

A CATALOG OF VERY ISOLATED GALAXIES FROM THE SLOAN DIGITAL SKY SURVEY DATA RELEASE 1

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ABSTRACT

We present a new catalog of isolated galaxies obtained through an automated systematic search. These 2980 isolated galaxies were found in $\approx 2099 \text{ deg}^2$ of sky in the Sloan Digital Sky Survey Data Release 1 (SDSS DR1) photometry. The selection algorithm, implementing a variation on the criteria developed by Karachentseva in 1973, proved to be very efficient and fast. This catalog will be useful for studies of the general galaxy characteristics. Here we report on our results.

Key words: atlases — catalogs — surveys

Online material: machine-readable table

1. INTRODUCTION

Over the past few decades, observational and theoretical work has shown that truly isolated “field” galaxies, if they exist at all, are a rarity in the universe, comprising less than 5% of all galaxies (Adams et al. 1980). Rare though they may be, they serve as an important comparison sample in studies of the effects of environment on galaxy morphologies and star formation rates (e.g., Adams et al. 1980; Haynes & Giovanelli 1980; Haynes et al. 1984; Koopmann & Kenney 1998). Truly isolated galaxies, which may have experienced no major interactions in billions of years, can act as a zero point in these studies.

Furthermore, isolated galaxies are interesting in their own right. Recent studies of isolated galaxies include those by Aars (2002, 2003), who looked at the photometric and spectroscopic properties of extremely isolated elliptical galaxies in the Karachentseva (1973) catalog; Pisano et al. (2002) and Pisano & Wilcots (2003), who performed an H I survey for the gaseous remnants of the galaxy formation process around nearby ($\lesssim 30 h^{-1} \text{ Mpc}$) isolated galaxies they identified in the “Nearby Galaxies Catalog” of Tully (1988); Sauty et al. (2003), who measured the molecular gas mass of 99 isolated late-type galaxies in the Karachentseva (1973) catalog using observations of the $^{12}\text{CO}(1-0)$ line; Stocke et al. (2004), who measured the luminosity functions of isolated elliptical and S0 galaxies in the Karachentseva (1973) catalog; and Varela et al. (2004), who studied the properties of disk galaxies in a catalog of isolated galaxies that they extracted from a volume-limited sample of the CfA Redshift Survey (Huchra et al. 2000).

A simple method of identifying isolated galaxy candidates was described by Karachentseva (1973). She selected all galaxies in the Catalog of Galaxies and Clusters of Galaxies (Zwicky et al. 1968; Zwicky catalog) whose nearest neighbors, of size within a factor of 4 of the same diameter, lie farther than 20 diameters away. Then she compiled her catalog from work

with prints of the Palomar Sky Survey. The original catalog contains 1052 candidate isolated galaxies, which was later reduced to 893 galaxies (Karachentseva 1980). She also showed that a significant number of the final catalog members are located in regions of low density in the periphery of superclusters. (Note that Leon & Verdes-Montenegro [2003] have recently updated the Karachentseva [1973] catalog with improved galaxy positions.)

Turner & Gott (1975) suggested an interesting prescription for isolating the classical uniform field population of galaxies in the Zwicky catalog. They placed galaxies brighter than 14th magnitude in two classes, the associated (A), which have at least one neighbor brighter than $m = 14$ within $45'$, and the single (S), which have none. The S galaxies, 43% of the sample, appear to be uniformly distributed across the sky, as expected for field galaxies. Later, Huchra & Thuan (1977) determined that only 12 of 1088 S galaxies ($\approx 1\%$) of the Turner & Gott sample can be considered as truly isolated. Turner & Gott S galaxies appeared to be single because the 14th magnitude cut-off misses fainter companions and the angular separation criterion of $45'$ mistakes members of nearby groups of galaxies with large angular extent for singles.

These earlier efforts at identifying homogeneous samples of isolated galaxies were magnitude limited to $B < 15$. The Sloan Digital Sky Survey (SDSS; York et al. 2000), which will eventually cover up to one-quarter of the sky with uniform photometry in five filters down to $g \approx 22$, provides an obvious hunting ground for isolated galaxies to much greater depths and volumes. Using a modified version of Karachentseva’s isolation criteria, we have extracted such an objectively defined catalog of isolated galaxies from the photometric catalog of the SDSS Data Release 1 (DR1; Abazajian et al. 2003). We present this catalog as follows. In § 2 we describe the region of the sky used for this preliminary search. In § 3 we describe the catalog construction techniques, and we present the catalog in § 4. In § 5 we conclude and describe our future plans.

2. THE DATA

The SDSS is a digital photometric and spectroscopic survey that will, when completed, cover one π steradian of the celestial sphere in the northern Galactic hemisphere and an additional 225 deg^2 in the southern Galactic hemisphere. The photometric mosaic camera (Gunn et al. 1998) images the sky by scanning

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TABLE 1
THE SLOAN DIGITAL SKY SURVEY DATA RELEASE 1 ISOLATED GALAXIES

ID (1)	SDSS ID (2)	g (3)	$A(g)$ (4)	Radius g (arcsec) (5)	z (6)	CI (7)
1.....	SDSS J000015.73-085327.92	16.639	0.145	6.256	0.055887	2.861
2.....	SDSS J000044.14+004022.80	16.203	0.106	6.823	0.062586	2.654
3.....	SDSS J000047.12-104809.00	16.879	0.133	5.913	0.061544	2.258
4.....	SDSS J000052.08-103512.84	17.187	0.140	8.356	0.062488	2.336
5.....	SDSS J000104.91-090915.55	16.448	0.141	9.741	0.055826	2.608

NOTE.—Table 1 is published in its entirety in the electronic edition of the *Astronomical Journal*. A portion is shown here for guidance regarding its form and content.

along great circles at the sidereal rate. The imaging data are produced simultaneously in five photometric bands (u , g , r , i , and z , with effective wavelength bands of 3551, 4770, 6231, 7625, and 9134 Å, respectively; see Fukugita et al. 1996) under photometric conditions (Hogg et al. 2001), and is targeting 10^6 objects for spectroscopy (Blanton et al. 2003), most of which are galaxies with r -band magnitude < 17.77 (Strauss et al. 2002).

The SDSS data are reduced by highly automated photometric and spectroscopic reduction pipelines (see Stoughton et al. 2002). The astrometric calibration is automatically performed by a pipeline that obtains absolute positions to better than $0''.1$ (Pier et al. 2003), sources are identified, deblended, and photometrically measured (Lupton et al. 2002), and then the magnitudes are calibrated to a standard star network approximately in the AB system (Smith et al. 2002). After selecting the targets for spectroscopy (Eisenstein et al. 2001; Strauss et al. 2002; Richards et al. 2002), spectroscopic fibers are placed (Blanton et al. 2003) and spectroscopic data reduction is automatically performed to measure redshift.

On 2003 April 17, the SDSS team made public their DR1 (Abazajian et al. 2003) to the astronomical community. SDSS DR1 covers ≈ 2099 deg² of five-band imaging data of the sky and includes spectra, with derived spectroscopic parameters, for 22,108 stars, 133,996 galaxies, and 18,678 quasars.⁶

We used all objects classified as galaxies by the SDSS imaging reduction software (PHOTO; Lupton et al. 2002) from the SDSS public database as our base catalog from whence we extracted our catalog of isolated galaxies.

