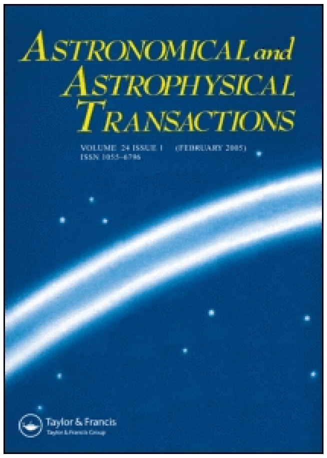

Astronomical & Astrophysical Transactions
The Journal of the Eurasian Astronomical Society
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713453505

Luminous red galaxy pairs from the Sloan Digital Sky Survey Data Release 3

X. -F. Deng [a]; P. Jiang [a]; J. Song [a]; Q. Zhang [a]; J. -Z. He [a]
[a] Mathematics and Physics College, Nanchang University, Jiangxi, PR China

Online Publication Date: 01 December 2005
To cite this Article: Deng, X. -F., Jiang, P., Song, J., Zhang, Q. and He, J. -Z. (2005) 'Luminous red galaxy pairs from the Sloan Digital Sky Survey Data Release 3', Astronomical & Astrophysical Transactions, 24:6, 455 - 461
To link to this article: DOI: 10.1080/10556790600583556
URL: http://dx.doi.org/10.1080/10556790600583556

Astronomical and Astrophysical Transactions
Vol. 24, No. 6, December 2005, 455–461

Luminous red galaxy pairs from the Sloan Digital Sky Survey Data Release 3

X.-F. DENG*, P. JIANG, J. SONG, Q. ZHANG and J.-Z. HE

Mathematics and Physics College, Nanchang University, Jiangxi 330047, PR China

(Received 16 May 2005)

By using cluster analysis, we select three luminous red galaxy (LRG) pair samples and study their various properties. We find that LRG pair samples identified at different radii have the same properties; there is a tendency for pair galaxies to have similar luminosities and sizes. Additionally, LRG pairs have the same properties as the whole LRG sample and isolated LRGs.

Keywords: Cosmology; Galaxy pairs; Cluster

1. Introduction

In the process of galaxy evolution, galaxy interactions are frequent and have a crucial role in determining galaxy properties. Interacting and merging galaxies are among the most fascinating astronomical objects in the Universe. These galaxy systems span a wide range of configurations, from single distant encounters to close encounters which may result in a single merged system. Typical morphologies include bridges between the interacting partners and tidal tails. These structures are usually associated with sites of strong star formation, resulting in dense star clusters or even dwarf-galaxy-sized objects.

A simple method of identifying isolated galaxy pairs was described by Karachentsev [1]. Two galaxies of angular diameter a_1 and a_2 whose separation is $x_{1,2}$ will satisfy the Karachentsev criterion if

$$\frac{x_{1,i}}{x_{1,2}} \geqslant 5\frac{a_i}{a_1}, \quad \frac{x_{2,i}}{x_{1,2}} \geqslant 5\frac{a_i}{a_2},$$

where i indicates each of the neighbouring galaxies whose diameter a_i is included in the intervals set by

$$\frac{1}{2}a_1 \leqslant a_i \leqslant 4a_1, \quad \frac{1}{2}a_2 \leqslant a_i \leqslant 4a_2.$$

Using the *Catalog of Galaxies and of Clusters of Galaxies* by Zwicky *et al.* [2], Karachentsev [1] identified 603 isolated pairs north of $\delta_{1950} = -3°$ for galaxies down to $m_{\rm pg} = 15.7$. Because

*Corresponding author. Email: xinfadeng@163.com

Astronomical and Astrophysical Transactions
ISSN 1055-6796 print/ISSN 1476-3540 online © 2005 Taylor & Francis
http://www.tandf.co.uk/journals
DOI: 10.1080/10556790600583556

of its size, completeness and relatively unbiased selection, this catalogue has been a popular sample for studies of isolated galaxy pairs [3–13].

Lambas *et al.* [14] studied galaxy pairs in the field selected from the 100 K public release of the Two-degree Field Galaxy Redshift Survey. Galaxy pairs were selected by radial velocity ΔV and projected separation r_p criteria. They excluded pairs in high-density regions by removing galaxies in groups and clusters and analysed the star formation activity in the pairs as a function of both the relative projected distance and the relative radial velocity. They found that star formation in galaxy pairs is significantly enhanced over that of isolated galaxies with similar redshifts in the field for $r_p < 25$ kpc and $\Delta V < 100\,\mathrm{km\,s^{-1}}$.

