Quasars Lensed by Globular Clusters of Spiral and Elliptical Galaxies

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Abstract—Based on the SDSS catalog, we have found new close quasar–galaxy pairs. We analyze the radial distribution of quasars from pairs around galaxies of different types. We show that the quasars from pairs follow the density profile of halo globular clusters. This is new observational evidence that the quasars projected onto the halos of galaxies are magnified by gravitational lensing by halo globular clusters.

Key words: quasar–galaxy pairs, globular clusters, radial distribution, lensing.

INTRODUCTION

This paper is a continuation of the series of works devoted to the problem of quasar–galaxy associations (Baryshev and Ezova 1997; Bukhmastova 2001, 2002, 2003). A pair of objects in which a distant quasar is projected onto the halo of a nearer galaxy will be called a quasar–galaxy association. The halo radius is assumed to be 150 kpc. The catalog of quasars (Veron-Cetty and Veron 1998) and the LEDA database (Paturel 1997) were used previously to select such pairs. A total of 8382 pairs have been selected from 77 483 galaxies and 11 358 quasars. Bukhmastova (2001) pointed out that if the galaxies and quasars were distributed randomly in space, then the number of such pairs would be ~2000. The discrepancy in the number of pairs by more than a factor of 4 provides evidence for the hypothesis about a nonrandom association of quasars with galaxies. Bukhmastova (2001, 2003) and Baryshev and Bukhmastova (2004) considered the following three hypotheses regarding the relatively close association between galaxies and quasars.

1. Among the 8382 pairs found, there are those formed by chance. The increase in the probability of occurrence of random pairs is particularly large where the redshift of a galaxy is too low, since the halo with a radius of 150 kpc in such a galaxy has a large angular area, covering much of the sky. A large number of randomly projected distant objects, including quasars, are seen through such a halo.

2. The pairs are formed through a nonuniform, fractal distribution of galaxies in space. According to his distribution, the space density of galaxies around a selected galaxy decreases as $r^{-a}$, where $r$ is the distance from the galaxy under consideration to the selected galaxy and $a$ is close to unity (Pietronero 1987; Sylos-Labini et al. 1998; Baryshev and Bukhmastova 2004); i.e., the galaxies tend to be arranged in hierarchical groups. The quasars are currently believed to be active galactic nuclei. Thus, if we observe a galaxy in a pair with a quasar, then there is a high probability that several more active galactic nuclei, i.e., quasars, will be in a pair with this galaxy. Conversely, several galaxies can be in a pair with one quasar. This explains the enhanced probability of
occurrence of Arp and Tyson quasar–galaxy associations.

3. Finally, the third main hypothesis of this paper consists in the following. The quasars from associations are distant compact objects (the nuclei of distant galaxies) whose fluxes enhanced by gravitational lenses on the line of sight. Globular clusters in the halos of nearer galaxies and clustered objects of hidden mass can be such lenses. As a result of gravitational lensing, we can see a magnified (and split) image of a distant source. The possible number of globular clusters in the halos of galaxies and their radial distribution relative to the center of the host galaxy should be taken into account in theoretical estimations of the expected number of such pairs. According to Blakeslee et al. (1997), Blakeslee (1999), and McLaughlin (1999), the globular clusters contain 25% of the baryonic mass of galaxies. In the section entitled “The Expected Number of Pairs”, we estimate the expected number of close quasar–galaxy pairs by taking into account the abundance of globular clusters.

The theory of gravitational lensing was well described by Bliokh and Minakov (1989), Zakharov (1997), and Schneider et al. (1992); many papers are devoted to quasar–galaxy associations (see, e.g., Thomas et al. 1995; Zhu Zong-Hong et al. 1997; Benitez et al. 2001; Menard and Bartelmann 2002; Scranton et al. 2005; for the possibility of strong gravitational magnification of quasars, see Yonehara et al. 2003).

Quasars are observed in pairs with galaxies of various types. If distant quasars and nearer galaxies are associated via halo globular clusters, then the distribution of quasars around elliptical galaxies must follow in a certain way the distribution of globular clusters around these galaxies. Does the distribution of quasars around elliptical and spiral galaxies have peculiarities of its own? This paper is devoted to a discussion of this hypothesis.