3. SELECTION CRITERIA

We have developed a systematic search criterion for isolated galaxies in SDSS DR1. We have made use of a computer code embodying a slightly modified version of the Karachentseva (1973) criteria. Under these criteria, a galaxy i with angular diameter a_i is considered isolated if the projected sky separation $x_{i,j}$ between this galaxy and any neighboring galaxy j of angular diameter a_j satisfies the following two relations:

$$x_{i,j} \geq 20a_j, \quad (1)$$

$$\frac{1}{4}a_j \leq a_i \leq 4a_j. \quad (2)$$

As noted above, we selected for our base catalog all SDSS DR1 objects that were classified as galaxies by PHOTO; we imposed the additional requirement that these objects have g -band Petrosian magnitudes $g > 0$ and Petrosian radii $R > 0$.

Under our modified Karachentseva criteria, a galaxy i with a g -band magnitude g_i and g -band Petrosian radius R_i is considered to be isolated if the projected sky separation between this galaxy and any neighboring galaxy j satisfies

$$x_{i,j} \geq 40R_j, \quad (3)$$

$$|g_i - g_j| > 3.0. \quad (4)$$

Note that a magnitude difference of 3 is about a factor of 16 in brightness; thus, equation (4) roughly approximates equation (2) for a galaxy with a flat surface brightness profile.

We considered only candidate isolated galaxies in the g -band magnitude limit (after correcting for Galactic extinction using the dust distribution estimated by Schlegel et al. 1998) of $16.0 \leq g_i \leq 21.0$. (As we show in § 4.3, our selection criteria effectively reduce this magnitude range to $16.0 \leq g_i \lesssim 19$.) Using these modified criteria, we found a total of 3813 candidates in 2099 deg². To remove spurious objects due to poor image deblending, one of us (S. S. A.) inspected all candidates by eye. She also used SExtractor (Bertin & Arnouts 1996) on the g -band SDSS FITS images to double-check galaxy identification. We removed 923 candidates because they were bright stars misidentified as galaxies (320), part of a bright galaxy (50), a diffraction spike from a nearby bright star (417), and finally 136 were found to be diffuse light. After all rejections and verifications, the final number of candidate isolated galaxies left for inclusion in this catalog was 2980, or ≈ 1.4 deg⁻².

We note that Prada et al. (2003) have also extracted isolated galaxies from the SDSS. In their case, however, they used the SDSS spectroscopic sample of galaxies, which is mostly restricted to magnitudes $r < 17.77$. Using the velocities of small satellite galaxies surrounding the isolated SDSS galaxies, they were able to measure the dark matter profile for relatively unperturbed galaxies. Our sample is complementary to theirs, in that our sample goes fainter and our isolation criteria is somewhat more restrictive. Also, since our criteria closely mimic those of Karachentseva (1973), our sample has a close connection with previous studies of isolated galaxies.

4. CATALOG

In Table 1 we list the general properties of the 2980 isolated galaxies: Column (1), a running identification number; column (2), galaxy name (following the IAU-designated SDSS naming convention); column (3), the g -band Petrosian magnitude corrected for Galactic extinction; column (4), the reddening in the g band as estimated from the Schlegel et al. (1998) reddening maps; column (5), the g -band Petrosian radius; column (6), the galaxy redshift (when available); and column (7), the concentration index. In Table 2 we summarize the mean and median

⁶ For more details see the online documentation at <http://www.sdss.org/dr1>.

TABLE 2
SLOAN DIGITAL SKY SURVEY DATA RELEASE 1 ISOLATED
GALAXY MEAN PROPERTIES

Property	Mean	Median
u	18.359 ± 0.0146	18.262
g	16.938 ± 0.0115	16.869
r	16.327 ± 0.0129	16.245
i	15.996 ± 0.0133	15.910
z	15.821 ± 0.0144	15.722
$u - g$	1.393 ± 0.007	1.346
$g - r$	0.613 ± 0.005	0.634
$r - i$	0.331 ± 0.003	0.352
$i - z$	0.176 ± 0.004	0.211
$R_{\text{Petro}}u$	9.072 ± 0.176	6.746
$R_{\text{Petro}}g$	7.933 ± 0.062	7.344
$R_{\text{Petro}}r$	7.811 ± 0.069	7.048
$R_{\text{Petro}}i$	7.516 ± 0.063	6.878
$R_{\text{Petro}}z$	7.359 ± 0.073	6.613
CI.....	2.528 ± 0.008	2.471
Redshift (1886).....	0.064237 ± 0.00071	0.0615
M_g (1886).....	-19.418 ± 0.0315	-19.675
M_r (1886).....	-19.984 ± 0.0322	-20.251
$M_u - M_g$ (1886).....	1.249 ± 0.0071	1.228
$M_g - M_r$ (1886).....	0.566 ± 0.0040	0.583
$M_r - M_i$ (1886).....	0.276 ± 0.0035	0.294
$M_i - M_z$ (1886).....	0.217 ± 0.0038	0.233

properties of the isolated sample. We also plot the distribution of apparent magnitudes, apparent colors, and Petrosian radii in Figures 1, 2, and 3, respectively.

Figure 4 presents the (apparent) $u - g$ versus $g - r$, the $g - r$ versus $r - i$, and the $r - i$ versus $i - z$ color-color diagrams for all galaxies classified as isolated by our criteria. The color distributions compare well with those of the analysis by Shimasaku et al. (2001) of bright SDSS galaxies (see their Fig. 7) and those of the galaxy number count analysis of the SDSS by Yasuda et al. (2001; their Fig. 2).

In Figure 5 we show a polar view of the 1886 isolated galaxies sample with spectroscopic redshift (*red dots*) and for comparison plotted all the SDSS DR1 galaxies with redshift information. The mean redshift for our sample is $z_{\text{mean}} = 0.0642$, which corresponds to a comoving distance of $\approx 190 h^{-1}$ Mpc, and the maximum redshift $z_{\text{max}} = 0.2374$, which corresponds to a comoving distance of $669 h^{-1}$ Mpc for an ($\Omega_M = 0.3, \Omega_\Lambda = 0.7$) cosmology.

We calculated the absolute magnitudes and colors for the 1886 isolated galaxies with spectroscopic redshifts by assuming a flat cosmological model with $\Omega_M = 0.3, \Omega_\Lambda = 0.7$, and $H_0 = 100 h \text{ km s}^{-1} \text{ Mpc}^{-1}$ and by applying k -corrections to the dereddened galaxy magnitudes by means of the publicly available KCORRECT (ver. 1.10) code of Blanton et al. (2003), where the luminosity distances were estimated using the analytical relation of Pen (1999). We plotted the absolute $M_g - M_r$