Allam *et al.* [15] presented a catalogue of 1479 merging pairs of galaxies extracted from the approximately 462 deg^2 of imaging data from the Sloan Digital Sky Survey (SDSS) Early Data Release [16]. The selection algorithm, implementing a variation on the original Karachentsev [1] criterion, proved to be very efficient and fast. Only galaxies with g^*-band Petrosian magnitudes $16.0 \leqslant g^* \leqslant 21.0$ were considered. To obtain isolated pairs, Allam *et al.* imposed the following criteria on any neighbouring galaxy i:

$$|g^*_{1,2} - g^*_i| > 3.0,$$
$$0.25R_{\mathrm{petro,1}} \leqslant R_{\mathrm{petro,i}} \leqslant 4R_{\mathrm{petro,1}}(\mathrm{g}^*\ \mathrm{band}),$$
$$0.25R_{\mathrm{petro,2}} \leqslant R_{\mathrm{petro,i}} \leqslant 4R_{\mathrm{petro,2}}(\mathrm{g}^*\ \mathrm{band}).$$

Finally, they classified each resulting galaxy pair by the separation of its two members as follows.

(i) For merging pairs, $x_{1,2} \leqslant (R_{\mathrm{petro,1}} + R_{\mathrm{petro,2}})$.
(ii) For intermediate pairs, $(R_{\mathrm{petro,1}} + R_{\mathrm{petro,2}}) < x_{1,2} \leqslant 3(R_{\mathrm{petro,1}} + R_{\mathrm{petro,2}})$.
(iii) For wide pairs, $3(R_{\mathrm{petro,1}} + R_{\mathrm{petro,2}}) < x_{1,2} \leqslant 10(R_{\mathrm{petro,1}} + R_{\mathrm{petro,2}})$.

They were concerned with only merging pair samples. After all rejections and verifications, the final number of candidate merging pairs left for inclusion in this catalogue was 1479.

We think that the above methods of identifying galaxy pairs are biased towards binaries with a small viewing angle but perhaps with a certain radial distance. This bias is due to the use of the galaxy diameter or projected separation criterion. In this paper, we identify galaxy pairs of luminous red galaxies (LRGs) by using three-dimensional cluster analysis [17]. LRGs are among the most luminous galaxies in the Universe and map large cosmological volumes. This makes LRGs an astrophysically interesting sample. Using cluster analysis, at very small radii, the sample mainly consists of single galaxies; few galaxies form close double and multiple systems. Here, those close double galaxies identified at very small radii are considered to be galaxy pairs.

Our paper is organized as follows. In section 2, we describe the data to be used. In section 3, we discuss the cluster analysis. In section 4, we analyse the basic properties of galaxy pairs of LRGs. Finally, in section 5, we summarize our main results.

2. Data

The SDSS [18] is one of the largest astronomical surveys to date. The SDSS was designed in scope and systematic control to permit the study of galaxy clustering over a wide range of scales and galaxy properties. Galaxy spectroscopic target selection proceeds by two algorithms. The primary sample [19] targets galaxies brighter than $r < 17.77$ (r-band apparent Petrosian magnitude). The surface density of such galaxies is about 90 deg^{-2}. This sample has a median redshift of 0.10 and few galaxies beyond $z = 0.25$. The LRG algorithm [20] selects 12 additional galaxies per square degree, using colour–magnitude cuts in g, r and i to select galaxies to $r < 19.5$ that are likely to be luminous early types at redshifts up to 0.5. The selection is extremely efficient, and the redshift success rate is very high. In detail, there are two sections of the LRG algorithm, known as cut I and cut II and described in [20].

The SDSS sky coverage is separated into three regions north of the Galactic plane, one region at the celestial equator and another region at high declination south of the Galactic plane which is a set of three stripes near the equator. Each of these areas covers a wide range of survey longitudes. We download data from the Catalog Archive Server of SDSS Data Release 3 using the SDSS SQL Search (http://www.sdss.org/), select from it 26 481 LRGs (SDSS flag, Primtarget_Galaxy_Red; redshift confidence level, $z_{\rm conf} > 0.95$; redshift region, $0.2 \leqslant z \leqslant 0.4$) and construct our LRG sample.