THE QUASAR–GALAXY PAIR SELECTION TECHNIQUE

To select quasar–galaxy pairs, we use the available catalog of 8382 pairs (Bukhmastova 2001) compiled from the LEDA database (Paturel 1997) and the catalog of quasars (Veron-Cetty and Veron 1998). We also select new pairs from the fourth version of the SDSS catalog of quasars and galaxies (www.sdss.org). The selection criteria are the following.

1. We select quasars and galaxies with available data on their spatial coordinates $\alpha$, $\delta$, and $z$. The apparent magnitudes are also known for the quasars.
2. Each quasar in a pair must be farther than the galaxy, i.e., $z_{qso} > z_{gal}$.
3. The quasars must be projected onto the galaxy halos. The halo size does not exceed 150 kpc.
4. We consider nearby quasars with $z < 0.3$.
5. We select pairs with $z_{gal}/z_{qso} > 0.9$.

Criterion 5 allows us to reduce significantly the number of random pairs. According to Bukhmastova (2001), the galaxies paired with quasars are either close to the observer, so that $a = z_{gal}/z_{qso} < 0.1$, or close to the quasar, so that $a > 0.9$, avoiding the central location on the observer–quasar ray. There may be a large number of random pairs among those with $a < 0.1$, because the halo of a nearby galaxy has a large angular size, thereby covering much of the sky. The probability of chance coincidences among the pairs with $a > 0.9$ is considerably lower. We will call the pairs with $a > 0.9$ close quasar–galaxy pairs, because the quasar and the galaxy in such a pair are close to one another not only in angular separation, but also in redshift.
Criterion 4 also reduces the sample by removing the distant quasars that can be paired with distant galaxies, which are undetectable in the surveys under consideration.

**SELECTION OF PAIRS BASED ON THE LEDA DATABASE AND THE CATALOG OF QUASARS (VERON-CETTY AND VERON 1998)**

Bukhmastova (2001) selected 8382 pairs based on criteria 1–3. Given the additional constraints 4 and 5, 64 close quasar–galaxy pairs listed in Table 1 are left. We will call the sample of pairs from Table 1 sample 1. The columns of this table give the following data: 1, the pair number in the original catalog; 2, the quasar name; 3 and 4, the equatorial coordinates of the quasar in radians; 5 and 6, the redshift and apparent magnitude of the quasar; 7, the galaxy name; 8, the galaxy redshift; 9 and 10, the distance from the galaxy center to the quasar projection in kpc and arcsec, respectively; 11, the presumed splitting angle between the quasar images under the assumption that the mass of the gravitational lens is \(3 \times 10^5 \, M_\odot\); and 12, the galaxy type according to the NED database (http://nedwww.ipac.caltech.edu).

The splitting angle between the images was calculated using the model of a point lens and corresponds to the radius of the Chwolson–Einstein ring. Although the putative lenses are globular clusters, which are well described by the King model (King 1962), this estimate of the splitting angle is admissible. In particular, for the rays passing outside the core of such a lens, we can use the point lens model, which is simpler for general estimations.

**SELECTION OF PAIRS BASED ON THE SDSS CATALOG**

Let us select new pairs based on the fourth version the Sloan Digital Sky Survey (www.sdss.org). 5224 quasars with \(z < 0.3\) and 321,516 galaxies are involved in the selection. This original sample of quasars and galaxies was compiled by N.L. Vasil’ev. The result of our selection using criteria 1–5 is presented in Table 2 (sample 2, 64 pairs). The odd rows in the table present data on the quasar in pairs. The columns give the following data: 1, the quasar–galaxy pair number in this sample; 2, the quasar identification number in the SDSS catalog; 3 and 4, the equatorial coordinates of the quasar in radians; 5 and 6, the redshift and apparent magnitude of the quasar; and 9, the presumed splitting angle between the quasar images under the assumption that the mass of the gravitational lens is \(3 \times 10^5 \, M_\odot\). The even rows in the table present data on the galaxies in pairs: 2, the galaxy identification number in the SDSS catalog; 3 and 4, the equatorial coordinates of the galaxy in radians; 5 and 6, the redshift and apparent magnitude of the galaxy; 7, the color index of the galaxy; and 8, the distance from the galaxy center to the quasar projection in kpc.