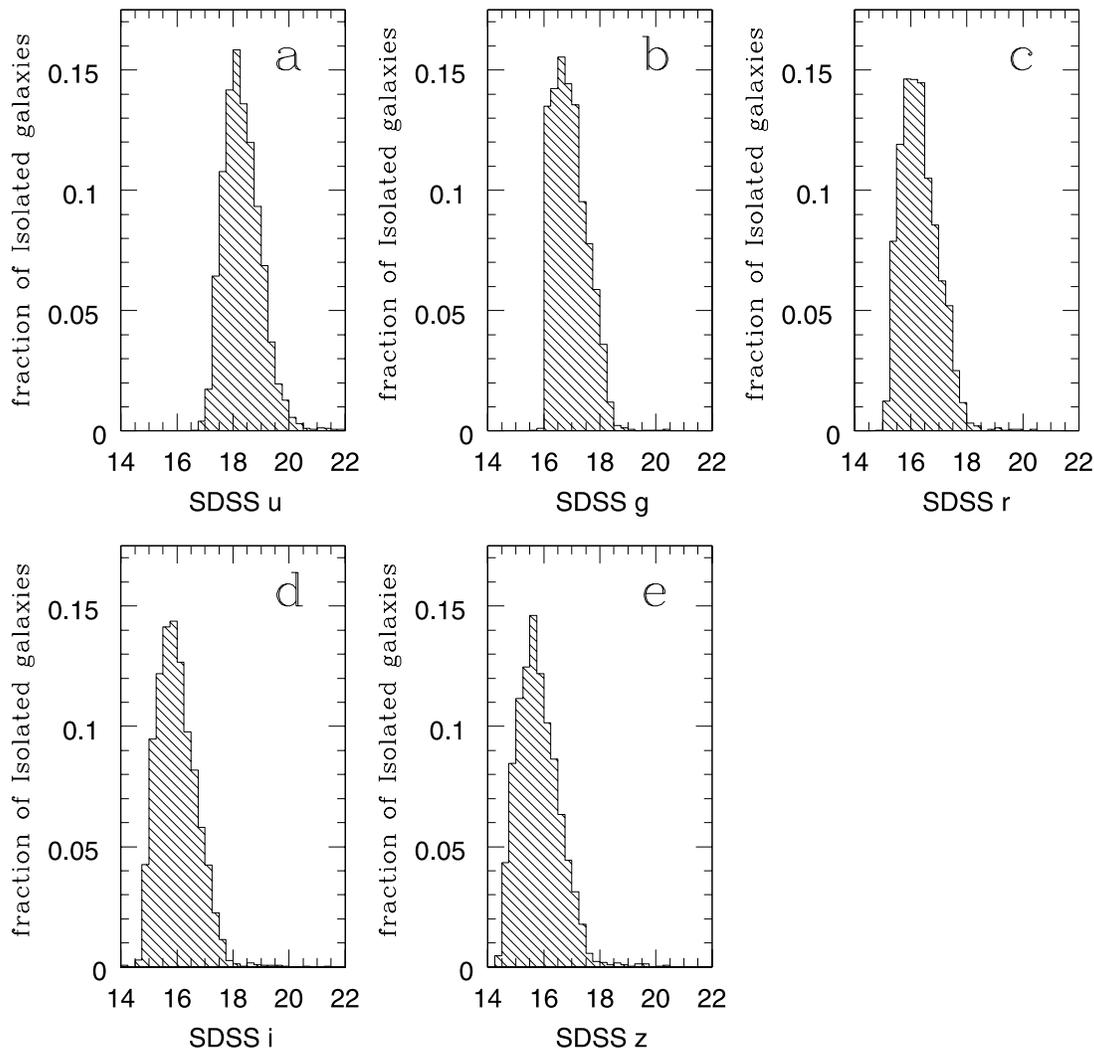


FIG. 1.—Distributions of the apparent magnitudes of the SDSS DR1 isolated galaxy sample in the five SDSS filters. Magnitudes are corrected for Galactic extinction.

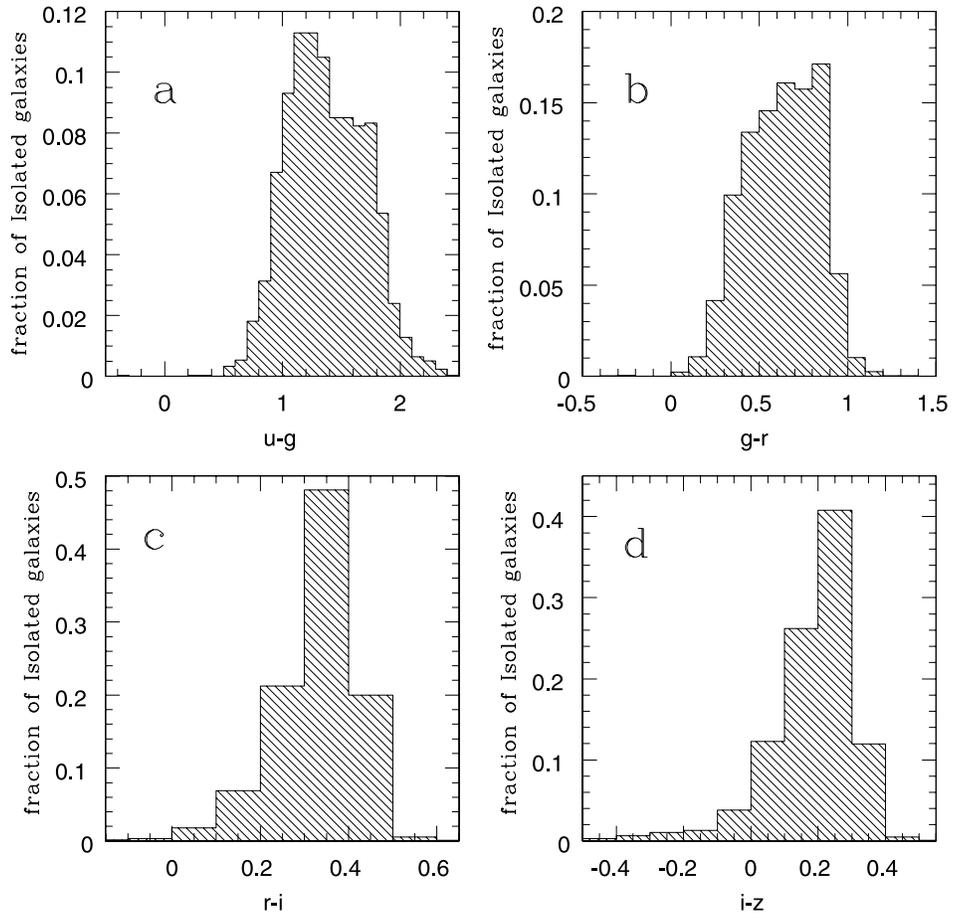


FIG. 2.—Distributions of the apparent colors of the SDSS DR1 isolated galaxy sample for $u-g$, $g-r$, $r-i$, and $i-z$. Colors are corrected for Galactic extinction.

