect to the background and its rms noise for the mean limiting surface brightness of about 25.2 mag arcsec^{-2}. The axis ratios were calculated from these measurements using the formula $R = D_{\rm minor}/D_{\rm major}$. Figure 6 compares the red and blue axis ratios for (*a*) early-type, (*b*) late-type, and (*c*) compact galaxies. We obtained the following fit and correlations:

Early.—$R(F) = (0.970 \pm 0.021)R(J) + (0.028 \pm 0.017)$, $r = 0.924 \pm 0.020$, $N = 363$.

Late.—$R(F) = (0.957 \pm 0.009)R(J) + (0.033 \pm 0.006)$, $r = 0.962 \pm 0.009$, $N = 870$.

Compact.—$R(F) = (0.947 \pm 0.029)R(J) + (0.057 \pm 0.025)$, $r = 0.924 \pm 0.028$, $N = 178$.

These data indicate that the axial ratios measured in the blue and red systems have no significant differences.

Once again, we used data from HYPERLEDA to verify the agreement of our axial ratio system with the standard $R(25)$ system (Paturel et al. 1997) separately for early- and late-type Markarian galaxies. We used the same galaxies for which we compared the angular diameters. Figure 7 compares HYPERLEDA and our axial ratios for (*a*) early-type and (*b*) late-type Markarian galaxies.

Early.—$R(25) = (0.800 \pm 0.039)R(J) + (0.140 \pm 0.031)$, $r = 0.774 \pm 0.038$, $N = 277$.

Late.—$R(25) = (0.852 \pm 0.019)R(J) + (0.085 \pm 0.013)$, $r = 0.880 \pm 0.020$, $N = 584$.

The Markarian galaxies axial ratios in HYPERLEDA and our measurements have no significant differences.

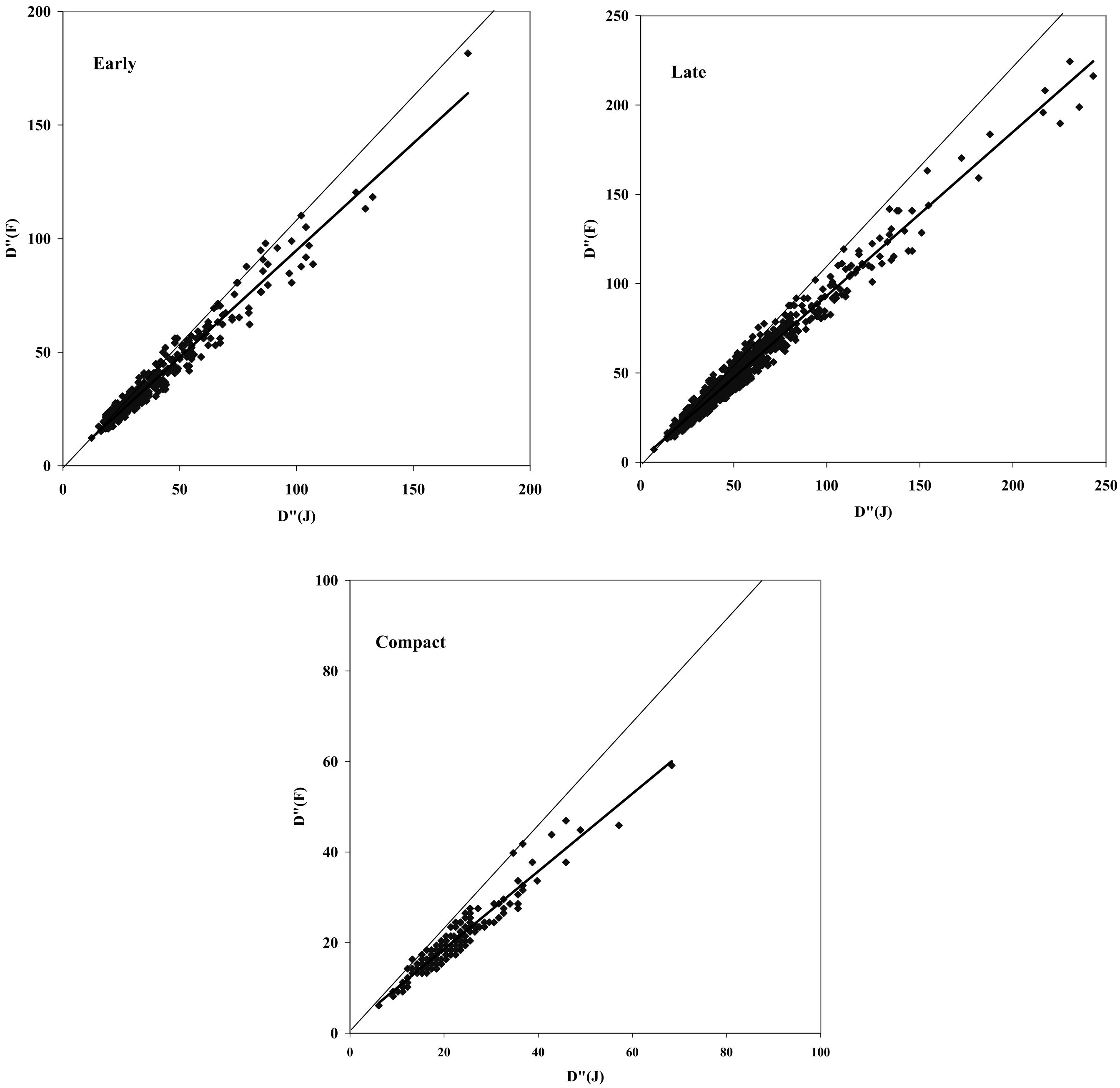


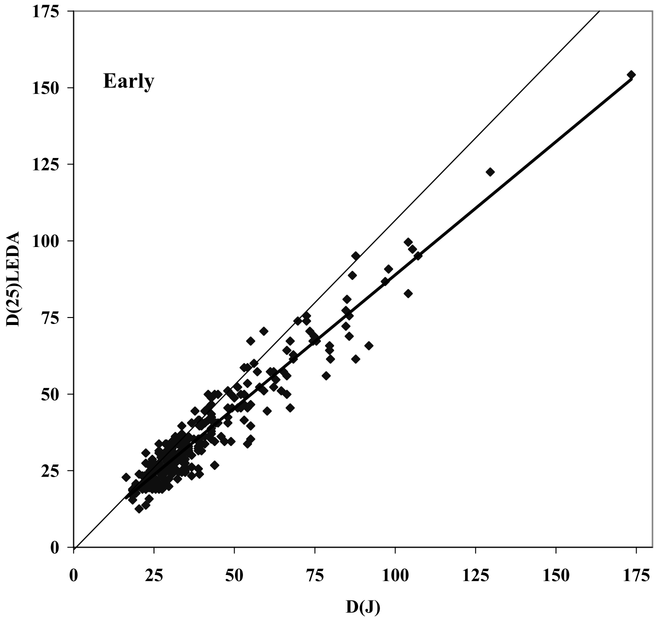
Fig. 4.—Comparison of the measured blue and red major diameters for (*a*) early morphological type, (*b*) late morphological type, and (*c*) compact morphological type Markarian galaxies. The best linear fit and 1:1 lines are plotted.

2.3.6. *Apparent J_{pg} (Blue) and F_{pg} (Red) Magnitudes*

According to previous determinations, the LF of Markarian galaxies resemble those of field galaxies (Huchra & Sargent 1973; Huchra 1977; Xu et al. 1988) and represent of 6%–11% of field galaxies. This percentage depends strongly on the absolute luminosity of the galaxies, and there are large uncertainties since the apparent magnitudes and redshifts are based on limited samples. In this database we provide our measurements of the apparent blue and red magnitudes for all Markarian objects with improved accuracy and in a homogeneous manner.

The magnitudes of the galaxies were measured from the POSS-II and UKSTU photographic survey plates that are available at STScI and used for the construction of the GSC-II catalog (McLean et al. 1998). These magnitudes of the stars on these plates were calibrated by observing stellar CCD sequences in every field (Bucciarelli et al. 2001). In order to measure the magnitudes of nonstellar objects, it was necessary to use a technique to derive the nonlinear intensity to photographic density transformation so that one can integrate in intensity units. It should be stressed that the photometric calibrations techniques used in the GSC-II (the all-sky catalog derived from the DSS images), or PSF growth techniques (e.g., Bacher et al. 2005) are applicable only to stars and not galaxies.