**ANALYSIS OF THE SELECTED PAIRS**

Let us analyze the derived samples of close quasar–galaxy pairs. Let us determine the linear distances from the galaxy centers at which the quasars from pairs are projected. Figures 1 and 2 show the distributions of quasars from samples 1 and 2, respectively. The distance from the galaxy center to the quasar projection in kpc is along the horizontal axis and the number of quasars is along the vertical axis.
According to the data presented in Table 1, sample 1 of close quasar-galaxy pairs is represented mostly by spiral galaxies. Our main assumption is that the quasars of sample 1 are associated with spiral galaxies via globular clusters in the halos of these galaxies. Thus, Fig. 1 leads us to conclude that 80% of the globular clusters in spiral galaxies are located in their halos at distances up to 40 kpc. Note that the clustered halo objects are predominantly within 10 kpc; further out, the number of such objects decreases sharply. Below, we will establish whether this is actually the case.

To establish the types of galaxies represented in sample 2, let us turn to the paper by Fukugita et al. (1995), who classified the galaxies according to their color indices. Table 3 presents these classifications for the SDSS catalog. Tables 2 and 3 lead us to conclude that about 70% of the galaxies in the pairs of sample 2 are elliptical ones. In the section on globular clusters in the elliptical galaxies A754, A1644, A2124, A2147, A2151, A2152 of the Abell cluster and in the galaxies IC 4051, M49, and M87, we will establish whether this means that the data in Fig. 2 reflect the spatial distribution of globular clusters in elliptical galaxies.

GLOBULAR CLUSTERS IN SPIRAL GALAXIES
AND QUASAR–GALAXY ASSOCIATIONS

To establish the peculiarities of the distribution of globular clusters in the halos of spiral galaxies, we use data on the locations of 150 globular clusters in the Milky Way halo (Harris 1996). Analysis of these data is presented in Fig. 3. It follows from this analysis that more than 80% of the globular clusters are actually located at distances of no larger than 40 kpc. To determine the density profile of globular clusters in the halos of spiral galaxies in more detail, let us turn to the data on 1164 candidates for globular clusters in the Andromeda Galaxy (Galetti et al. 2004). Figure 4 shows the distribution of these globular clusters in projection onto the galactic plane. The distances from the galaxy center (point 0,0) to the globular clusters are along the axes. We counted the halo globular clusters in rings of a fixed radius. The upper straight line in Fig. 5 represents the density profile of globular clusters in the Andromeda Galaxy. We see that the radial density of globular clusters in the halos of spiral galaxies is well described by a power law in the form

\[ n_{GC}(r_p) = A_0 r_p^\alpha, \]

where \( \alpha = -2.1 \pm 0.3 \) and \( \alpha = -2.5 \pm 0.3 \) for the Andromeda and the Milky Way, respectively; \( n_{GC} \) is the number of globular clusters per unit area of the halo ring; and \( r_p = R \) is the galactocentric distance of the globular cluster in projection onto the galactic plane.

Let us select the close pairs from samples 1 and 2 in which the quasar is projected onto the halo of a spiral galaxy. The result is indicated by the lower straight line in Fig. 5. For these quasars, \( \alpha = -2.6 \pm 0.3 \) in a segment up to 80 kpc. Figure 5 leads us to conclude that the distribution of globular clusters in the plane of the halos of spiral galaxies and the distribution of quasar projections onto the halos of spiral galaxies are described by a power law with a mean index \( \alpha \approx -2.4 \), i.e., the quasars from close quasar–galaxy pairs may follow the halo globular clusters in their radial distribution.
Let us select the quasar–galaxy pairs from samples 1 and 2 in which the quasar is projected onto an elliptical galaxy. We will construct a dependence similar to that in Fig. 5. The result indicated by the lower line in Fig. 6 leads us to conclude that the distribution of quasars in the halos of elliptical galaxies obeys a power law with an index $\alpha = -1.5 \pm 0.3$ up to 80 kpc. The quasars farther than 80 kpc may be background ones unassociated with the presumed gravitational lenses of the halo.