In calculating the comoving distance we use a cosmological model with a matter density $\Omega_0 = 0.3$, cosmological constant $\Omega_{\rm A} = 0.7$ and Hubble constant $h = 0.7$.

Because the LRG sample spans a wide range of redshifts, the interpretations of the sample often require the application of K corrections and stellar population evolution corrections ($K + e$ corrections) for comparison of photometry at different redshifts. As described in appendix B of the paper by Eisenstein *et al.* [20], we use the measured redshift and the observed $r^*_{\rm petro}$ magnitude to construct the rest frame, passively evolved $g^*_{\rm petro}$ absolute magnitude M^*_g. In this paper, we have selected the 'non-star-forming' model presented in appendix B of the paper by Eisenstein *et al.* [20] and normalized to M^*_g at $z = 0$.

3. Cluster analysis

Cluster analysis [17] is a general method, which has found wide application in many sciences to study the geometry of point samples. The kernel of the method is an objective automated procedure to separate the sample into individual systems. Let us draw a sphere of radius R around each sample point (in our case, a galaxy). If within this sphere there are other galaxies they are considered to belong to the same system, call these close galaxies 'friends'. Now draw spheres around new neighbours and continue the procedure using the rule that 'any friend of my friend is my friend'. The procedure stops when no more new neighbours or 'friends' can be added; a system is identified. So, finally, each system consists either of a single isolated galaxy or of a number of galaxies having each at least one neighbour at a distance not exceeding R. At very small radii, the sample mainly consists of single galaxies; few galaxies form close double and multiple systems.

4. The basic properties of galaxy pairs of luminous red galaxies

Using cluster analysis, we select the LRGs close double LRGs identified at the radii $R = 1$ Mpc, $R = 1.5$ Mpc and $R = 2$ Mpc (in the LRG sample, the radius of the sphere with unit population is $R_0 = 23.04$ Mpc; $R = 2$ Mpc is very small compared with R_0) as three pair samples, referred to as sample 1, sample 1.5 and sample 2 respectively. Sample 1 includes 376 LRGs (1.4% of the total galaxy number in the LRG sample), sample 1.5 includes 526 LRGs (2% of the total galaxy number) and sample 2 includes 740 LRGs (2.8% of the total galaxy number). In figures 1 and 2, we analyse the size and luminosity M^*_g distributions of the three pair samples. The two Petrosian radii R_{50} and R_{90} listed in the photometric output are the radii enclosing 50% and 90% respectively of the Petrosian flux for each band. We select the r-band R_{50}, denoted

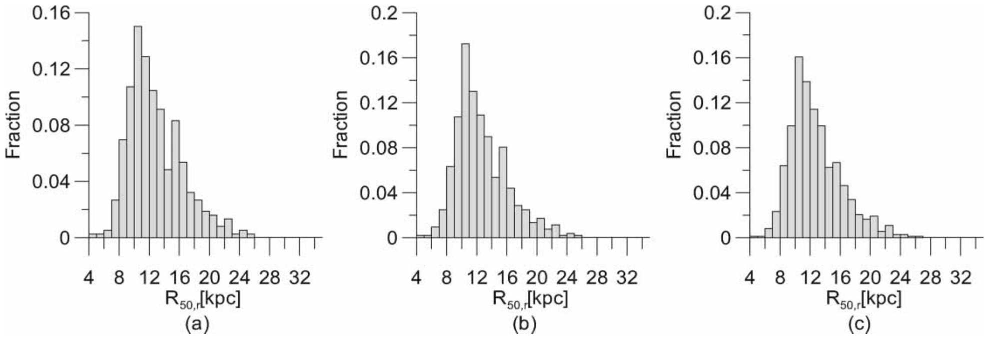

Figure 1. The histograms of the size distributions of galaxy pairs forming (a) at $R = 1$ Mpc, (b) at $R = 1.5$ Mpc and (c) at $R = 2$ Mpc.