We have implemented a modification of the technique developed by the APM group (Bunclark & Irwin 1983), to internally calibrate photographic plates using the measured stellar profiles. This is an iterative process, which as a by-product determines the photographic density-intensity (D-I) function for that plate. By adding a step to this iterative process of a least-squares fit of the



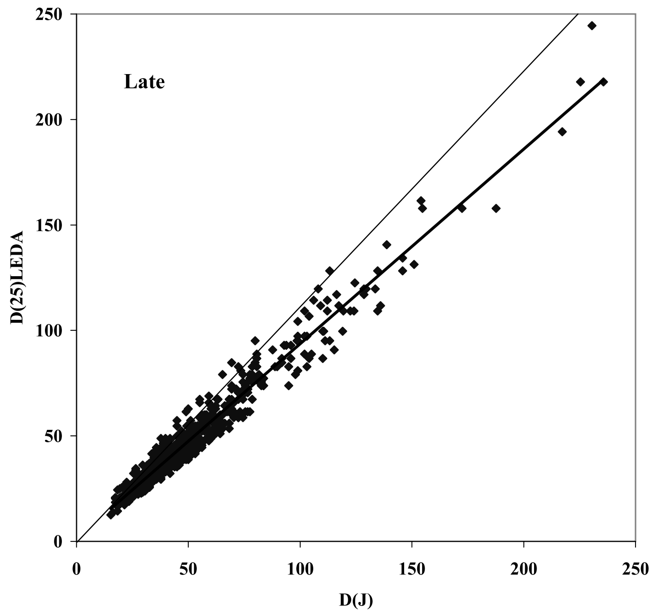


FIG. 5.—Comparison of the measured blue major diameters with HYPERLEDA for (*a*) early morphological type and (*b*) late morphological type Markarian galaxies. The best linear fit and 1:1 lines are plotted.

derived magnitudes of the GSC-II stars in the field to their catalog magnitudes we effectively constrain the calibration to be linear and with a determined zero point. One can then take the D-I function and zero point to integrate the intensity within the isophotal contours of the galaxy and convert that to a magnitude. In cases where we were unable to automatically deblend overlapping objects in software, a manual procedure was used to mark a boundary between objects in order to assign the pixel's surface brightness to the correct object. This does not eliminate measurement errors due to the saturation that can occur in the nuclei of the brighter galaxies or possible field effects where the D-I response varies over the plate. The blue and red apparent magnitudes of Markarian galaxies were measured from the J_{pg} and F_{pg}-band images of the objects in homogeneous way at the isophote corresponding to 3 times the background rms noise, which is approximately 25.2 mag arcsec^{-2}.

Even though a large number of surface or aperture photometry studies have been carried out over the last 3 decades, only a fraction of the Markarian sample has published magnitudes. In addition, comparisons among these data are complicated since most data have been obtained using different telescopes and reduced with different methods. One of the best and most homogeneous photometric studies of Markarian galaxies that includes data for 196 objects was published by Huchra (1977). We chose to use this sample in order to test our techniques. For the galaxies included in his Table 2 of integrated properties, we compare our J_{pg} magnitudes as well as $(J_{pg} - F_{pg})$ colors with his B integrated magnitudes and $(B - R)$ colors. A number of Markarian galaxies with multicomponent structure (e.g., Mrk 86, 116, etc.) have been excluded from the comparisons. Figure 8 shows the relation between (*a*) magnitudes and (*b*) colors. The dependence between magnitudes and color systems can be fitted with linear regressions, which have the following forms and coefficients of correlation, respectively:

$$\begin{aligned} B &= (0.996 \pm 0.027)J_{pg} + (0.273 \pm 0.397), \\ r &= 0.958 \pm 0.026, \ N = 125, \\ [B - R] &= (0.819 \pm 0.052)(J_{pg} - F_{pg}) + (0.295 \pm 0.061), \\ r &= 0.845 \pm 0.053, \ N = 102. \end{aligned}$$

The mean absolute differences between the Huchra (1977) B and our J_{pg} magnitudes is 0.28 ± 0.18 and Huchra (1977) $(B - R)$ and our $(J_{pg}-F_{pg})$ colors is 0.16 ± 0.12. These minor differences are reasonable given the uncertainties associated with Huchra's aperture corrections (his largest apertures were, on average, slightly smaller than the effective diameter of our outer isophotes), and the fact that the photometric systems are slightly different (Sandage vs. Johnson-Kron-Cousins). Among the galaxies with larger magnitude and/or color differences, there are interacting systems (e.g., Mrk 325, 333), edge on galaxies (e.g., Mrk 416, 479, etc.), and galaxies with extended low surface brightness outer structures (e.g., Mrk 391, 430, etc.), which can account for the errors.

Overall, our magnitude measurements are in good agreement with Huchra (1977) and give us an independent estimate of our error to be $\sim$0.3 mag. Using the total sample of Markarian galaxies we employ $V/V_{\rm max}$ and log N versus limiting magnitude methods to examine the completeness of this sample at increasing limiting $m(J_{pg})$ and $m(F_{pg})$ magnitudes. We conclude that the Markarian galaxy sample is incomplete at $m(J_{pg}) > 15.2$, and at $m(F_{pg}) > 14.3$. This estimate of completeness is in good agreement with MB86.

It is well known that the $(B - R)$ color of galaxies depends on their morphological type (e.g., Jansen et al. 2000). In this respect, a comparison of our measured blue and red magnitudes of Markarian galaxies is done for the samples of early (elliptical, S0, S0/a) and late (spiral and irregular) galaxies separately. The mean color difference for early- and late-type Markarian galaxies, respectively, are 1.24 ± 0.28 and 1.11 ± 0.33, which are typical values for similar morphological type galaxies (e.g., Jansen et al. 2000).

A comparison of our J_{pg} band magnitude measurements with HYPERLEDA B-band magnitude determinations was also conducted separately for the early- and late-type Markarian galaxies. In this comparison we include all Markarian galaxies excluding only multicomponent objects. Figure 9 compares HYPERLEDA B

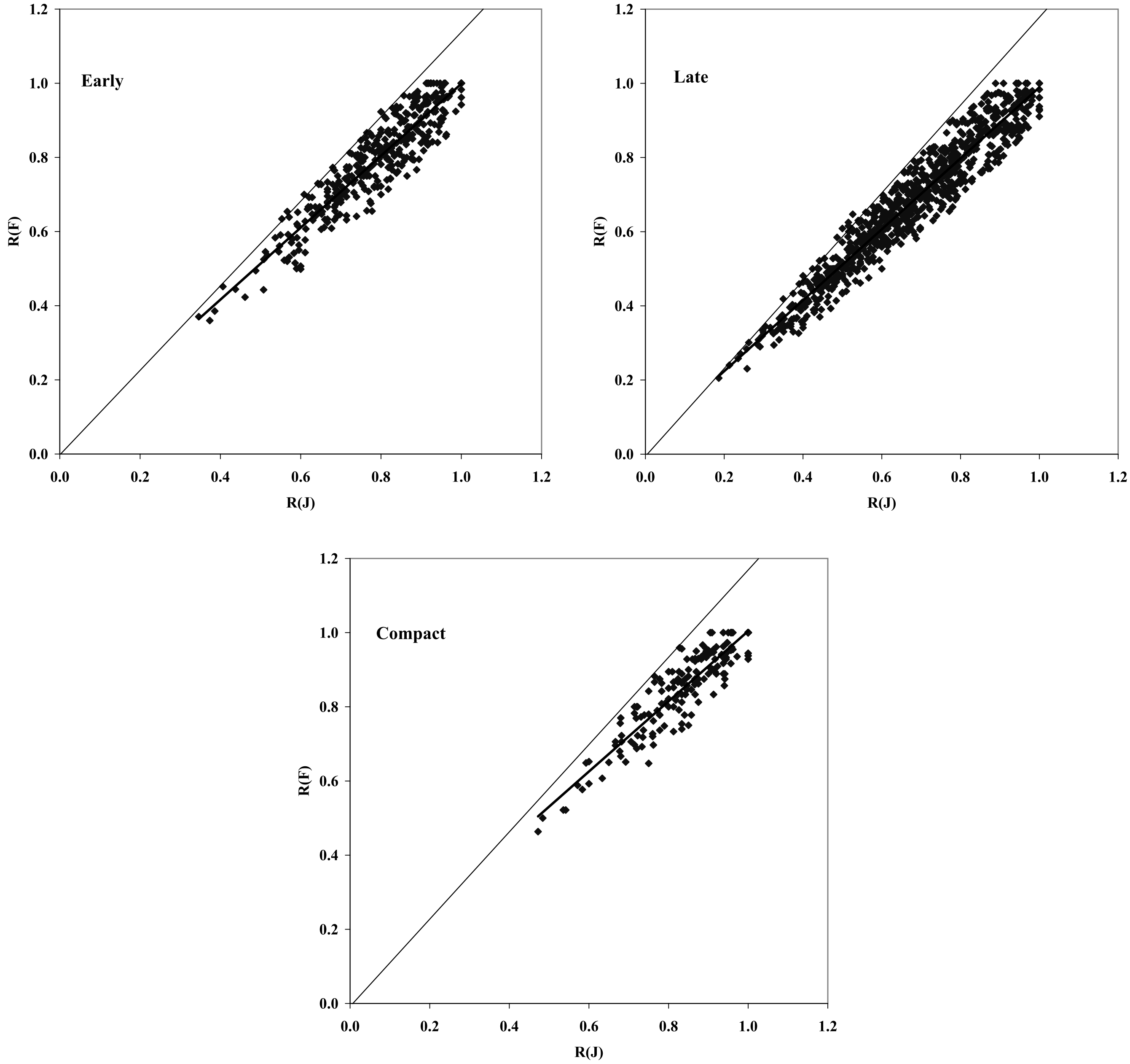


FIG. 6.—Comparison of the measured blue and red axial ratios for (*a*) early morphological type, (*b*) late morphological type, and (*c*) compact morphological type Markarian galaxies. The best linear fit and 1:1 lines are plotted.

and our J_{pg} magnitudes for (*a*) early-type and (*b*) late-type galaxies. The calculated transformations are as follows:

Early.—$B = (0.984 \pm 0.031)J_{pg} + (0.523 \pm 0.446)$, $r = 0.862 \pm 0.027$, $N = 357$.