The upper straight line in Fig. 6 was constructed by analyzing the galaxy–galaxy pairs. We selected the galaxy–galaxy pairs from the SDSS catalog in a similar way as the quasar–galaxy pairs. It was necessary to determine how the radial distribution of galaxies seen through the halo of a nearer galaxy fell off. We see that the galaxies are distributed uniformly in projection onto the sky. Note that the radial distribution of galaxies seen through the halos of nearer galaxies and the distribution of quasars projected onto the halos of elliptical galaxies at distances larger than 80 kpc are identical.

The distribution 263 globular clusters in the elliptical galaxy M49 within 30 kpc of its center is clearly presented in Cote et al. (2003). This galaxy contains a total of $\sim 6000$ globular clusters within 100 kpc of its center. Cote et al. (2001) analyzed the distribution of 278 globular clusters in the elliptical galaxy M87 within 30 kpc of its center. There are $\sim 13000$ globular clusters within 100 kpc of its center. Woodworth and Harris (2000) provided the spatial distribution of globular clusters in the galaxy IC 4051. The question of whether the total area of the halo covered by globular clusters is enough to cover and magnify distant sources (quasars) is considered in the section entitled “The Expected Number of Pairs”. The density of globular clusters in elliptical galaxies increases toward the center. As an example, the density profile of globular clusters can be traced for the galaxy A754 (see Fig. 7). The globular clusters in the galaxies A1644, A2124, A2147, A2151, and A2152 show a similar behavior. This led Blakeslee (1999) to conclude that the radial density of globular clusters in the halos of elliptical galaxies is well described by a power law in form (1) with a mean $\alpha \approx -1.5$.

Thus, Figs. 6 and 7 suggest that the distribution of globular clusters in the plane of the halos of elliptical galaxies and the distribution of quasar projections onto the halos of elliptical galaxies are described by a power law with an index $\alpha \approx -1.5$, i.e., the quasars from close quasar–galaxy pairs follow the halo globular clusters in their radial distribution.

**THE EXPECTED NUMBER OF PAIRS**

Let us estimate the expected number of close quasar–galaxy pairs using the above selection criteria, i.e., let us answer the question of how probable is the fact that distant compact sources (galactic nuclei) can be magnified by globular clusters in the halos of nearer galaxies. Without gravitational lensing, such a source would remain invisible for an observer.

The main condition for strong gravitational amplification (by $3\times 10^4$) by gravitational lenses with a King mass distribution, which include globular clusters, is the projection of distant source onto the core of such a lens. The Milky Way clusters have core radii in the range 0.08–24 pc (Harris 1996). Let us assume
that the parameters of globular clusters in other galaxies are similar to those of the Milky Way clusters and fix the core radius at 9 pc. Assume that the galaxy with the surrounding gravitational lenses lies at $z = 0.08$. The maximum of the distribution of SDSS galaxies lies at this redshift $z$. For definiteness, we take the halo size to be 40 kpc. Most of the halo globular clusters are located within this radius (as follows from the calculations given below, this quantity plays no role). The halo area of such a galaxy is $\sim 10^{-4}$ square degrees. If the density of distant sources in the sky is assumed to be $10^6$ objects per square degree, then such a halo will cover $\sim 100$ distant sources. Let us now estimate the fraction of the halo area occupied by the cores of globular clusters. To this end, we must estimate the possible number of globular clusters in the halo. Table 4 from Bukhmastova (2003) presents data on the number of globular clusters in spiral and elliptical galaxies. The columns of the table contain the following: 1, the galaxy name; 2, the galaxy type; 3, the number of quasars projected onto the galaxy; and 4, the number of halo globular clusters. Based on these data, we assume that the mean number of globular clusters in the halos of galaxies is $10^5$. Thus, multiplying the number of globular clusters by the area of the globular cluster core and dividing the value obtained by the area of the galaxy halo, we obtain $5 \times 10^{-5}$, the fraction of the area occupied by globular clusters. Multiplying this value by the number of sources covered by the halo yields $5 \times 10^{-3}$. This means that five of every thousand galaxies located at $z = 0.08$ may have at least one magnified source (quasar) in their halo. According to Fig. 8, the number of galaxies located at this distance is $\sim 2.6 \times 10^4$. As a result, the expected number of galaxies in pairs quasars is 130 against 128 galaxies listed in Tables 1 and 2. Thus, these simple estimates are consistent with observations and suggest that close quasar–galaxy pairs can actually be produced by gravitational amplification of distant sources considered as quasars. Gravitational lenses can be globular clusters of galaxy halos or other clustered objects of hidden mass with masses and radii close to those of globular clusters.