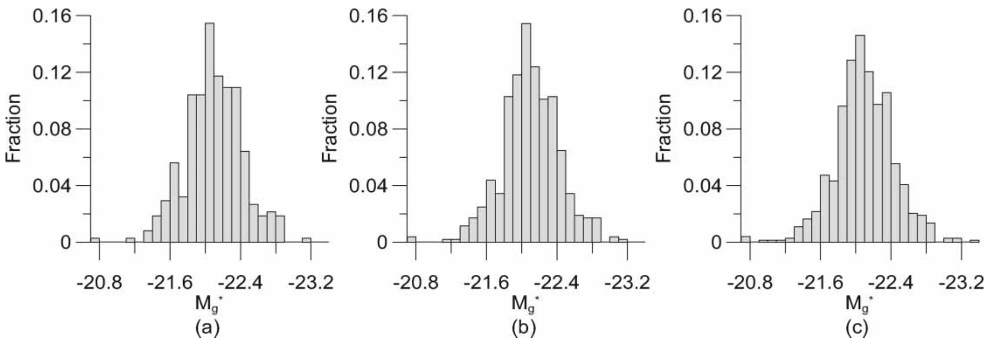

Figure 2. The histograms of the luminosity distributions of galaxy pairs forming (a) at $R = 1$ Mpc, (b) at $R = 1.5$ Mpc and (c) at $R = 2$ Mpc.

$R_{50,r}$, as the parameter of galaxy size. The luminosity M_g^* is the g-band absolute magnitude, which has been K corrected and passively evolved to rest-frame magnitudes at $z = 0$. In order to derive and compare quantitative parameters of the distributions, we fit all histograms. The available fits are the normal distribution (Gaussian). The fit results are given in table 1. We find that the size and luminosity M_g^* distributions of the three pair samples are almost the same. This demonstrates that close double galaxies identified in this radius region by cluster analysis have definite basic properties and can be considered good galaxy pair samples.

At intermediate radii, some galaxies of the sample begin to form galaxy groups and clusters. At a large radius, most galaxies of the sample merge into less dense regions of groups and clusters, and even a huge and less dense system. Few galaxies are isolated. These single-galaxy systems can be considered to be real isolated galaxies in three-dimensional space. We select

Table 1. The Gaussian fit results for figures 1 and 2.

	Sample	Average	Standard deviation
The histogram of the size distribution (figure 1)	Sample 1	12.8165	3.586 48
	Sample 1.5	12.6508	3.434 62
	Sample 2	12.718	3.401 63
The histogram of the luminosity distribution (figure 2)	Sample 1	−22.1012	0.322 291
	Sample 1.5	−22.1004	0.326 495
	Sample 2	−22.0958	0.333 256

the isolated LRGs identified at the dimensionless radius $r = 1.3$ (the dimensionless radius $r = R/R_0$, where R_0 is the radius of the sphere with unit population; within the redshift region $0.2 \leqslant z \leqslant 0.4$, the calculated result for R_0 of the LRG sample is 23.04 Mpc) as our isolated LRG samples. It includes 2239 LRGs (8.5% of the total galaxy number in the LRG sample). In figures 3 and 4, we compare the size and luminosity M_g^* distributions of the pair sample identified at the radius $R = 1.5$ Mpc with that of the whole LRG sample and the isolated galaxy sample identified at the dimensionless radius $r = 1.3$. The Gaussian fit results for figures 3 and 4 are given in table 2. We find that these basic properties of galaxy pairs, isolated galaxies and the whole LRG sample are almost the same.

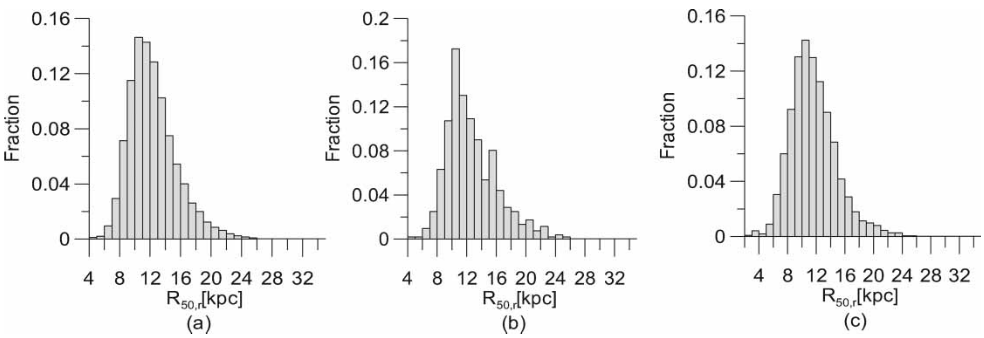

Figure 3. The histograms of the size distributions (a) for all LRGs, (b) for galaxy pairs forming at $R = 1.5$ Mpc and (c) for isolated galaxies forming at $r = 1.3$.