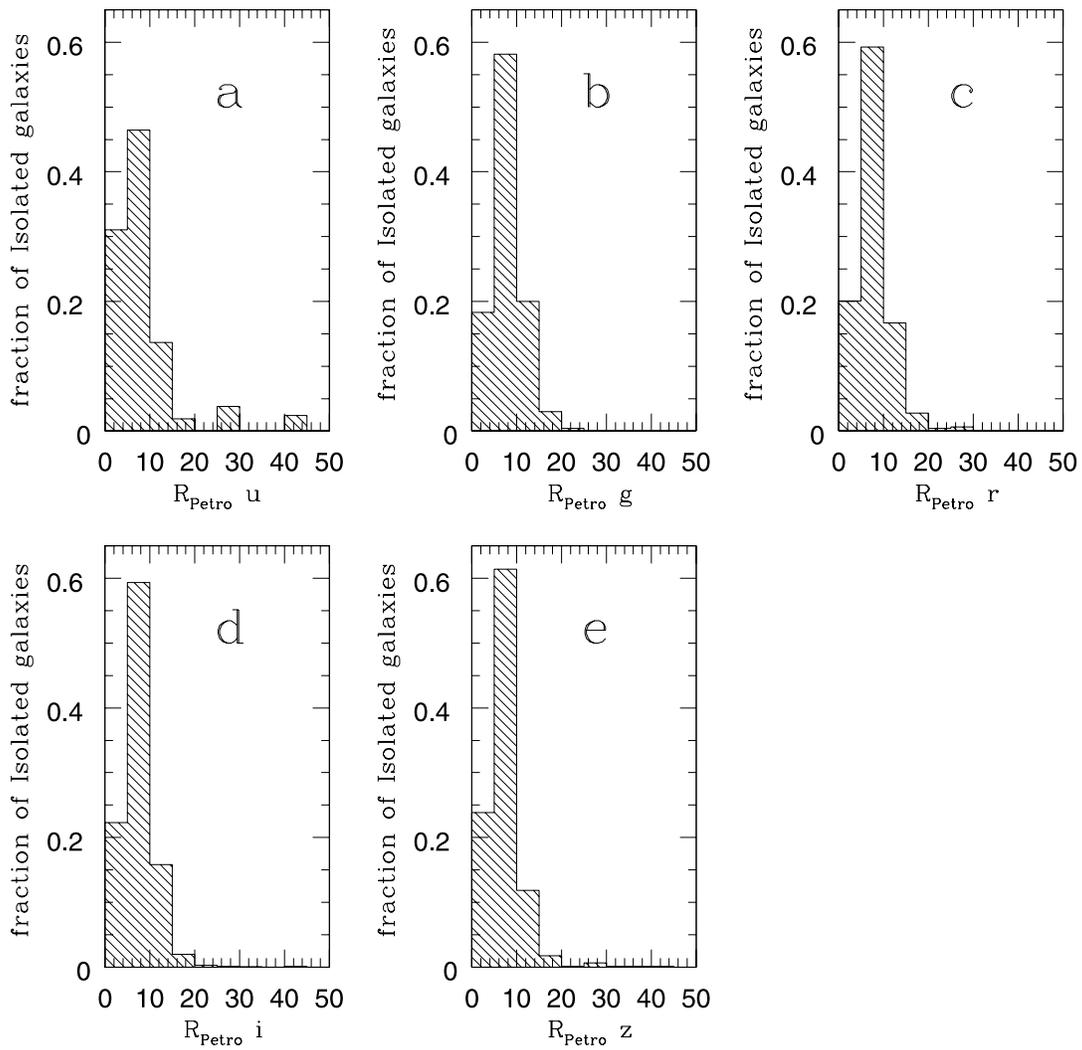


FIG. 3.—Distribution of the Petrosian radii of the SDSS DR1 isolated galaxy sample in the five SDSS filters.

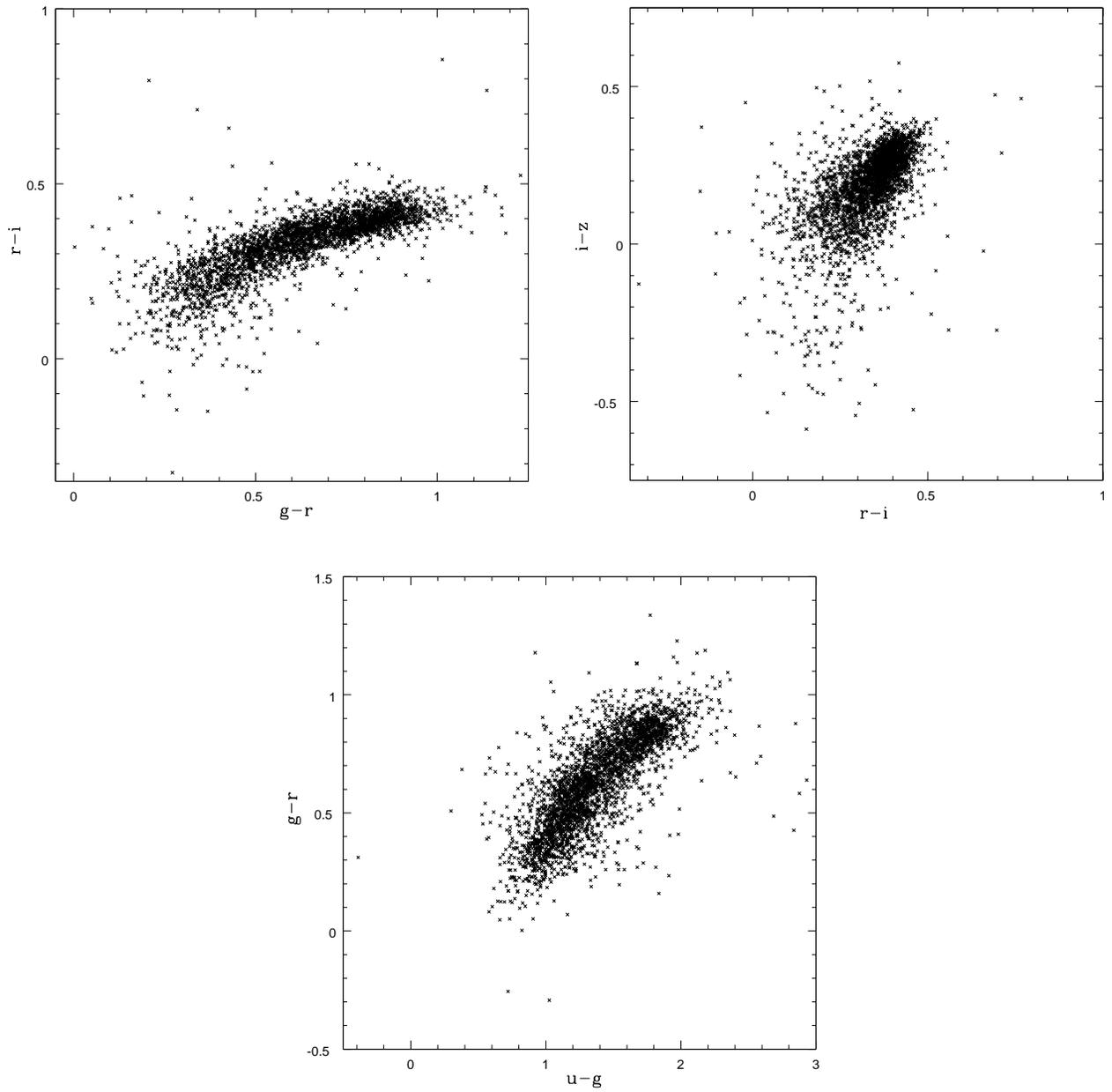


FIG. 4.—The (apparent) color-color diagrams for the SDSS DR1 isolated galaxy sample.