Late.—$B = (0.999 \pm 0.019)J_{pg} + (0.272 \pm 0.283)$, $r = 0.880 \pm 0.017$, $N = 832$.

The mean absolute differences of the HYPERLEDA B and our J_{pg} magnitudes, respectively, for the early- and late-type Markarian galaxies are 0.39 ± 0.34 and 0.40 ± 0.38. For 68% early-type and 70% late-type Markarian galaxies the HYPERLEDA B and our J_{pg} magnitude difference is less than 0.5 mag and, respectively, for 6% and 10% galaxies this difference is greater than 1.0 mag. The 0.2–0.5 mag internal error of our measurements has its contribution on individual differences but the following factors also affect the residuals.

The apparent total B magnitudes in HYPERLEDA are reduced to the RC3 system for standard 25 mag arcsec^{-2} isophotal level. Our J_{pg} magnitudes are determined at the 25.2 mag arcsec^{-2} isophotal level. This 0.2 mag difference in the lowest isophotal level can have a significant effect on the integrated J_{pg} magnitudes. In HYPERLEDA, a growth curve fitting method was used to transfer determined magnitudes from different sources to the RC3 system. While this method derives homogeneous photometric parameters, it ignores the morphology of individual galaxies: the relative brightness of the bulge, disks, arms, active nuclei, etc. (Prugniel & Heraudeau 1998), will introduce errors. This is why there are 72 Markarian galaxies in HYPERLEDA that have B magnitudes fainter than 17 mag even though the FBS (Markarian 1967) had a well-defined limiting magnitude of 17. As discussed in § 2.3.5, in HYPERLEDA a number of Markarian galaxies have erroneous identification (e.g., Mrk 586, 902, 1154, etc.). These galaxies have large ($J_{pg} - B$) residuals. Some of the galaxies with large ($J_{pg} - B$) residuals are objects in close interaction (e.g., Mrk 109, 220, 582, etc.). The presence of close neighbors can

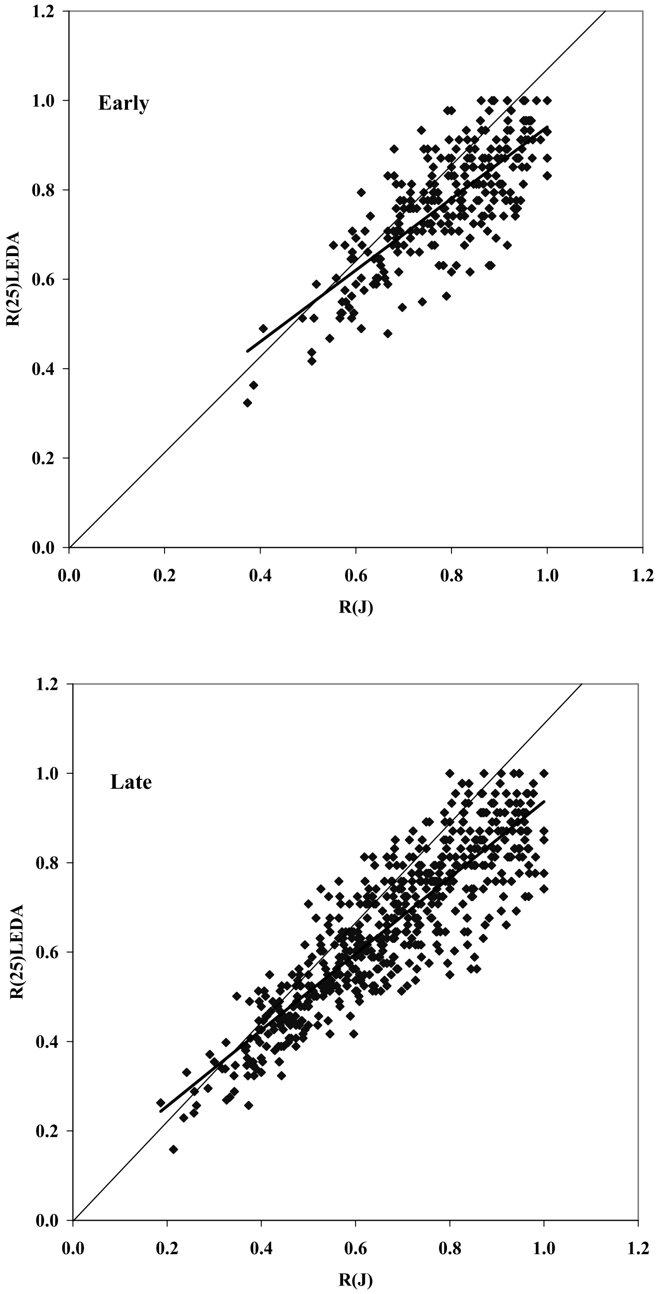


FIG. 7.—Comparison of the measured blue axial ratios with HYPERLEDA for (*a*) early morphological type and (*b*) late morphological type Markarian galaxies. The best linear fit and 1:1 lines are plotted.

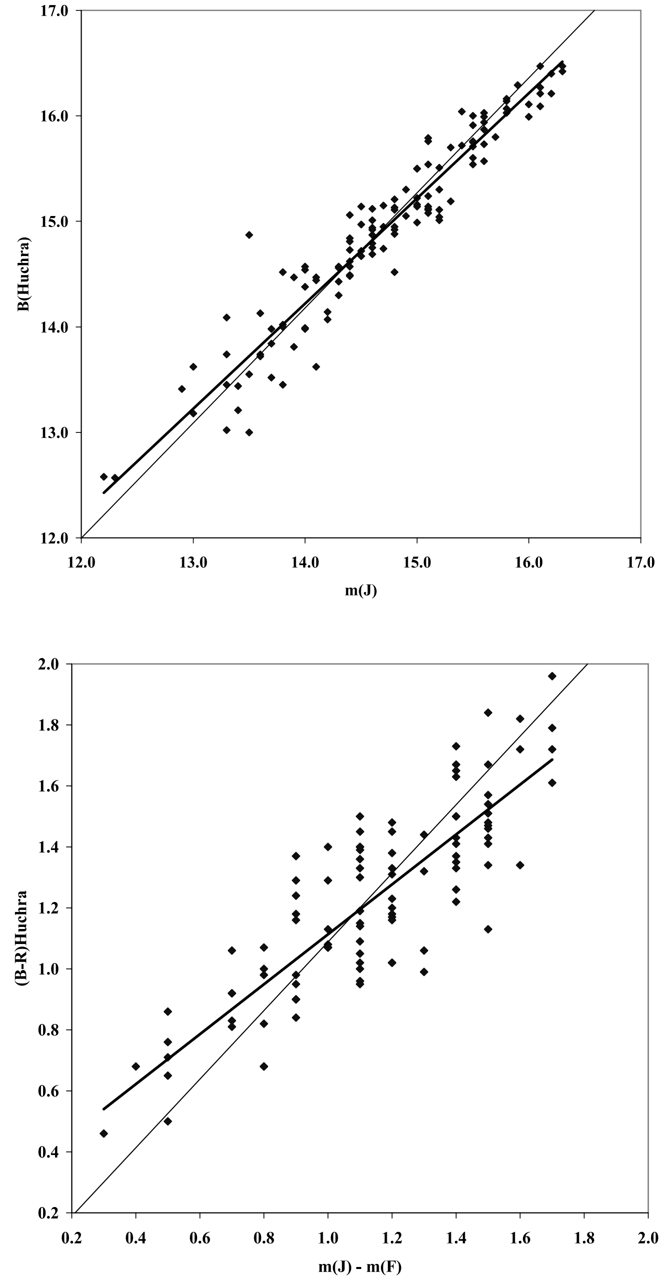


FIG. 8.—(*a*) Comparison of the measured J_{pg} and Huchra (1977) *B* apparent magnitudes. (*b*) Comparison of the $(J_{pg} - F_{pg})$ colors with Huchra (1977) $(B - R)$ colors. The best linear fit and 1:1 lines are plotted.

introduce a larger error in either our or HYPERLEDA magnitude determinations if they are not properly separated by the software algorithms. Similarly, galaxies with projected stars (e.g., Mrk 327, 498, 689, etc.) can introduce errors in either our or HYPERLEDA magnitude determinations if they are not properly treated by the software algorithms.

2.3.7. *Position Angles*

The position angles (P.A.) of the major axes were determined at the same (25.2 mag arcsec^{-2}) isophotal level as the angular diameter and magnitude measurements. P.A. is measured from the north (P.A. $= 0°$) toward east between 0° and 180°. Similar to §§ 2.3.4 and 2.3.5, the P.A. were reduced to a single uniform system. We compared the red and blue results for all three subsamples (Fig. 10) with the result that there are no significant differences or dependence on the morphological class of the objects.