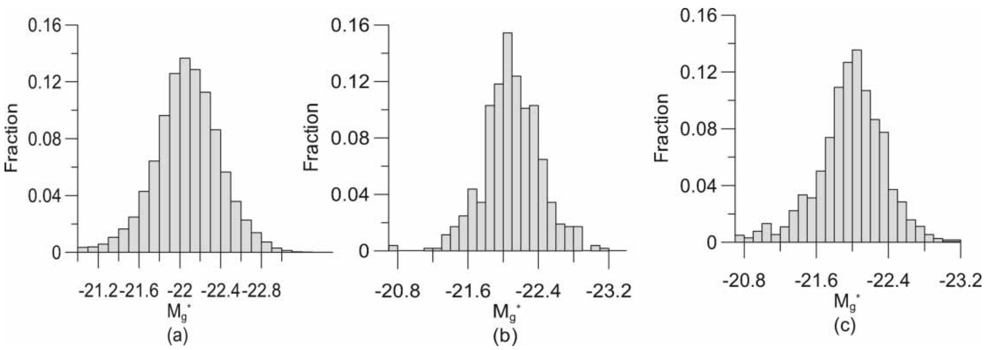

Figure 4. The histograms of the luminosity distributions (a) for all LRGs, (b) for galaxy pairs forming at $R = 1.5$ Mpc and (c) for isolated galaxies forming at $r = 1.3$.

Table 2. The Gaussian fit results for figures 3 and 4.

	Sample	Average	Standard deviation
The histogram of the size distribution (figure 3)	All LRGs	12.335	3.104 08
	Galaxy pairs (sample 1.5)	12.6508	3.434 62
	Isolated galaxies (forming at $r = 1.3$)	11.6262	3.161 3
The histogram of the luminosity distribution (figure 4)	All LRGs	−22.0762	0.315 934
	Galaxy pairs (sample 1.5)	−22.1004	0.326 495
	Isolated galaxies (forming at $r = 1.3$)	−21.9815	0.366 69

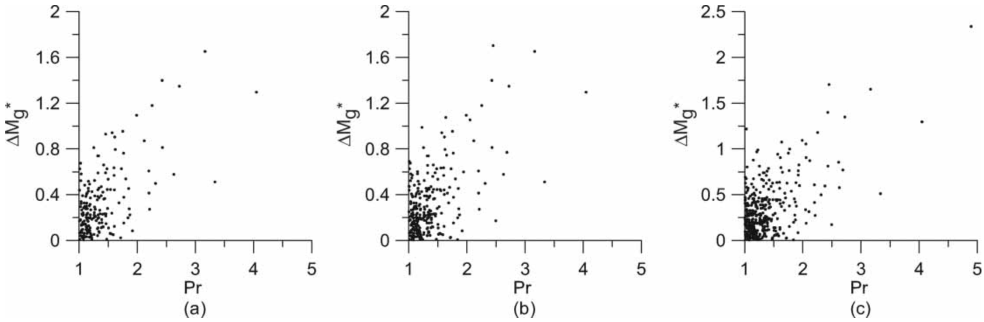

Figure 5. The luminosity differences ΔM_g^* and diameter ratios P_r of every galaxy pair in the three pair samples (a) forming at $R = 1$ Mpc, (b) forming at $R = 1.5$ Mpc and (c) forming at $R = 2$ Mpc.

We think that the member galaxies of physical pairs may have similar properties. So, we have calculated the luminosity difference $\Delta M_g^* = |M_{g,1}^* - M_{g,2}^*|$ and diameter ratio P_r (equal to $R_{50,r}$ of the large galaxy divided by that of the small galaxy in pairs) ($P_r \geqslant 1$) of member galaxies in pairs. Figure 5 shows the luminosity difference ΔM_g^* and diameter ratio P_r of each pair in three pair samples. We find that there is a tendency for pair galaxies to have similar luminosities and sizes. In the three pair samples, most pairs have a smaller luminosity difference ΔM_g^* and a diameter ratio P_r close to 1. The average values of the luminosity difference ΔM_g^* and diameter ratio P_r are as follows: for sample 1, $\overline{\Delta M_g^*} = 0.3151$ and $\overline{P_r} = 1.3707$; for sample 1.5, $\overline{\Delta M_g^*} = 0.3151$ and $\overline{P_r} = 1.3562$; for sample 2, $\overline{\Delta M_g^*} = 0.3247$ and $\overline{P_r} = 1.3561$. Figure 5 also shows that some pairs have large luminosity differences ΔM_g^*, and they correspondingly have large diameter ratios P_r. This demonstrates that the luminosities of member galaxies in pairs have a correlation with their sizes. Additionally, we also note that the analysed results for the three pair samples are almost the same.