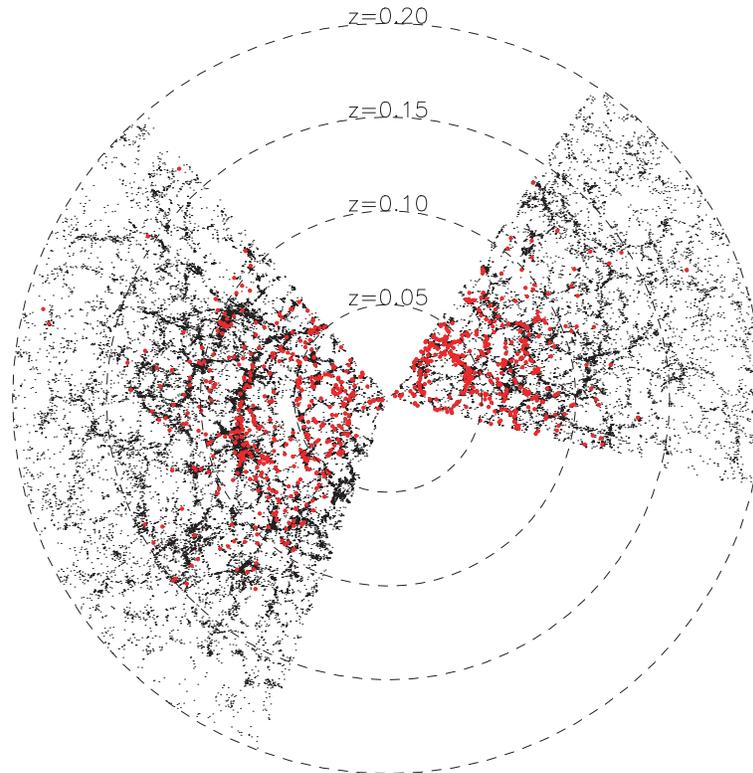


FIG. 5.—Redshift-R.A. wedge plot of the sample of all SDSS DR1 galaxies with redshift (*black dots*) and of the sample of isolated galaxies that have redshifts (*red dots*).

color versus spectroscopic redshift for the galaxies (Fig. 6). In Figures 7–9, we plot rest-frame color-magnitude and color-color diagrams for these isolated galaxies.

4.1. Concentration Index

The concentration index (CI) is defined by the ratio of the two r -band Petrosian radii, $CI \equiv r_{90}/r_{50}$, where r_{90} and r_{50}

correspond to the radii at which the integrated fluxes are equal to 90% and 50% of the r -band Petrosian flux, respectively. Shimasaku et al. (2001) report that this CI parameter shows the strongest correlation with visually classified morphology among simple photometrically defined parameters. Spiral galaxies are usually found to have small CI (≤ 2.5), whereas elliptical galaxies have higher CI (> 2.5). We thus separate morphologies into early and late types, depending on whether $CI \leq 2.5$ or $CI > 2.5$, respectively, which corresponds to the division at S0/a. In Figure 10 we show the distribution of CIs for isolated galaxies. We find our sample of isolated galaxies to contain 1414 ± 38 (47%) late-type spiral galaxies and 1566 ± 40 (53%) early-type galaxies. (Error bars are based on $N^{1/2}$ statistics.) Note that late-type spiral galaxies only marginally outnumber early-type galaxies in our sample.

4.2. The Atlas

Because of the large number of galaxies in our catalog, we do not provide a hardcopy atlas. Instead, we have prepared an online color atlas from the SDSS DR1 located at our public URL.⁷

4.3. Completeness

As is typical for isolated galaxy catalogs based on observed angular sizes and distances between galaxies, our catalog—like that of Karachentseva (1973)—is more representative than it is complete, owing to the unintended exclusion of galaxies that would have otherwise met the isolation criteria but contained a foreground/background galaxy within its isolation radius (Karachentseva 1980; Sauty et al. 2003; Stocke et al. 2004).

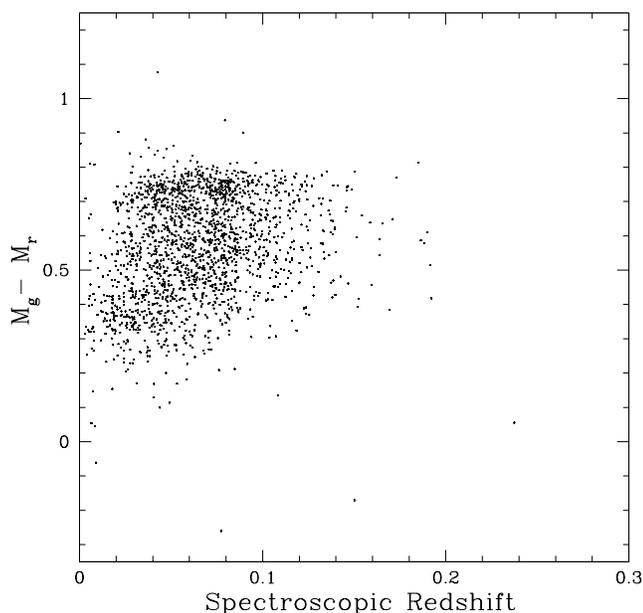


FIG. 6.—The k -corrected absolute $g-r$ colors for those isolated galaxies with a spectroscopic redshift as a function of redshift. The colors have also been corrected for Galactic reddening from the Milky Way.

⁷ See <http://home.fnal.gov/~sallam/ISOLATED>.

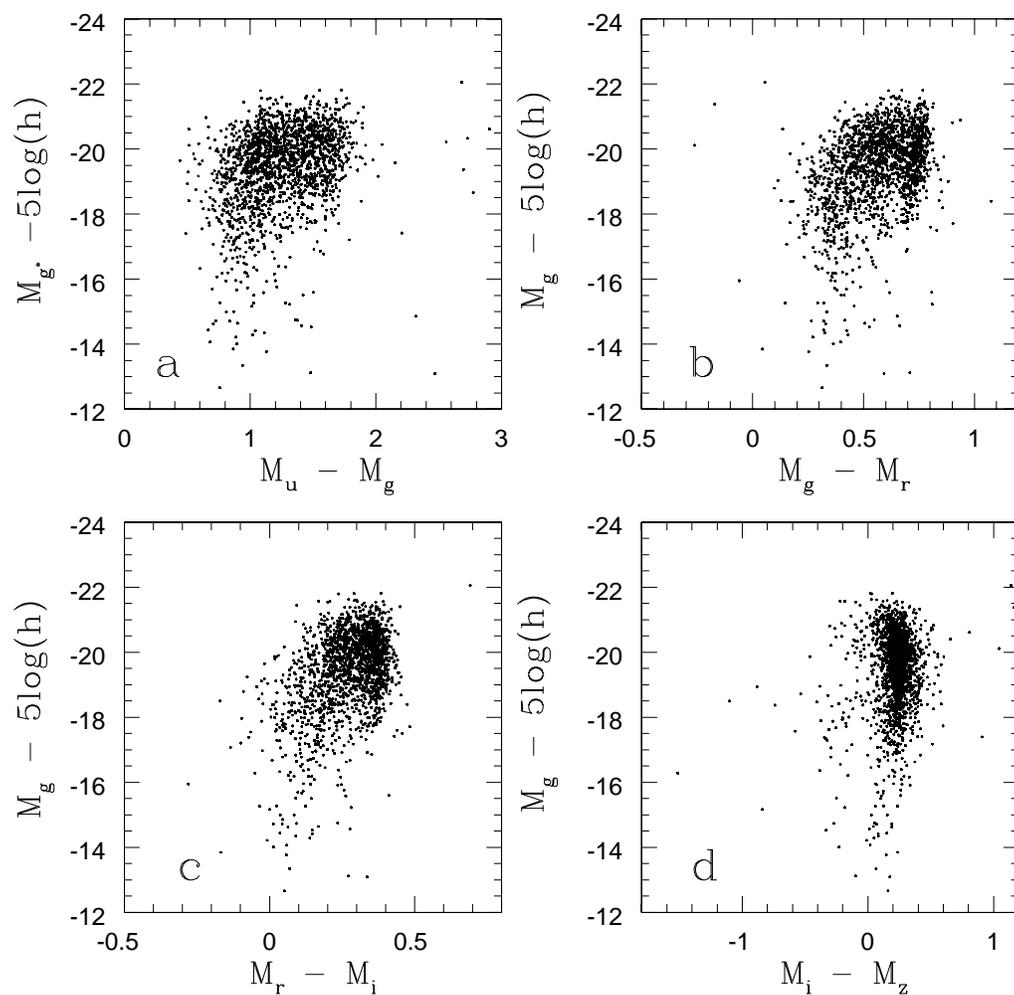


FIG. 7.—Absolute color-magnitude diagrams for the g band for those isolated galaxies with a redshift. Colors and g magnitudes have been k -corrected and reddening corrected.