A comparison of our P.A. blue measurements for Markarian galaxies with HYPERLEDA determinations for the same objects has been done and is shown in Figure 11. Despite a large scatter, the dependence between our and HYPERLEDA's P.A. measurements can be fitted in with the linear regression, which has following form and coefficient of correlation:

$$\mathrm{P.A.}(25) = (0.741 \pm 0.022)\mathrm{P.A.}(J) + (23.850 \pm 2.403),$$
$$r = 0.721 \pm 0.022, \; N = 1013.$$

The mean absolute difference between the HYPERLEDA's and our blue P.A. for Markarian galaxies is 12.2° ± 15.4°, which is approximately twice larger than difference between our blue

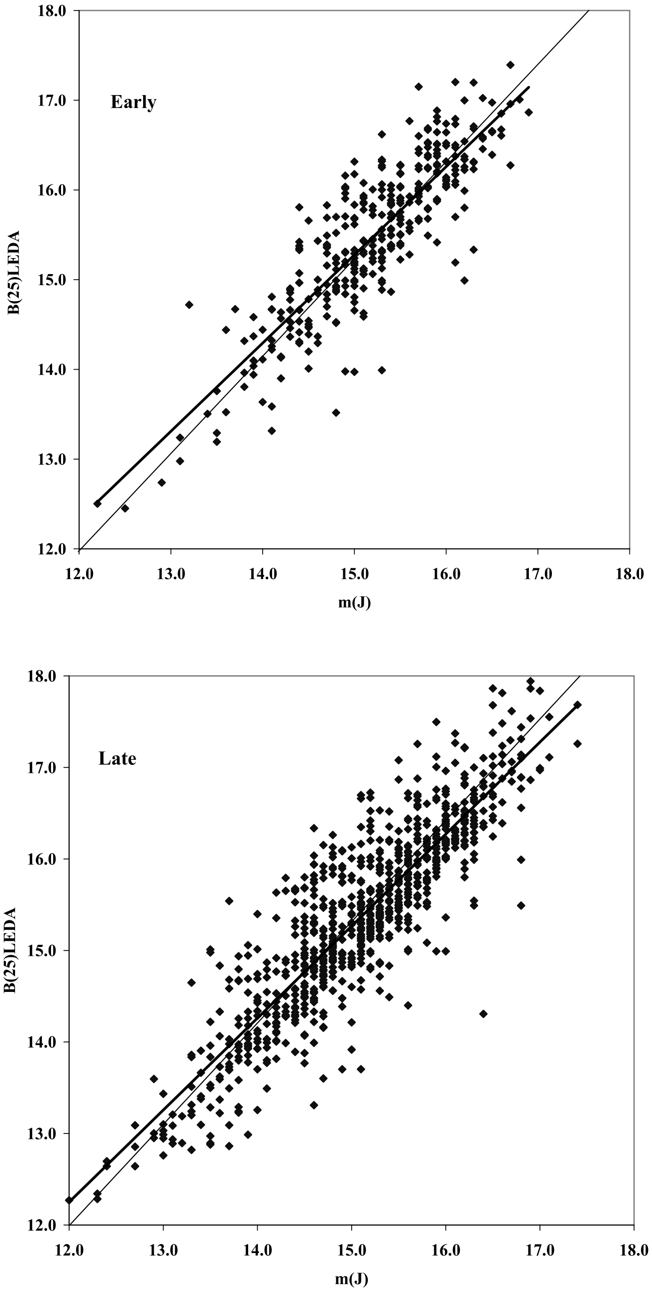


FIG. 9.—Comparison of the J_{pg} apparent magnitudes with HYPERLEDA B for (*a*) early morphological type and (*b*) late morphological type Markarian galaxies. The best linear fit and 1:1 lines are plotted.

and red P.A. measurements. For most Markarian galaxies, the P.A. in HYPERLEDA and our measurements are not significantly different. There are several possible reasons for the large scatter:

1. Misidentification of Markarian galaxy. For example Markarian 902 is the eastern component of the interacting system with P.A. obviously equal to 5°–10°. HYPERLEDA's P.A. measurement equal to 85° is for neighbor object.

2. Existence of a bright star or large neighbor object very close to the Markarian galaxy. For example, the bright star projected very close to Markarian 1259 can affect the measurement.

3. Our P.A. relate to the major diameter of Markarian galaxies on about a 25.2 mag arcsec^{-2} isophotal level. HYPERLEDA's P.A. relate to the major diameters of the galaxies on a standard 25 mag arcsec^{-2} level. For Markarian late-type or peculiar galaxies a 0.2 mag arcsec^{-2} difference in outer isophotal level can have a crucial influence on P.A. determination. For example the P.A. of peculiar galaxy Markarian 273 obviously is 14°–19° but not 174° as in HYPERLEDA, or the P.A. of another peculiar galaxy Markarian 716 is closer to 42°–52° than 146°.

2.3.8. *Counts of Neighbor Galaxies*

The overall relationship between Markarian galaxies and their local environment has been discussed by Gisler (1978) and Petrosian & Turatto (1986a, 1986b) and studied in more detail for a subsample of Markarian AGNs (e.g., Petrosian 1982; Dahari 1985; MacKenty 1989, 1990; Laurikainen & Salo 1995; De Robertis et al. 1998) with some controversial results. In order to address some of these issues and deal with random projection effects in a statistical manner, we systematically counted the neighboring galaxies around each Markarian galaxy to build a homogeneous data set for analysis. These counts of neighboring galaxies were done for all Markarian objects that have determined redshifts $z > 0.005$ by projecting a circle of 50 kpc radius around each galaxy. All galaxies detected within this circle were counted if their angular sizes differed from that of the Markarian galaxy by no more than factor of 2 (e.g., Karachentsev 1972), and wherever redshifts were available, have a velocity difference within ± 800 km s^{-1} (e.g., Madore et al. 2004). The counts of neighbor galaxies were checked in the 50 kpc circles extracted from both the J_{pg}- and F_{pg}-band images. There were 77 Markarian objects closer than $z = 0.005$ that were not used because of the difficulty in reliably determining associated objects over a wider field of view as random projections become more dominant.

3. THE OPTICAL DATABASE

Table 1 contains observational data for the 1544 Markarian objects aligned in 15 columns, which are described below.

Column (*1*).—Markarian number as it appears in the original lists. For objects newly added to the database, we add an "a" or "b" letter designation (e.g., Mrk 799a and 799b). In all cases, the eastern galaxy or component is labeled "a," and the western galaxy or component with "b." There are three duplications in the lists. Mrk 107 is the same object as Mrk 20, Mrk 1318 is Mrk 49, and Mrk 890 is Mrk 503.

Columns (*2*) *and* (*3*).—Equatorial coordinates (equinox J2000.0).

Column (*4*).—The morphological description of the galaxy. The numerical coding used here for the morphological description of the galaxies is a slightly modified and simplified version of the morphological types T given in the RC3 catalog. The following codes were used: E = −5; E/S0 = −3; S0 = −2; S0/a = 0; Sa = 1; Sab = 2; Sb = 3; Sbc = 4; Sc = 5; Scd = 6; Sd = 7; Sdm = 8; Sm = 9; Im = 10; Im/BCD = 11; BCD/Im = 12; BCD = 13; Compact = 14; Interacting system or Merger = 15; and H II region = 16. A bar is marked by "B."

Column (*5*).—Spectral classification according to M+89. For newly added Markarian objects spectral classes are from descriptions of these objects in the original lists.

Column (*6*).—Activity class, when available, and description of the spectra according to M+89. The various Seyfert classes are denoted by the symbols "Sy1," "Sy1.5," "Sy1.8," "Sy1.9," and "Sy2." The symbol "Sy3" refers to LINERs. Starburst nuclei are indicated by "SB" and galaxies with Wolf-Rayet features in their spectra are indicated with the symbol "WR." QSOs, BL Lacertae objects, and Galactic stars (isolated or projected on the galaxies) are also identified. New determinations and revised AGN classes are included and described in the corresponding notes to the database.