5. Summary

In this paper, we identify LRG pairs by using cluster analysis and study the properties of LRG pair samples identify at different radii. The whole LRG sample is limited in the redshift region $0.2 \leqslant z \leqslant 0.4$ and includes 26481 LRGs. We select three LRG pair samples: sample 1, forming at the radius $R = 1$ Mpc, includes 376 LRGs (1.4% of the total galaxy number in the LRG sample); sample 1.5, forming at the radius $R = 1.5$ Mpc, includes 526 LRGs (2% of the total galaxy number); sample 2, forming at the radius $R = 2$ Mpc, includes 740 LRGs (2.8% of the total galaxy number). The main results can be summarized as follows.

(1) The size and luminosity M_g^* distributions of three pair samples are almost the same. This demonstrates that close double galaxies identified in this radius region by cluster analysis have definite basic properties and can be considered good galaxy pair samples.
(2) In figures 3 and 4, we compare the size and luminosity M_g^* distributions of the pair sample identified at the radius $R = 1.5$ Mpc with those of the whole LRG sample and of the isolated galaxy sample identified at the dimensionless radius $r = 1.3$ and find that these basic properties of galaxy pairs, isolated galaxies and the whole LRG sample are almost the same.
(3) We have calculated the luminosity difference $\Delta M_g^* = |M_{g,1}^* - M_{g,2}^*|$ and diameter ratio P_r of member galaxies in pairs. Figure 5 shows that there is a tendency for pair galaxies to have similar luminosities and sizes.

Acknowledgement

This work was supported by the National Science Foundation of China (grant 10465003).

References

[1] I. Karachentsev, Soobshch. Spetsial'noj Astrofiz. Obs. **7** 1 (1972).
[2] F. Zwicky, E. Herzog, P. Wild *et al.*, *Catalog of Galaxies and of Clusters of Galaxies* (California Institute of Technology, Pasadena, California, 1968).
[3] H. Oleak, Astron. Nachr. **297** 1 (1976).
[4] M.A. Arakelian and A.P. Magtesian, Astrofizika **17** 53 (1981).
[5] I. Karachentsev, Astrofizika **17** 675 (1981).
[6] W.C. Keel, Astrophys. J. **375** 5 (1991).
[7] G.T. Petrov and V.A. Mineva, Bolgarski Akad. Nauk Dokl. **45** 5 (1992).
[8] P. Flin, Astron. J. **105** 473 (1993).
[9] W.C. Keel, Astrophys. J., Suppl. Ser. **106** 27 (1996).
[10] H. Toledo, D. Dultzin-Hacyan, J. Gonzalez *et al.*, Astron. J. **118** 108 (1999).
[11] G. Byrd and M. Valtonen, Astron. J. **121** 2943 (2001).
[12] P. Teerikorpi, Astron. Astrophys. **371** 470 (2001).
[13] A. Franco-Balderas, H.M. Hernández-Toledo, D. Dultzin-Hacyan *et al.*, Astron. Astrophys. **406** 415 (2003).
[14] D.G. Lambas, P.B. Tissera, M. Sol Alonso *et al.*, astro-ph/0212222 (2002).
[15] S.S. Allam, D.L. Tucker, J.A. Smith *et al.*, astro-ph/0312214 (2003).
[16] C. Stoughton, R.H. Lupton, M. Bernardi *et al.*, Astron. J. **123** 485 (2002).
[17] J. Einasto, A.A. Klypin, E. Saar *et al.*, Mon. Not. R. Astron. Soc. **206** 529 (1984).
[18] D. York, J. Adelman, J.E. Anderson, Jr *et al.*, Astron. J. **120** 1579 (2000).
[19] M.A. Strauss, D.H. Weinberg, R.H. Lupton *et al.*, Astron. J. **124** 1810 (2002).
[20] D.J. Eisenstein, J.Annis, J.E. Gunn *et al.*, Astron. J. **122** 2267 (2001).