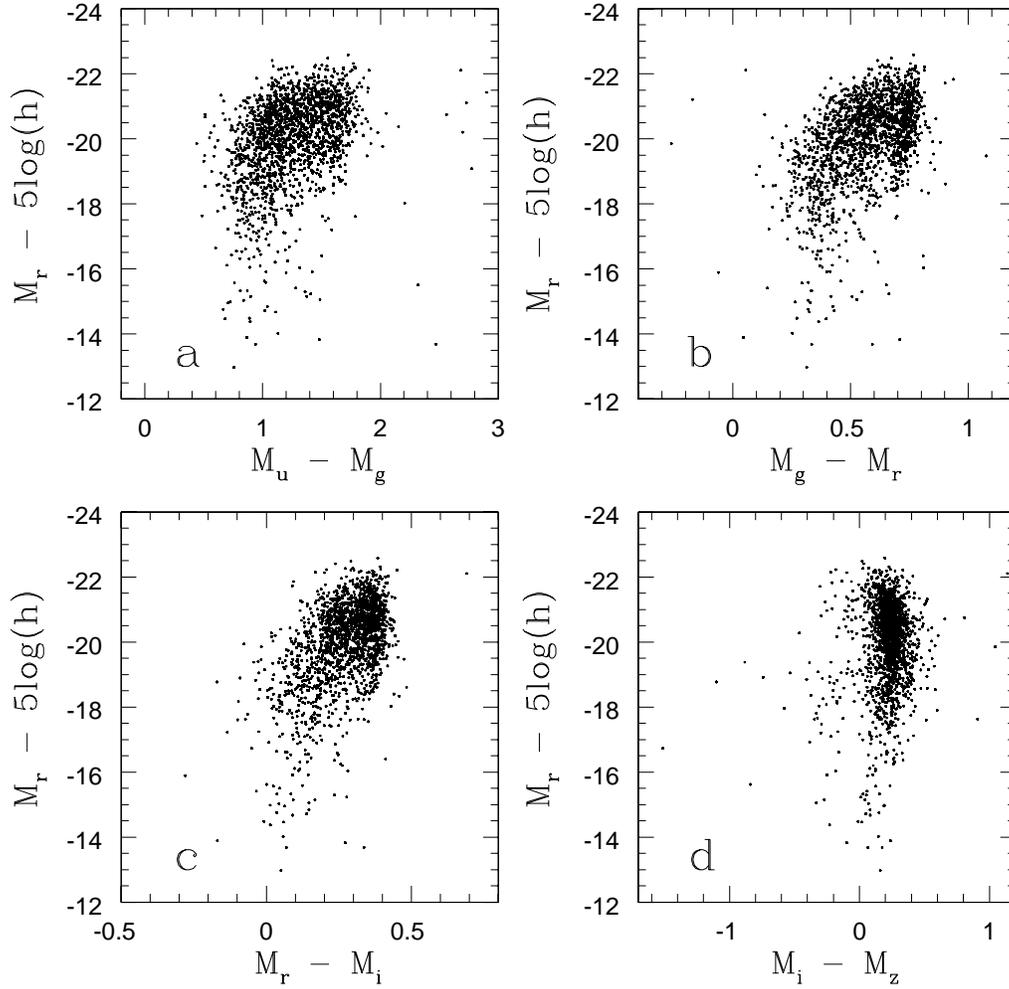


FIG. 8.—Absolute color-magnitude diagrams for the r band for those isolated galaxies with a redshift. Colors and r magnitudes have been k -corrected and reddening corrected.

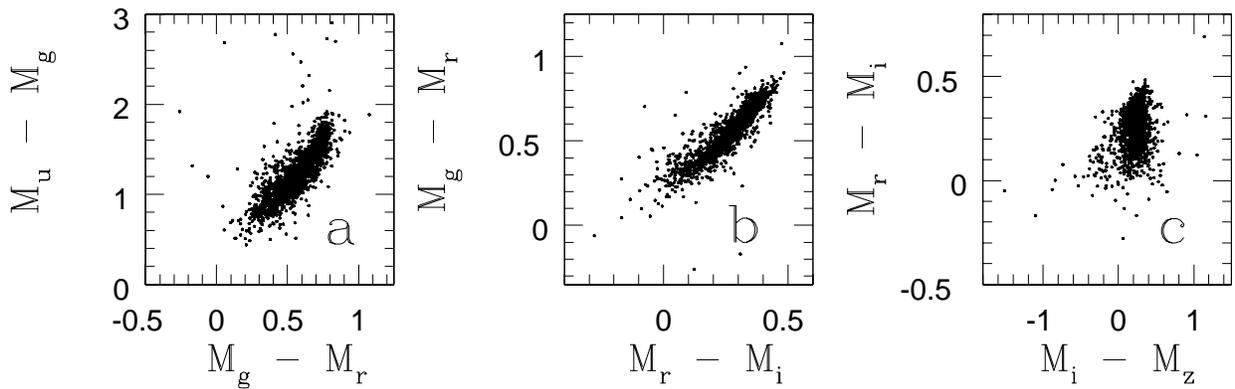


FIG. 9.—Absolute color-color diagrams for those isolated galaxies with a redshift. Colors have been k -corrected and reddening corrected.

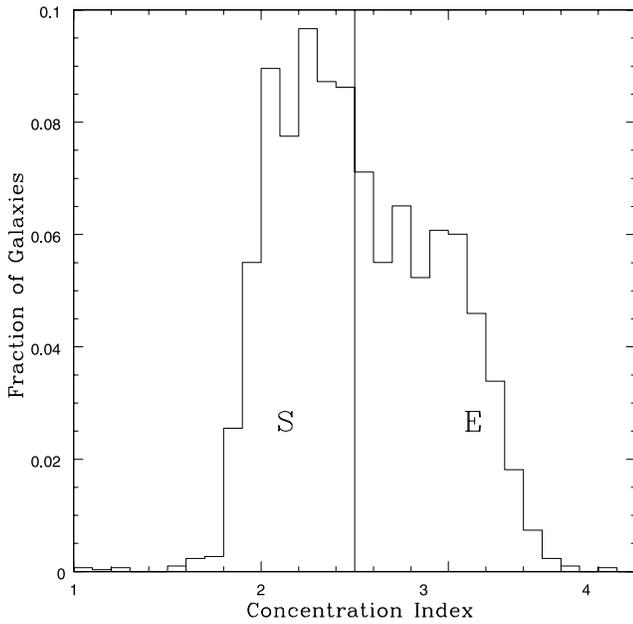


FIG. 10.—Distribution of CI for the isolated galaxy sample.