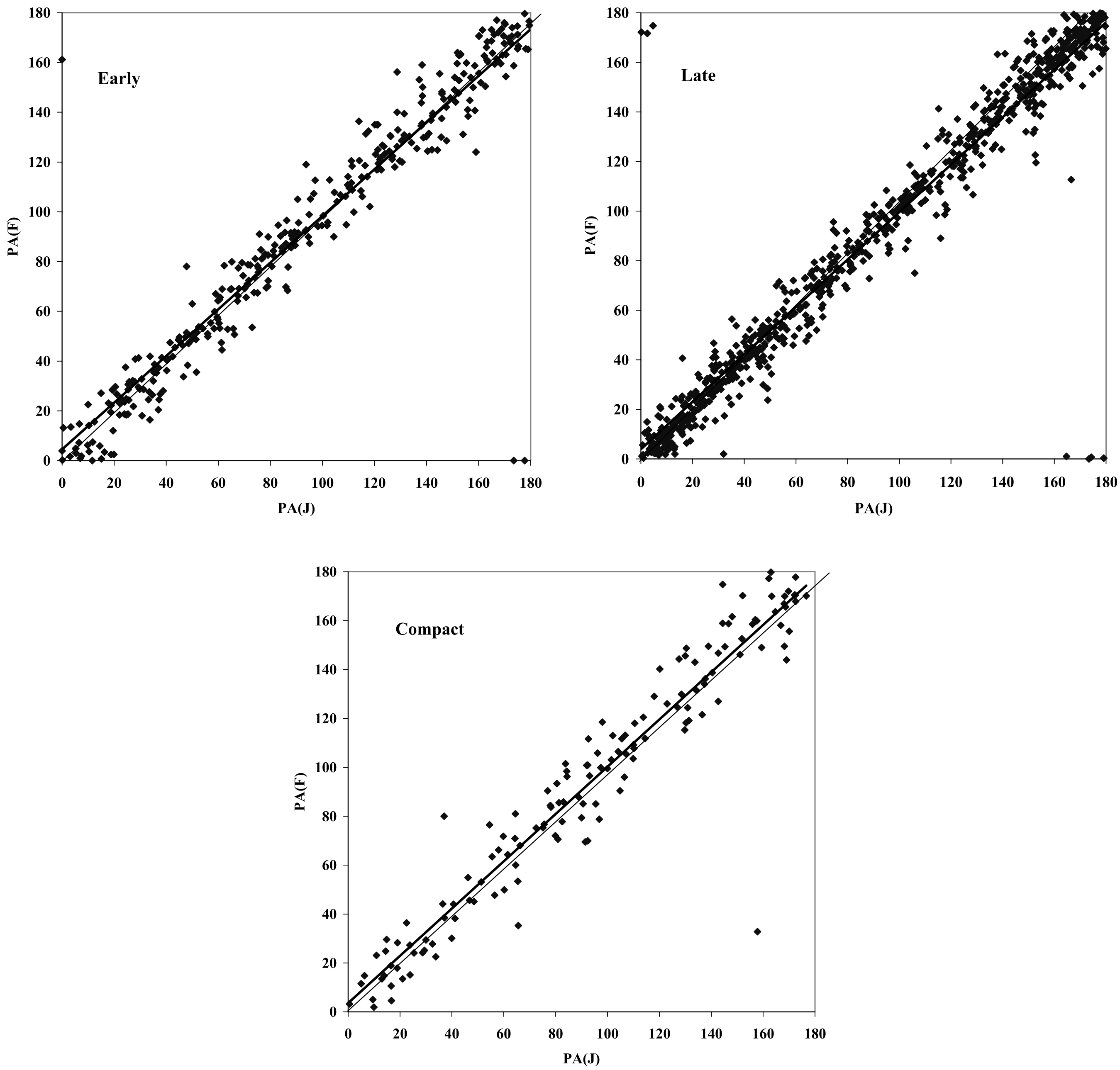


FIG. 10.—Comparison of the measured blue and red position angles for (*a*) early morphological type, (*b*) late morphological type, and (*c*) compact morphological type Markarian galaxies. The best linear fit and 1:1 lines are plotted.

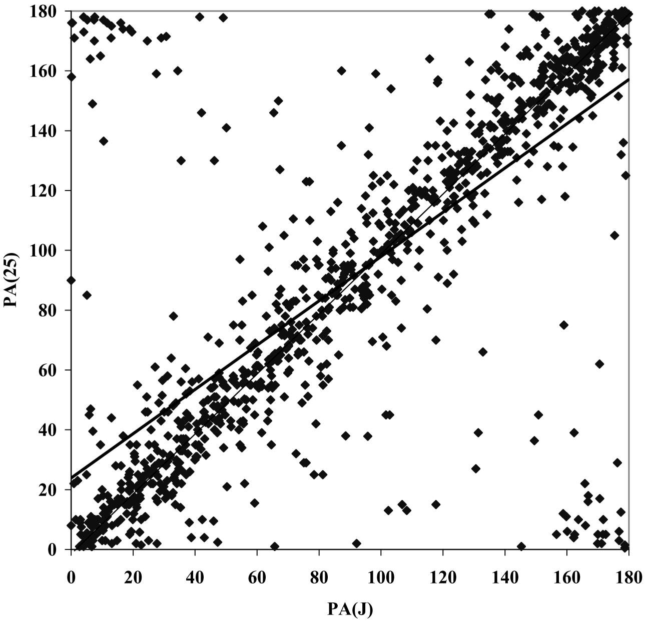


FIG. 11.—Comparison of the measured blue position angles with HYPERLEDA. The best linear fit and 1:1 lines are plotted.

Column (*7*).—Heliocentric redshifts when available. New determinations and revised redshifts are included and described in the corresponding notes to the database.

Column (*8*).—Major J_{pg} band diameter $D(J)$ in arcseconds.

Column (*9*).—Major F_{pg} band diameter $D(F)$ in arcseconds.

Column (*10*).—Axial ratio in J_{pg} band $R(J)$.

Column (*11*).—Axial ratio in F_{pg} band $R(F)$.

Column (*12*).—Apparent isophotal J_{pg} magnitude.

Column (*13*).—Apparent isophotal F_{pg} magnitude.

Column (*14*).—The $E(B-V)$ galactic color excess at the position of Markarian object from HYPERLEDA and calculated according to Schlegel et al. (1998) maps.

Column (*15*).—Position angle in J_{pg} band P.A.(J). It is measured from north (P.A. $= 0°$) toward east between $0°$ and $180°$. For round galaxies with axial ratio $R(J) = 1.00$ position angles were not measured.

Column (*16*).—Position angle in F_{pg} band P.A.(F). It is measured from north (P.A. $= 0°$) toward east between $0°$ and $180°$. For round galaxies with axial ratio $R(F) = 1.00$ position angles were not measured.

Column (*17*).—Number of galaxies (N) detected within a 50 kpc projected radius. The mark "nd" (no data) in this column relates to Markarian galaxies with redshifts smaller than 0.005 for which neighbor counts were not performed.

Columns (*18*)–(*20*).—We provide near-IR J, H, and K magnitudes for 1384 Markarian galaxies. For 1372 galaxies 2MASS (e.g., Jarrett et al. 2000) total J, H, and K magnitudes are listed. For 12 Markarian galaxies, 2MASS observations are absent and for these galaxies J or J and K magnitudes are from DENIS observations (Paturel et al. 2005). These 12 galaxies are Mrk 616, 902, 964, 981, 1059, 1154, 1188, 1256, 1309, 1382, 1394 and 1504.

Column (*21*).—Attached notes: "s" denotes galaxies with information about their isolation or membership in the pair, triplet, group, or cluster of galaxies; "a" denotes galaxies with new and revised AGN classification; and "z" denotes galaxies with new and revised radial velocities. All notes and references to notes are available in the machine-readable table.

The database Table 1, object notes, and references are provided separately at the end of the article. A statistical investigation of the data collected in the database is in progress, and results will be presented in forthcoming papers.

4. THE ATLAS

In Figure 12 of the article we show $2' \times 2'$ regions from the digitized QV or EJ images. Each plate shows 100 Markarian objects except for the last one, which shows those galaxies added by M+89 to the final version of the First Byurakan Survey catalog. The order within the plate is given by the Markarian number. The contrast of the images has been adjusted to provide the best subjective compromise between displaying the outer regions of the galaxies and preserving the structure of their inner regions. For completeness, Markarian objects identified as stars are retained in these plates.

Since we are particularly concerned about the connection between galaxy activity, star formation, and galaxy interactions, we pay special attention to the interacting and merging Markarian galaxies. Mergers and close interacting systems are distinguished as a separate class of objects according to the following definitions (Petrosian et al. 2002):

Merger.—Two or more galaxies are in a common envelope, or the object has double or multiple nuclei. For this class the nuclei have approximately similar brightness. Multiple nuclei are often connected with structural details (spiral arms, jets, tails, etc.). Some of these nuclei may be luminous H II regions that do not necessarily belong to a dynamically distinct in a merger. It is also possible that, similar to clumpy irregulars (e.g., Casini & Heidmann 1976), some objects classified as mergers are irregular galaxies with a large network of giant H II regions. More detailed imaging observations will be required in order to identify such objects and isolate the real mergers among the total listed.

Galaxies in interaction.—Two or more galaxies seen separately but apparently connected with tidal features (tails, bridges, loops, etc.). One or more galaxies in the interacting system can have a disturbed structure. Usually a Markarian galaxy is one component of an interacting system, but there are also cases when an entry in the Markarian catalog is the interacting system itself. Occasionally it is difficult to distinguish a merger from an interacting system, and merger and interacting systems can indeed be classified within the same scheme (e.g., Borne et al. 1999). Nevertheless, for many cases, it was possible to define a morphological class for each of the galaxy forming interacting system.

In Figure Set 13 we have created gray-scale representations and contour diagrams of the F_{pg}-band images of Markarian galaxies in interaction and merging systems. These images are presented in plates of two images each, comprising 210 Markarian galaxies. The contour levels are in arbitrary units. The lowest contour level was chosen at the about 3 σ level of the local background. The contour interval is constant, but different in each case; usually it is between 10%–30% of the local background. The interval was chosen in order to best illustrate both the inner and outer structure of the galaxy. In the same fashion field size (and thus magnification) was selected individually for each system to clearly illustrate its morphological structure.