CONCLUSIONS AND OBSERVATIONAL TESTS

Quasars projected onto the halos of nearer galaxies are encountered among the multitude of quasars observed at various distances from us. Among them there are quasars that are close to the galaxies not only in angular separation, but also in redshift. Such quasar–galaxy pairs are called close pairs. In this paper, we developed further the hypothesis that such pairs appear, because the fluxer on the nucleus of the more distant galaxy passes through halo globular clusters of the nearer galaxy, resulting in magnification and splitting of the image of the source that we interpret as a quasar. To corroborate this hypothesis, we analyzed the distribution of quasars in the plane of the halos of these galaxies. The quasars from close pairs were found to follow the density profile of globular clusters in the halos of elliptical and spiral galaxies with slopes of $\alpha \approx -1.5$ and $\alpha \approx -2.4$ for elliptical and spiral galaxies, respectively. This suggests that quasars do not appear near galaxies by chance and that quasars are associated with galaxies via halo globular clusters.

The quasars from close quasar–galaxy pairs can be observed to study the splitting of their images. The presumed splitting angles between the images are very small (several milliarcseconds), but they are nevertheless accessible to such telescopes as the VLTI in Chile. Another observational test consists in the following. If the quasars from pairs are actually the central sources of galaxies...
magnified by globular clusters in the nearer galaxy, then, since $z_{gal}/z_{qso} > 0.9$ in close pairs, then stars of the host galaxy of the quasar will be mixed with stars of the nearer lensing galaxy for an observer. This may give rise to lines in the galaxy spectra corresponding to two redshifts.

We were unable to perform similar studies with irregular galaxies, because we found no close pairs, i.e., quasars and galaxies close in redshift, among the 203 quasar–irregular galaxy pairs found (Bukhmastova 2001). However, the following fact is of considerable interest: despite the smaller number of quasar–irregular galaxy pairs compared to the number of quasar–elliptical galaxy and quasar–spiral galaxy pairs, the relative contribution of irregular galaxies in pairs is considerably higher, i.e., among the elliptical and spiral galaxies, 1–2% of their total number are in pairs with quasars, while among the irregular galaxies, about 9% of their total number are in pairs with quasars (Bukhmastova 2003). This suggest that there may be an enhanced number of compact objects with masses and radii typical of globular clusters around the irregular galaxies at distances of $\sim 50–100$ kpc. Detection of these effects would be yet another observational tests on the possibility of an association between quasars and nearby galaxies.

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Table 1. Close quasar–galaxy pairs found based on the catalog of quasars (Veron-Cetty and Veron 1998) and the LEDA database (Paturel 1997)