We can look at this in two ways. First, consider Figure 11. Here we plot the number counts for all SDSS DR1 galaxies and the number counts for just the galaxies in our SDSS DR1 isolated galaxy catalog. In both cases, the number counts are for 0.1 mag bins and the error bars associated with each symbol are Poisson ($N^{1/2}$). The number counts for the sample of all SDSS DR1 galaxies exhibit a linear behavior in $\log N$ versus g , showing no obvious signs of evolution in this magnitude range ($g = 16-21$). The number counts for the isolated sample, however, clearly reaches a maximum around $g = 17$ and drops off essentially to zero for $g \gtrsim 19$. If we assume that the fraction of true isolated galaxies does not evolve substantially over this magnitude range, it is clear that fainter isolated galaxies are missing from our sample.

Second, to see that this incompleteness is inherent in the selection criteria, consider Figure 12. Here we have plotted the minimum value of the scaled separation $x_{i,j}/R_j$ (see eq. [3]) for each of 3354 galaxies in a subset of the SDSS DR1. (For each of these 3354 galaxies, only neighbors within 3.0 mag are considered; see eq. [4].) Galaxies whose nearest neighbor (in the sense of $x_{i,j}/R_j$) lies more than $40R_j$ away, i.e., above the horizontal dashed line in Figure 12, would be considered isolated. Note that the $x_{i,j}/R_j \geq 40$ isolation criterion is quite restrictive. Essentially, only “outliers” meet it, and the number of outliers decreases with increasing g magnitude; in the DR1 subsample plotted, no galaxies fainter than $g \approx 18.5$ meet this criterion.

4.4. Nearest Neighbor and Comparison with a Field Sample

To test our isolation criteria for our isolated galaxies, we used all SDSS DR1 galaxies with redshifts to construct the search for the nearest neighbor distance, d_{\min} , which represents the separation in the three-dimensional redshift space. To calculate the separation between each isolated galaxy and its nearest neighboring SDSS galaxy, we introduce the concept of a distance field (Stavrev 1990). Such an approach has been applied also by Frisch et al. (1995), Lindner et al. (1995), and Aikio & Maehoenen (1998).

Let ISO be an isolated galaxy with Cartesian coordinates $x_{\text{ISO}}, y_{\text{ISO}}, z_{\text{ISO}}$ in a three-dimensional coordinate system, and let

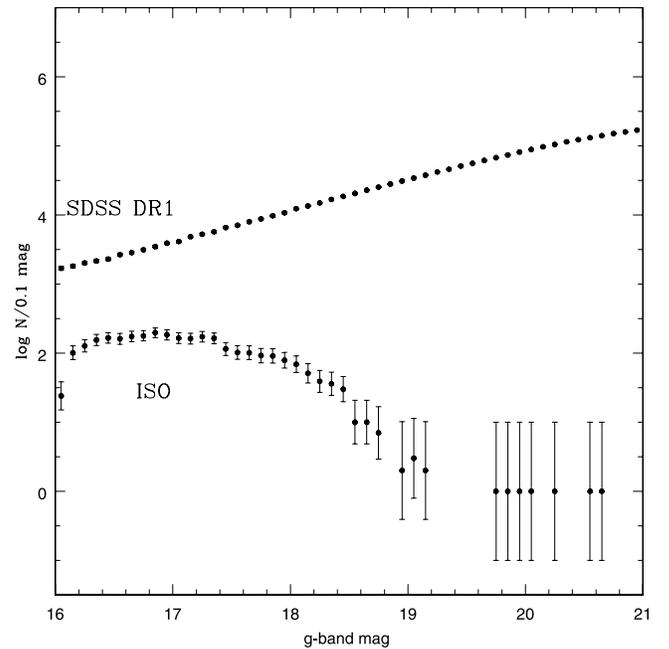


FIG. 11.—The g -magnitude distribution in 0.1 mag bins of all SDSS DR1 galaxies and of the SDSS DR1 isolated galaxies.

j be any *other* SDSS galaxy with Cartesian coordinates x_j, y_j, z_j . To speed the calculation, we only consider SDSS galaxies j that lie within a 1 deg^2 box centered on an isolated galaxy’s right ascension and declination. For each isolated galaxy the distance to its nearest neighboring object is computed as

$$d_{\min} = \min \left[\sqrt{(x_{\text{ISO}} - x_j)^2 + (y_{\text{ISO}} - y_j)^2 + (z_{\text{ISO}} - z_j)^2} \right]. \quad (5)$$

The mean nearest neighbor distance for the 1839 isolated galaxies is $4.18 \pm 0.24 h^{-1} \text{ Mpc}$, and the median is $1.144 h^{-1} \text{ Mpc}$.

In order to have a fair comparison, we have constructed a random field sample taken from the SDSS DR1 redshift sample having the exact same number of galaxies and having the same redshift distribution as the isolated galaxy sample. Figure 13 shows the distribution of the nearest neighbor distances for the 1839 isolated galaxies (*solid line*) and the field sample (*dash line*). The mean nearest neighbor distance for the 1839 field galaxies is $3.12 \pm 0.19 h^{-1} \text{ Mpc}$, and the median is $0.978 h^{-1} \text{ Mpc}$. A one-dimensional Kolmogorov-Smirnov (K-S) test (Press et al. 1992) indicates that the distributions of nearest neighbors for the isolated and field galaxies have only a 0.0003% probability that they derive from the same parent (Fig. 14).

It is not surprising that the field sample has smaller mean and median nearest neighbor distances, since the field sample should be more clustered on average than the isolated galaxies—after all, the field sample is likely contaminated at about the 10% level by cluster galaxies, whereas the typical isolated galaxy will more likely sit in a wall or filament or the outer parts of a cluster.

5. CONCLUSIONS

A key problem in astronomy involves the role of the environment in the formation and evolution of galaxies. In order to answer this question it is necessary to characterize a reference sample with a minimum influence from the environment so that its evolution is completely determined by nature.