In the Markarian survey, 5 galaxies were identified (Mrk 71, 94, 404, 1039 and 1315) that appear to be giant H II complexes within larger galaxies or even projected on satellites of the primary galaxy (e.g., Mrk 71 and 94). We add to this list another 6 Markarian galaxies (Mrk 59, 86b, 256b, 489b, 1236, and 1379a). Several studies have been carried out on these Markarian galaxies, but the focus has been on the primary galaxy and not the H II complex itself; this has introduced some confusion in the published data. To retain clarity in the database we list these cases separately as H II class objects and Figure 14 shows gray-scale

TABLE 1

Properties of Markarian Galaxies

Mrk (1)	R.A. (2)	Decl. (3)	Morph. (4)	SC (5)	AC (6)	Z (7)	$D''(J)$ (8)	$D''(F)$ (9)	$R(J)$ (10)	$R(F)$ (11)	$m(J)$ (12)	$m(F)$ (13)	$E(B-V)$ (14)	P.A.(J) (15)	P.A.(F) (16)	Nn (17)	J (18)	H (19)	K (20)	Notes (21)
1................	1 16 7.26	33 5 21.3	2	sd2e	Sy2	0.0159	40.8	43.9	0.68	0.6	15.2	13.6	0.06	68	70	1	12.27	11.61	11.17	s
2................	1 54 53.84	36 55 4.7	1 B	s2	SB	0.0188	47.94	43.9	0.87	0.86	13.9	13	0.081	171	177	1	11.7	10.95	10.64	s
3................	6 15 36.32	71 2 15.3	−2	ds2e	Sy2	0.0135	97.92	80.58	0.92	0.84	14.2	12.7	0.189	25	29	0	10.03	9.29	8.97	s
4................	6 27 59.78	74 18 6.7	5 B	sd2e:	SB	0.0177	104.04	98.9	0.43	0.39	14.6	13.3	0.119	17	22	0	11.42	10.76	10.41	s, z
5................	6 42 15.71	75 37 38.1	11	d1e	WR	0.0026	34.68	32.6	0.68	0.62	15.7	15	0.087	13	2	nd				
6................	6 52 11.99	74 25 38.2	0	s1e	Sy1.5	0.0185	55.08	53	0.61	0.58	14.8	13.4	0.136	130	129	0	11.08	10.22	9.56	s
7................	7 28 12.06	72 34 27.8	10	d2	e	0.0102	53.04	52	0.6	0.57	14.7	13.3	0.031	22	24	0	12.78	12.17	12.22	s
8................	7 29 25.41	72 7 44.7	10	d1	e	0.012	63.24	62.2	0.77	0.75	14.2	13.2	0.026	179	165	0	12.59	11.87	11.58	s
9................	7 36 56.99	58 46 13.5	1	s1e:	Sy1	0.0399	37.74	33.7	0.95	0.97	15.2	13.7	0.058	29	37	0	12.14	11.31	10.59	s
10..............	7 47 28.85	60 56 2.1	3	s1e:	Sy1	0.0293	110.16	92.8	0.43	0.44	13.6	13.1	0.047	123	120	0	11.36	10.74	10.35	s

Note.—Table 1 is available in its entirety in the electronic edition of the *Astrophysical Journal Supplement*. A portion is shown here for guidance regarding its form and content.

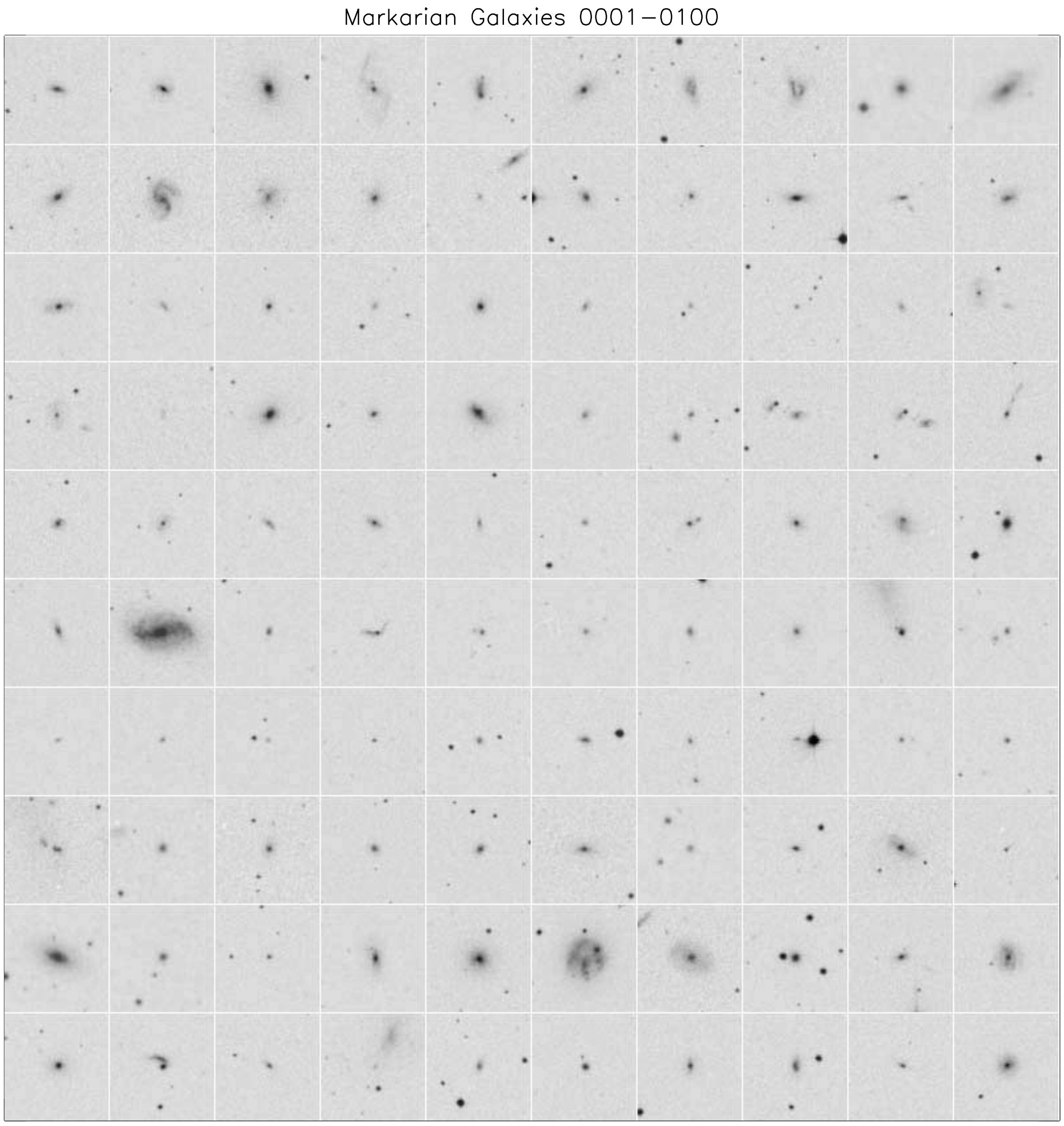


FIG. 12.—$2' \times 2'$ field QV or EJ images for all Markarian objects. North is up, and east is to the left. The order within the plate is given by Markarian galaxies number. The contrast of the images has been adjusted to provide the best subjective compromise between displaying the outer regions of the galaxies and preserving the structure of their inner regions. [*See the electronic edition of the Supplement for additional parts to this figure.*]

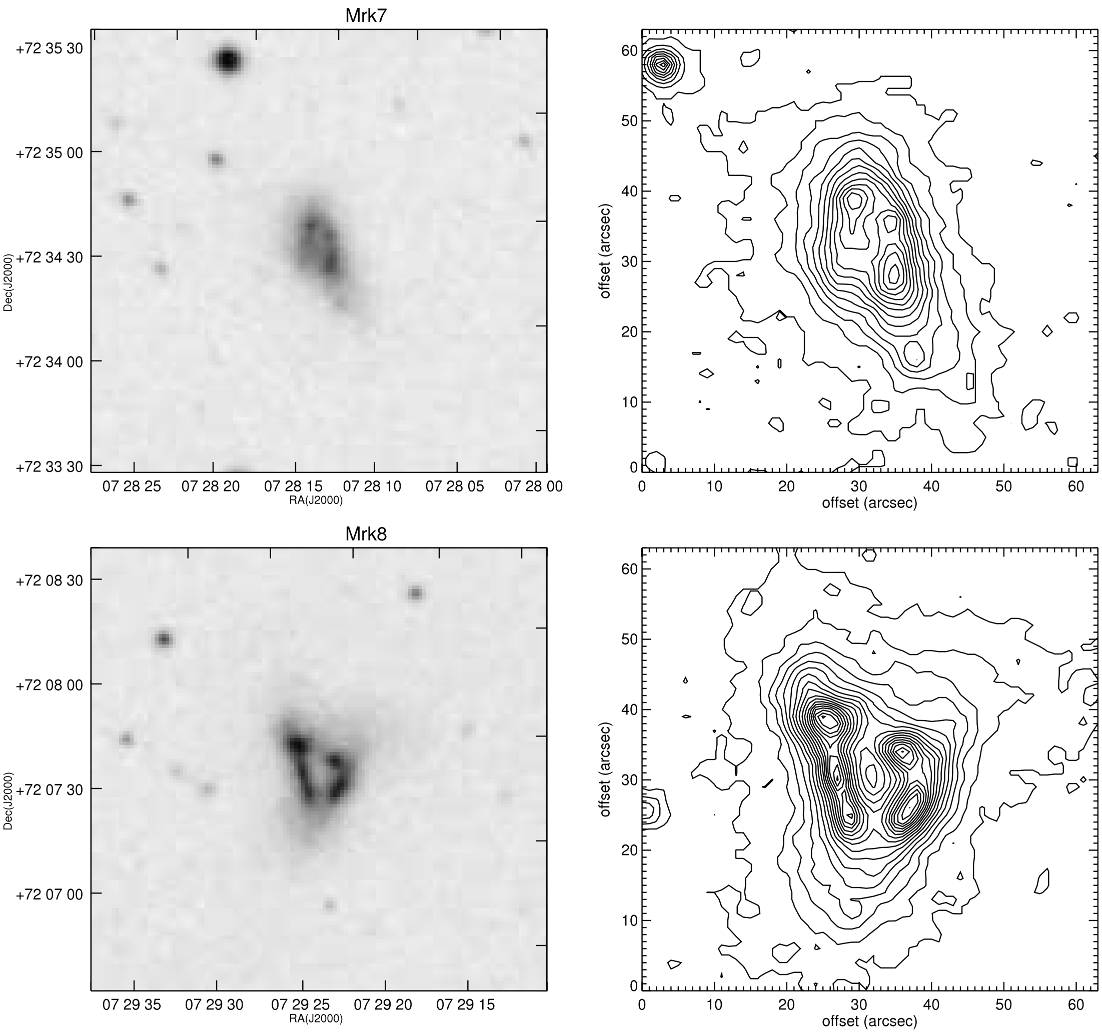


FIG. SET 13.—Gray-scale representations and contour diagrams of the *F*-band images of Markarian galaxies in interaction and merging systems. Contour levels and axis labels are as in Fig. 1. [*See the electronic edition of the Supplement for Figs. 13.2–13.105.*]