| Name_gal | RA_gal | DEC_gal | z_gal | Name_gal | z_gal | r_KM | r" | Q" | type_gal |
|----------|--------|---------|-------|----------|-------|------|----|----|---------|
| PG 0026+129 | 0.116217 | 0.22674 | 0.142 | 15.41 | PGC001790 | 0.1419 | 0.7 | 0.2 | 0.0020 | Sy1 |
| Q 0051-3933 | 0.226049 | -0.69031 | 0.224 | 17.3 | LEDA0125101 | 0.2233 | 12.5 | 2.3 | 0.0021 | - |
| PG 0052+251 | 0.227700 | 0.43906 | 0.155 | 15.43 | PGC003237 | 0.1549 | 0.4 | 0.1 | 0.0017 | Sh,Sy1 |
| F 9 | 0.357152 | -1.03090 | 0.046 | 13.83 | LEDA0138429 | 0.0859 | 24.1 | 11.5 | 0.0054 | - |
| MS 0357+1046 | 0.418995 | -0.98160 | 0.086 | 15.5 | LEDA0138429 | 0.1075 | 0.5 | 0.1 | 0.0003 | Sh,Sy1 |
| MARK 1014 | 0.511694 | 0.00266 | 0.163 | 16.59 | PGC007551 | 0.1628 | 51.8 | 19.5 | 0.0081 | Sb,Sy1 |
| RJS 0207+2930 | 0.541692 | 0.51094 | 0.111 | 16.0 | LEDA008076 | 0.1094 | 51.8 | 19.5 | 0.0081 | Sb,Sy1 |
| 4U 0241+61 | 0.702538 | 1.08659 | 0.045 | 12.19 | LEDA0074110 | 0.044 | 7.5 | 7.0 | 0.0639 | Sy1 |
| MS 0244+9128 | 0.719315 | 0.33989 | 0.176 | 16.66 | LEDA0138357 | 0.1759 | 29.0 | 6.8 | 0.0013 | Sy1 |
| PKS 0312-77 | 0.841808 | -1.34478 | 0.225 | 16.1 | LEDA0080874 | 0.2228 | 8.0 | 1.4 | 0.0037 | Sy1 |
| ESO 109+623 | 0.833351 | -0.89939 | 0.078 | 15.1 | PGC019151 | 0.0779 | 16.4 | 8.6 | 0.0066 | Sc,S0/a |
| 0321+424 | 0.880528 | -0.74014 | 0.2 | 16.6 | LEDA0088125 | 0.1999 | 34.2 | 7.1 | 0.0010 | Sy1 |
| MS 0357+1046 | 1.036063 | 0.18813 | 0.182 | 16.78 | LEDA0138680 | 0.1814 | 16.0 | 3.6 | 0.0030 | Sy1 |
| IRAS 04050-2958 | 1.267770 | -0.52316 | 0.286 | 16.0 | LEDA0075249 | 0.2858 | 35.2 | 5.0 | 0.0007 | Sy1 |
| IRAS 06115-3240 | 1.629697 | -0.57043 | 0.05 | 14.1 | PGC018655 | 0.0499 | 72.7 | 60.1 | 0.0008 | Sab,Sy2 |
| VII Zw 118 | 1.843074 | 1.12883 | 0.079 | 14.61 | PGC020174 | 0.0788 | 0.8 | 0.4 | 0.0091 | Sab |
| IRAS 07483+0328 | 2.043739 | 0.06061 | 0.099 | 15.2 | LEDA0097223 | 0.0989 | 7.1 | 2.9 | 0.0041 | Sy1 |
| B3 0754+394 | 2.071007 | 0.68899 | 0.096 | 14.36 | LEDA0139042 | 0.0957 | 7.3 | 3.1 | 0.0075 | Sy1,Sy2 |
| MS 08019+2129 | 2.102874 | 0.37507 | 0.118 | 15.92 | LEDA0139051 | 0.1179 | 29.8 | 10.4 | 0.0029 | - |
| PG 0804+761 | 2.114422 | 1.32980 | 0.1 | 14.71 | PGC02946 | 0.0999 | 2.6 | 1.1 | 0.0040 | Sy1 |
| PG 0844+349 | 2.288846 | 0.60974 | 0.064 | 14.5 | PGC024702 | 0.0639 | 0.2 | 0.1 | 0.0006 | Sy1 |
| MS 09063+1111 | 2.383661 | 0.19540 | 0.16 | 16.93 | LEDA0139171 | 0.1599 | 138 | 35.6 | 0.0016 | Sy6 |
| IRAS 09435+1307 | 2.546415 | -0.22897 | 0.131 | 16.3 | LEDA0082528 | 0.1309 | 6.3 | 1.9 | 0.0023 | Sy2 |
| MS 0944+1333 | 2.548915 | 0.23671 | 0.131 | 16.05 | LEDA0139211 | 0.1309 | 48.3 | 15.2 | 0.0023 | Sy1 |
| PG 1001+05 | 2.625506 | 0.09529 | 0.161 | 16.23 | PGC02908 | 0.1609 | 1.0 | 0.2 | 0.0015 | Sy1 |