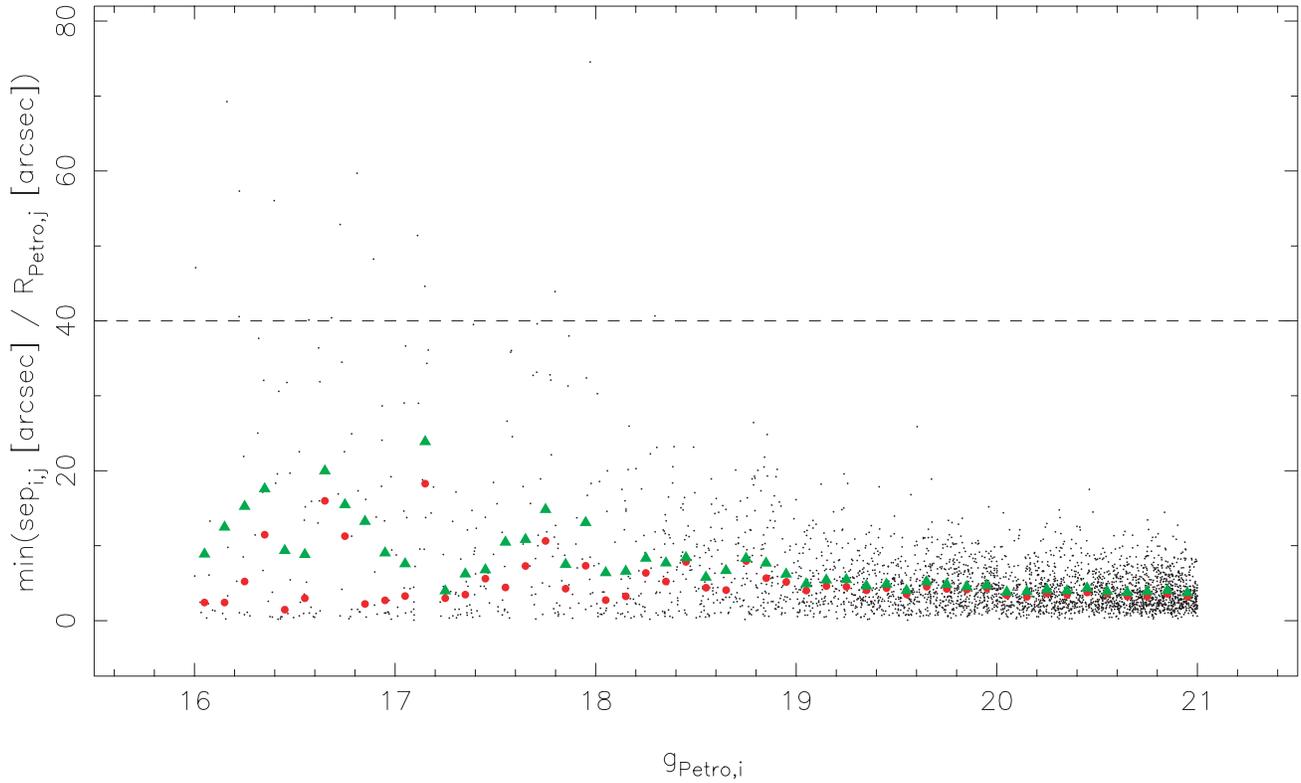


FIG. 12.—Minimum value of the scaled separation $x_{i,j}/R_j$ (see eq. [3]) vs. g -band Petrosian magnitude for each of 3354 galaxies in a subset of the SDSS DR1. (For each of these 3354 galaxies, only neighbors within 3.0 mag are considered; see eq. [4].) Black dots are the individual values for $x_{i,j}/R_j$ vs. g ; the green triangles and the red circles are the mean and median values in 0.1 mag bins, respectively. The dashed horizontal line at $x_{i,j}/R_j = 40$ indicates the isolation criterion of eq. (3); any galaxies whose $x_{i,j}/R_j$ are plotted above this line would be considered isolated.

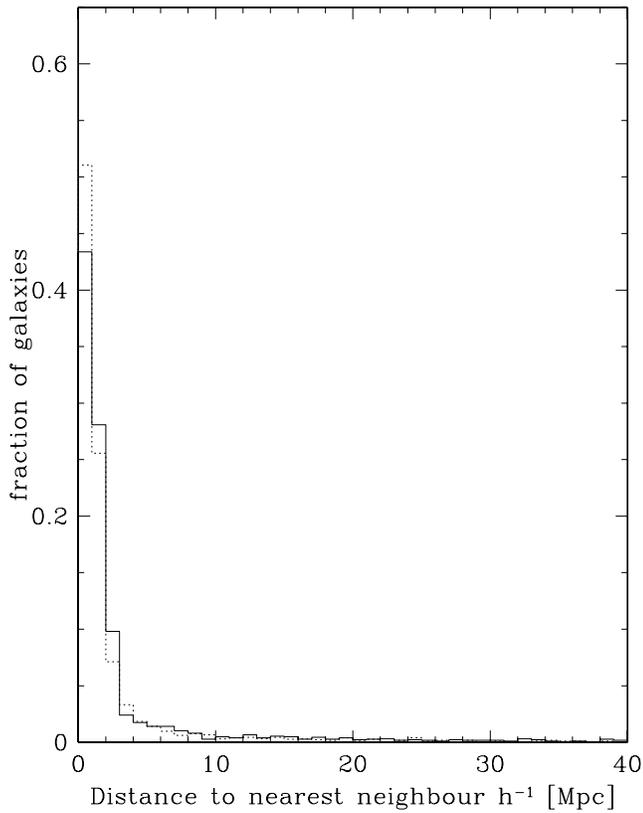


FIG. 13.—Distribution of nearest neighbor distances for the isolated galaxy sample.

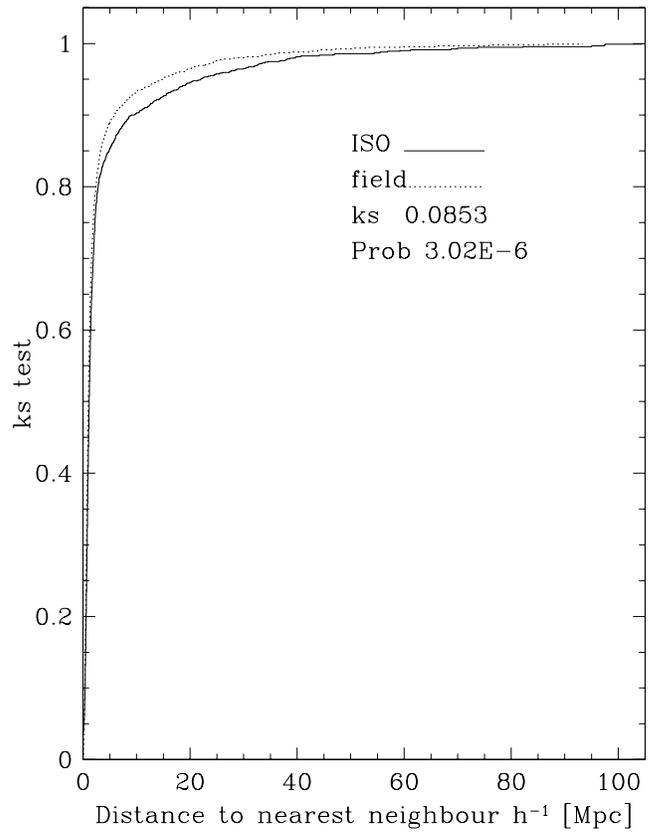


FIG. 14.—K-S test comparing the distributions of nearest neighbor distances for the isolated galaxy sample and for the field galaxy sample.

A fundamental issue in galactic evolution is the relative importance of initial conditions versus environment. To address the role of noncluster environments, we present a new catalog of isolated galaxies in the SDSS DR1 data.

At a detection rate of 1.4 isolated galaxies deg^{-2} , we expect that the final catalog, based on the completed SDSS, covering up to one-quarter of the sky, will contain on the order of $\approx 14,000$ galaxies. This catalog will allow statistical study of the properties of the interstellar medium as a function of galaxy environment, and its relation to star formation, morphology, and luminosities, as well as nuclear activity frequency (e.g., Lisenfeld et al. 2003). This catalog will also be useful for future studies of dark matter density profile of isolated galaxies (e.g., Prada et al. 2003). Finally, this catalog will offer a sample of galaxies that can greatly aid in the investigation of galaxy evolution and galaxy formation.

This paper is dedicated to the memory of Prof. Gamal El Din. During his career at the National Research Institute of As-

tronomy and Geophysics, the late Gamal El Din has had a major impact on astronomy research in Egypt.

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