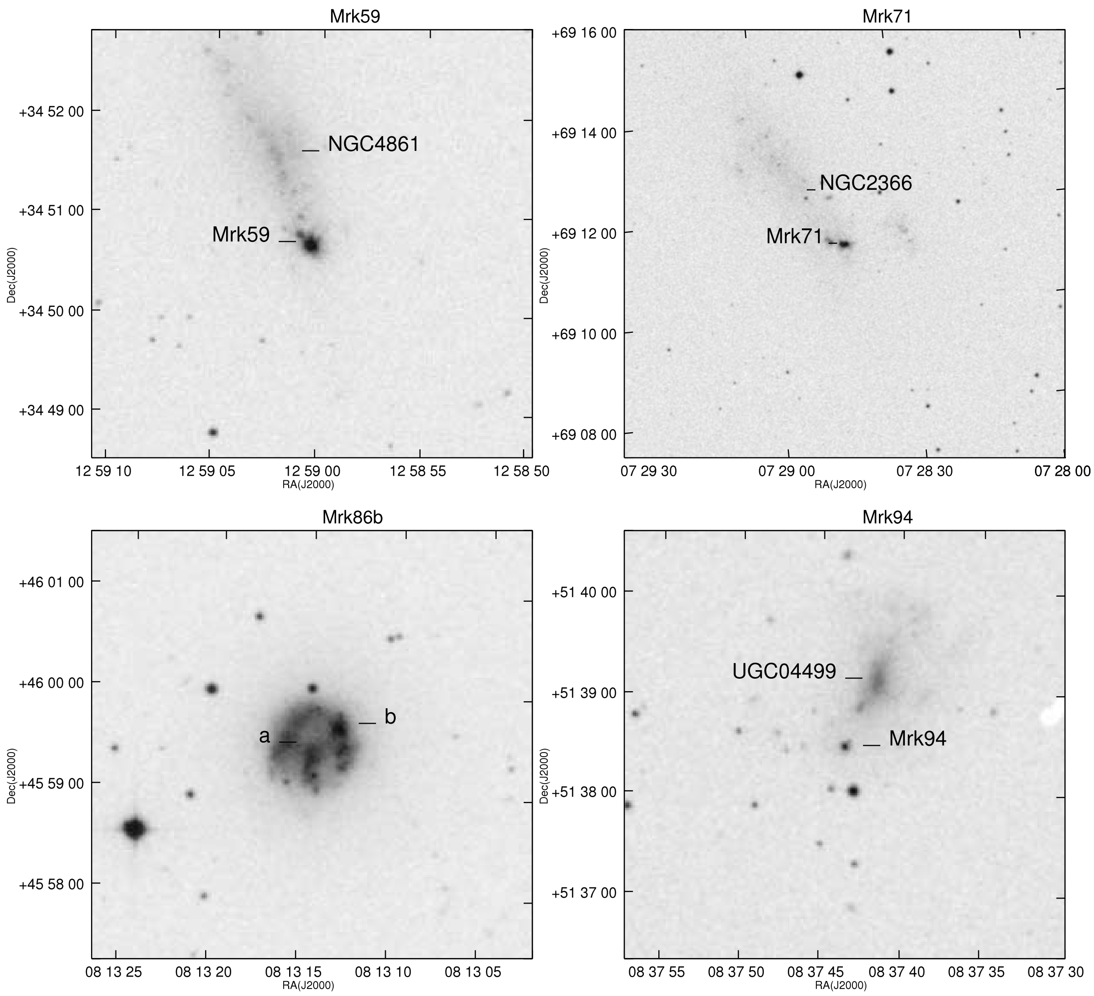


Fig. 14.—Gray-scale representations of the *F*-band images of Markarian objects, which are giant H II regions within larger galaxies or even projected on satellites of the primary galaxy.