| MS 10302-2757 | 2.750042 | -0.48810 | 0.148 | 16.0 | LEDA0139395 | 0.1479 | 101.9 | 28.4 | 0.0018 | - |
| CSO 292 | 2.827862 | 0.61073 | 0.147 | 16.6 | LEDA0139451 | 0.1469 | 25.1 | 7.0 | 0.0019 | Sy1 |
| PG 1114+445 | 2.942334 | 0.77665 | 0.144 | 16.05 | PGC034449 | 0.1439 | 23.7 | 6.7 | 0.0019 | Sy1 |
| PG 1115+407 | 2.948588 | 0.71044 | 0.154 | 16.02 | PGC034570 | 0.1539 | 20.2 | 5.4 | 0.0017 | Sy1 |
| WAS 26 | 3.048508 | 0.38775 | 0.063 | 14.9 | PGC036264 | 0.0628 | 91.1 | 59.8 | 0.0143 | Sy1 |
| N   | name_QSO       | RA_QSO | DEC_QSO | Z_QSO | m_r_QSO | g'-r' | r' |
|-----|----------------|--------|---------|-------|---------|-------|-----|
| 1   | 75094095038513152  | 2.549328 | 0.003205 | 0.12670 | 17.928 | 0.00624 |
| 2   | 75650757918779392  | 2.616505 | 0.012400 | 0.06557 | 17.954 | 0.001208 |
| 3   | 75650759413952000  | 2.02270 | 0.06518 | 0.61713 | 139.3 | 0.000330 |
| 4   | 77628572222619648  | 2.813987 | 0.16559 | 0.11498 | 17.770 | 0.000330 |
| 5   | 82132249917510208  | 3.330977 | 0.017590 | 0.08956 | 17.909 | 0.003614 |
| 6   | 82132249303572352  | 3.330766 | 0.017277 | 0.08346 | 16.376 | 0.704 134.2 |
| 7   | 110279116122007000 | 0.11876 | 0.003049 | 0.06404 | 18.187 | 0.00200 |
| 8   | 110279116122007000 | 0.11876 | 0.003049 | 0.06404 | 18.187 | 0.00200 |
| 9   | 110279116122007000 | 0.11876 | 0.003049 | 0.06404 | 18.187 | 0.00200 |
| 10  | 13375931016370000  | 0.16479 | 0.001210 | 0.10615 | 17.463 | 0.881 118.4 |
| 11  | 12623370016000320  | 2.335550 | 0.995266 | 0.14356 | 18.647 | 0.00927 |
| 12  | 13617542522316000  | 2.335669 | 0.995051 | 0.14254 | 16.512 | 1.058 122.6 |
| 13  | 12686685939027700  | 2.399436 | 0.989773 | 0.11136 | 17.409 | 0.00114 |
| 14  | 12686685729492500  | 2.399617 | 0.989458 | 0.11036 | 16.796 | 0.947 147.8 |
| 15  | 13927161059298600  | 2.383945 | 1.159152 | 0.04679 | 16.292 | 0.002662 |
| 16  | 13927161059298600  | 2.383945 | 1.159368 | 0.04584 | 16.858 | 0.626 97.6 |
| 17  | 13927161059298600  | 2.383945 | 1.159368 | 0.04584 | 16.858 | 0.626 97.6 |
| 18  | 79181915422039184  | 2.903113 | 0.015500 | 0.09615 | 15.753 | 0.883 80.9 |
| 19  | 151938426139049980 | 3.942942 | 0.044272 | 0.12155 | 18.329 | 0.001628 |
| 20  | 16601233679793100 | 3.942942 | 0.044041 | 0.11915 | 17.612 | 0.874 109.6 |
| 21  | 16179150207320640  | 2.693336 | 0.090672 | 0.18952 | 18.102 | 0.00683 |
| 22  | 28085704310810690  | 2.693336 | 0.090765 | 0.18848 | 17.518 | 1.160 76.4 |
| 23  | 15593911560488500  | 3.128785 | 1.140000 | 0.12839 | 18.655 | 0.00856 |
| 24  | 22033834670829440  | 3.128785 | 1.140000 | 0.12839 | 18.655 | 0.00856 |
| 25  | 44861723402478300  | 3.942942 | 0.133533 | 17.980 | 0.001258 |

Table 2. Close quasar–galaxy pairs found based on the fourth version of the SDSS catalog (www.sdss.org).
Table 3. Classification of SDSS galaxies according to their color indices (Fukugita et al. 1995)

| Type galaxy | $g'-r'$ | $g'-r'$ z=0.2 |
|-------------|--------|---------------|
| E           | 0.77   | 1.31          |
| S0          | 0.68   | 1.13          |
| Sab         | 0.66   | 1.02          |
| Sbc         | 0.52   | 0.71          |
| Scd         | 0.48   | 0.62          |
| Im          | 0.20   | 0.32          |

Table 4. Estimated number of globular clusters in spiral and elliptical galaxies

| PGC          | Type   | Number  |
|--------------|--------|---------|
| PGC041297    | E2     | 3       |
| PGC044324    | Sab    | 1       |
| PGC043008    | E1-2   | 1       |
| PGC044553    | E      | 1       |
| PGC013344    | S0     | 2       |
| PGC013418    | E1pec  | 1       |
| PGC013433    | E1     | 1       |
| PGC024930    | Sb     | 4       |
| PGC032226    | E5     | 1       |
| PGC032256    | E1     | 6       |
| PGC036487    | E3     | 2       |
| PGC039764    | E1     | 2       |
| PGC039246    | Sb     | 12      |
| PGC041327    | E0     | 2       |
| PGC041968    | E0     | 34      |
| PGC042051    | E6     | 3       |
| PGC042628    | E5     | 7       |
| PGC000218    | Sab    | 1       |
FIGURES

Fig. 1. Distribution of 64 quasars from sample 1 relative to the centers of the galaxies onto the halos of which they are projected.

Fig. 2. Same as Fig. 1 for sample 2.

Fig. 3. Distribution of 150 Milky Way globular clusters relative to the Galactic center.

Fig. 8. Redshift distribution of SDSS galaxies.
Fig. 4. Distribution of globular clusters of the Andromeda Galaxy in the halo plane. The equatorial coordinates recalculated to galactocentric distances are along the axes.

Fig. 5. Density profiles of globular clusters in the Andromeda Galaxy (upper straight line) and quasars (lower straight line) projected onto the halos of spiral galaxies. The logarithm of the galactocentric distance of each object (in kpc) is along the horizontal axis; the logarithm of the number of objects (globular clusters and quasars) per unit area of the halo ring is along the vertical axis. The distribution of globular clusters in the plane of the halos of spiral galaxies and the distribution of quasar projections onto the halos of spiral galaxies are well described by a power law with an index $\alpha \approx -2.4$.

Fig. 6. Radial distribution of galaxies seen through the halos of nearer galaxies (upper straight line). The density profile of quasars projected onto the halos of elliptical galaxies (lower straight line). The logarithm of the galactocentric distance of each object (2 corresponds to 100 kpc) is along the horizontal axis; the logarithm of the number of objects per unit area of the halo ring is along the vertical axis. The distribution of quasar projections onto the halos of elliptical galaxies is well described by a power law with an index $\alpha \approx -1.5$. 
Fig. 7. Density profile of globular clusters in the elliptical galaxy A754 (Blakeslee 1999). The galactocentric distances of the globular clusters (in arcsec) are along the horizontal axis; the number of globular clusters per unit area of the halo is along the vertical axis.