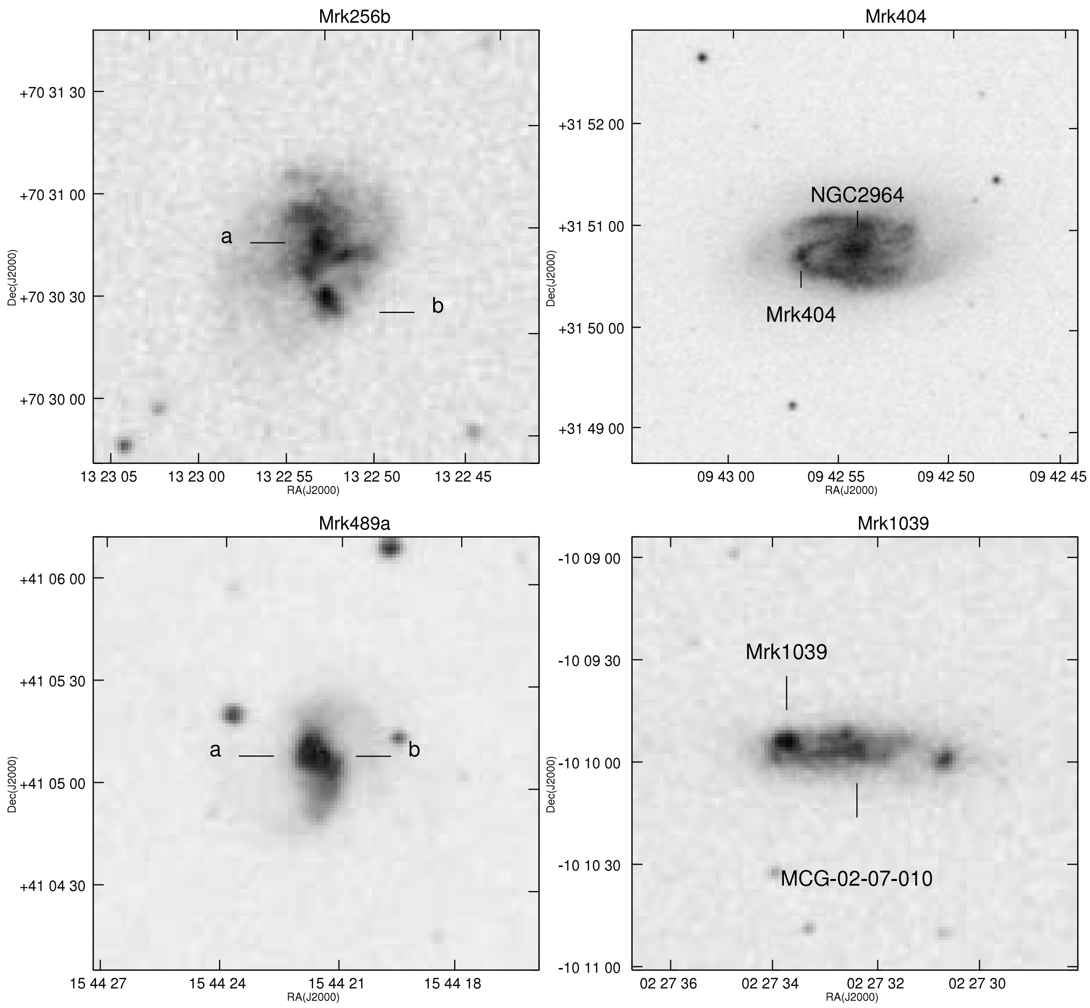


FIG. 14—*Continued*

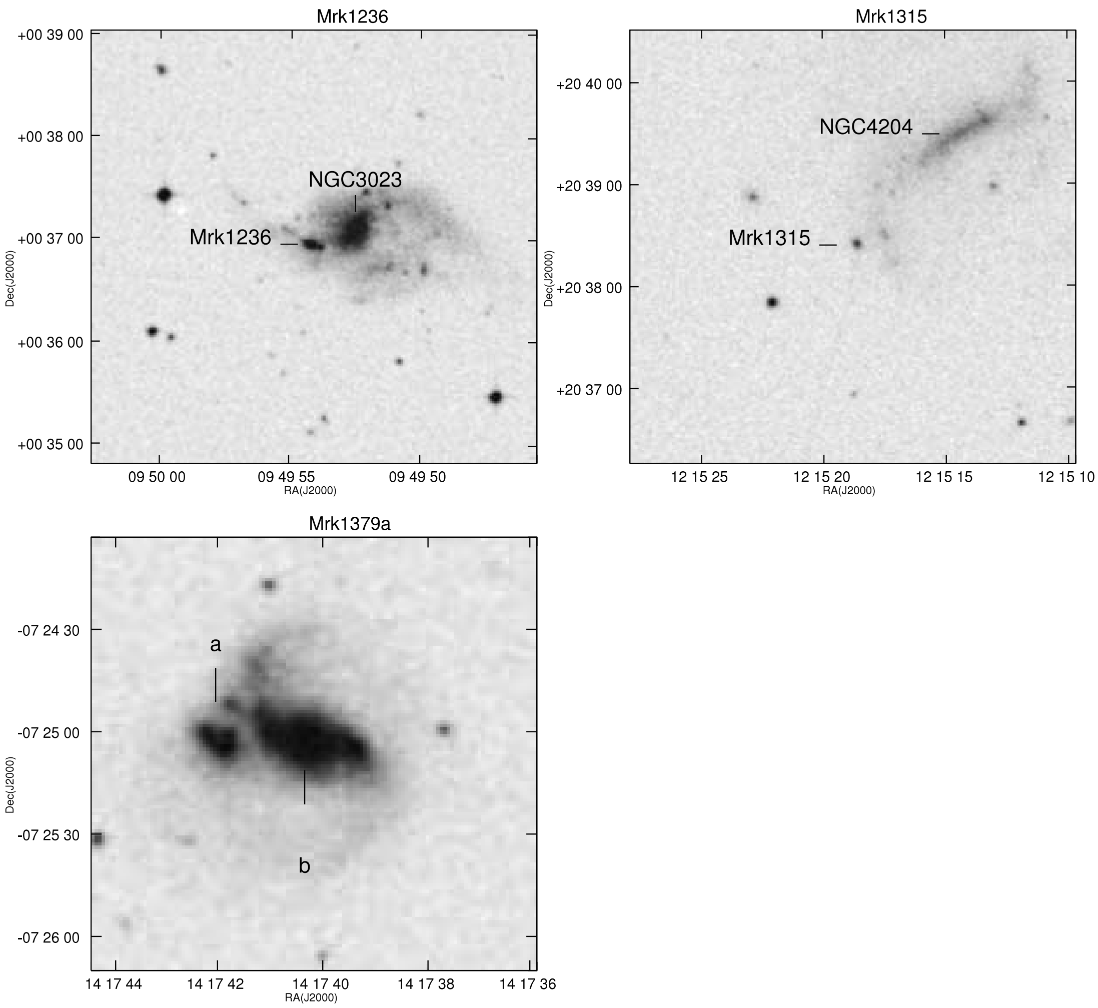


FIG. 14—*Continued*

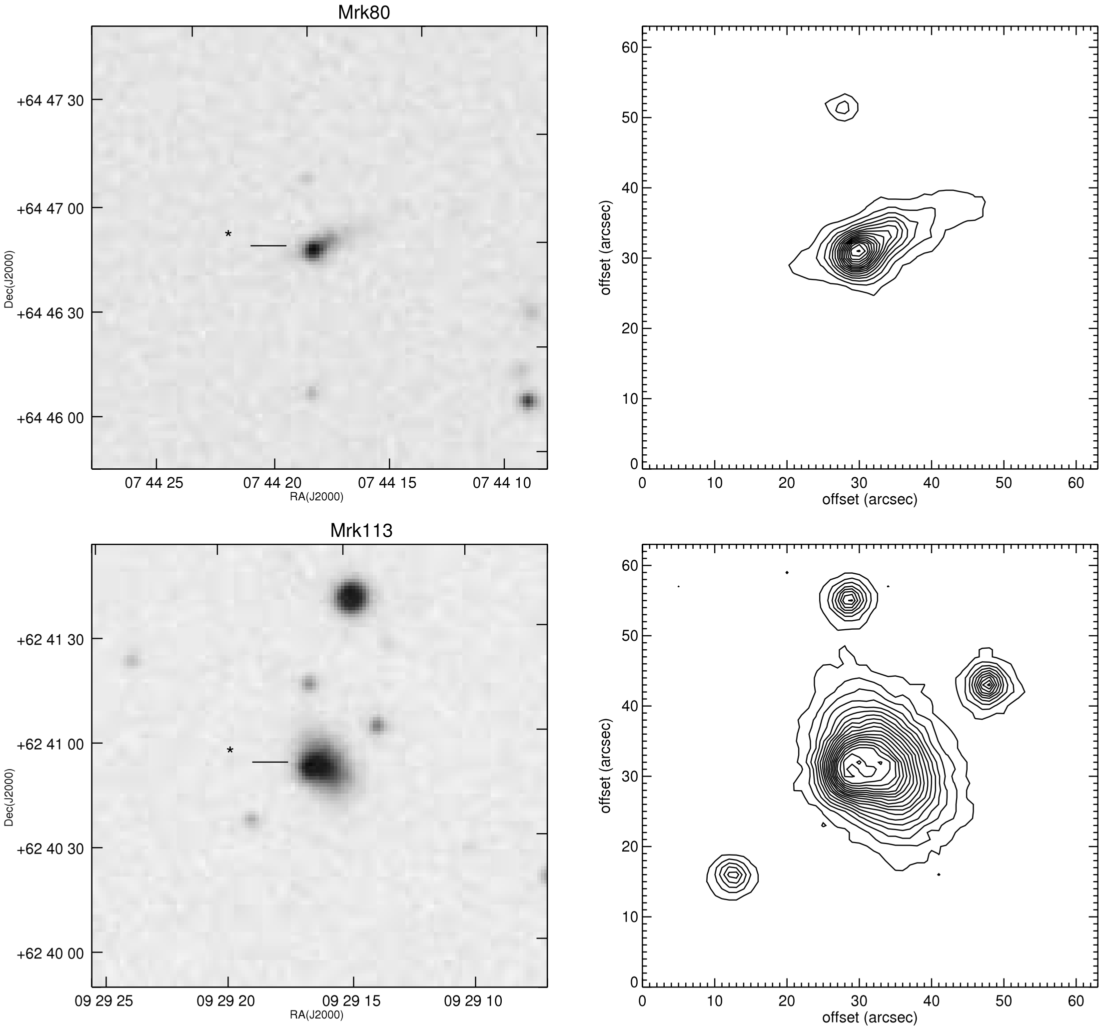


Fig. 15.—Gray-scale representations and contour diagrams of the *F*-band images of 20 Markarian galaxies that by spectral observations were classified as Galactic stars but obviously have diffuse structure and are UV galaxies with projected Galactic stars. Contour levels and axis labels are as in Figure 1. [*See the electronic edition of the Supplement for additional parts to this figure.*]

representations of the F_{pg}-band images of these 11 Markarian galaxies.

In M+89 it is reported that from the list of 1515 Markarian galaxies, 40 objects that are Galactic stars and Galactic star + galaxy projections were deleted. It is interesting that of 14 objects, which were classified and deleted by M+89 as Galactic star + galaxy projection cases, 9 have determined spectral classes that show existence of real or uncertain emission lines. These objects are located mainly at high Galactic latitudes ($|b^{\rm II}| \geq 20°$), and some of them in the original Markarian lists are described as galaxies, but not as compact star–like objects (e.g., Mrk 80, 227, 351, 861, 1217). One of these galaxies Mrk 227 was observed by SDSS, and according to SDSS DR3 it is a strong emission-line galaxy with redshift $z = 0.0961$. It is our opinion that this sample of Markarian galaxies is interesting by itself and needs more attention. The anonymous referee has postulated that some of these objects may be unresolved super-star clusters (SSCs). To stress the importance of this sample of Markarian galaxies, we do not delete them from the database and present them in Figure 15.

The authors thank the referee whose suggestions and remarks contributed significantly to improve the paper. A. R. P. acknowledges the hospitality of the Space Telescope Science Institute during his stay as visiting scientist supported by the Director's Discretionary Research Found. This research has made use of NASA/IPAC Extragalactic Database (NED), which is operated by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration and HYPERLEDA (Leon-Meudon Extragalactic Database). Two Micron All Sky Survey (2MASS), which is a joint project of the University of Massachusetts and the Infrared Processing and Analysis Center, funded by the National Aeronautics and Space Administration and the National Science Foundation. The Digitized Sky Survey was produced at the Space Telescope Science Institute under US Government grant NAG W-2166. The images of this survey are based on photographic data obtained using the Oschin Schmidt Telescope on Palomar Mountain and the UK Schmidt Telescope. The plates were processed into the present digital form with the permission of these institutions. The Second Palomar Observatory Sky Survey (POSS-II) was made by the California Institute of Technology with funds from the National Science Foundation, the National Aeronautics and Space Administration, the National Geographic Society, the Sloan Foundation, the Samuel Oschin Foundation, and the Eastman Kodak Corporation. The California Institute of technology and Palomar Observatory operate the Oschin Schmidt Telescope. Funding for the creation and distribution of the SDSS Archive has been provided by the Alfred P. Sloan Foundation, the Participating Institutions, the National Aeronautics and Space Administration, the National Science Foundation, the US Department of Energy, the Japanese Monbukagakusho, and the Max Planck Society. For image processing, both the IDL language (available from Research Systems, Inc.) and the ADHOC software (developed by Jacques Boulesteix, Marseille Observatory, France) were intensively used.

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