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Nature and environment of Very Luminous Galaxies⋆

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Abstract. The most luminous galaxies in the blue passband have a larger correlation amplitude than L^* galaxies. They do not appear to be preferentially located in rich clusters or groups, but a significant fraction of them seem to be in systems which include fainter members. We present an analysis of fields centered on 18 Very Luminous Galaxies ($M_B \leq -21$) selected from the Southern Sky Redshift Survey 2, based on new observations and public data of the 2dF Galaxy Redshift Survey; we present also additional data on a CfA VLG and on Arp 127. We find that all the selected VLGs are physically associated with fainter companions. Moreover, there is a relation between the VLG morphology (early or late) and the dynamical properties of the system, which reflects the morphology–density relation. 6 out of the 18 SSRS2 VLGs are early type galaxies: 2 are in the center of rich Abell clusters with velocity dispersion $\sigma \sim 600$ km s^{-1}, and the other 4 are in poor clusters or groups with $\sigma \sim 300$. The VLG extracted from the CfA catalog is also an elliptical in a Zwicky cluster. The remaining 2/3 of the sample are late–type VLGs, generally found in poorer systems with a larger spread in velocity dispersion, from ~100 up to ~750 km s^{-1}. The low velocity dispersion, late–type VLG dominated systems appear to be analogous to our own Local Group. The possibile association of VLG systems with dark matter halos with mass comparable to rich groups or clusters, as suggested by the comparable correlation amplitude, would imply significant differences in the galaxy formation process. This work also shows that observing fields around VLGs represents an effective way of identifying galaxy systems which are not selected through other traditional techniques.

Key words. cosmology: observations – galaxies: distances and redshifts – galaxies: kinematics and dynamics

1. Introduction

From the analysis of the Southern Sky Redshift Survey 2 (SSRS2, da Costa et al. 1994), we have found that the amplitude of galaxy clustering increases significantly as a function of galaxy luminosity, but only when $L > L^*$ (Benoist et al. 1996; see also Willmer et al. 1998); moreover, the analysis of high–order moments shows that the bias is not linear, without a significant dependence on scale (Benoist et al. 1999), analogous to the bias between clusters and galaxies (Cappi & Maurogordato 1995). We have also found that the clustering amplitude of the most luminous galaxies in the sample, having absolute magnitude $M_B \leq -21$ (i.e. $L \geq 4L^*$), which we defined as Very Luminous Galaxies (VLGs), is similar to that of clusters, with a correlation length $r_0 \sim 16\ h^{-1}$ Mpc. From the analysis of the 2dF Galaxy Redshift Survey (2dFGRS) Norberg et al. (2001) have confirmed the reality of luminosity segregation for galaxies more luminous than L^*, even if their most luminous galaxies show a correlation amplitude not as high as the SSRS2 VLGs.

The large value of the VLG correlation function could be explained if VLGs were in clusters, as originally suggested by Hamilton (1984): in this case, most of them should be luminous ellipticals. However, in our statistical analysis of the SSRS2 VLGs (Cappi et al. 1998, Paper I) we have shown that the fractions of the different morphological types are comparable to lower luminosity samples, and that most of the VLGs are not in rich clusters. Only a minority of VLGs were found in known groups, but in most cases our visual inspection of the Digitized Sky Survey images revealed the presence of fainter companions, often with signs of interaction.

In fact, if VLGs are neither in clusters nor in rich groups, they can nevertheless be associated with poorer systems. In biased galaxy formation (Kaiser 1984; Bardeen et al. 1986) more massive halos, which represent rare fluctuations of the matter density field, have a larger correlation amplitude. This suggests

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⋆ Figures 1, 2 and Appendix B are only available in electronic form at http://www.edpsciences.org

an association of VLGs to high density peaks; the fact that they are dominant galaxies in poor systems with much fainter galaxies can have interesting implications, concerning for example the efficiency of galaxy formation or the overabundance of predicted subhalos relative to the observed dwarf satellites of the Milky Way and M 31 (see e.g. Moore et al. 1999): for this reason, it would be useful to have a statistical sample of galaxy systems similar to our own Local Group.

Unfortunately the properties of poor galaxy systems, especially those comparable to the Local Group, are not well known. Zabludoff & Mulchaey (2000) have studied a sample of six nearby poor groups, finding evidence for a different luminosity function, with an increasing dwarf to giant galaxy ratio with the mass density of the system. More generally, Zabludoff & Mulchaey (1998, 2000) have examined the properties of 12 poor groups of galaxies with PSPC images: 9 of them have diffuse X–ray emission and a bright, central elliptical galaxy.

Our approach is complementary, as it selects another class of poor systems. In fact, a main problem is the bias on the properties of the selected galaxy groups due to the adopted selection criteria. A selection algorithm defines a priori the properties of the systems: well known examples are Abell clusters (Abell 1958) and Hickson compact groups (Hickson 1982). The introduction of automated methods can give a more objective selection, but it is obviously impossible to recover a system if only its most luminous member is present in the original photometric catalogue. Moreover, the typical friends–of–friends algorithms used to select "galaxy groups" require the detection of at least three neighbouring galaxies above the limiting magnitude of the catalogue (see e.g. White et al. 1999): this means that many groups are classified as "binaries". It is clear that the problem becomes critical when going towards poorer and more distant systems, with increasing contamination and spurious detections.

Let us take the best example of VLG system, i.e. our Local Group, which contains two VLGs: M 31 and our Milky Way (with respectively $M_V = -21.2$ and $M_V = -20.9$, see van den Bergh 1999 and references therein), and is usually considered as a "typical group". If this is true, it is surely not reflected in group catalogs, for a simple reason: VLGs are rare galaxies. For example, the third brightest galaxy of the Local Group M 33 (with an absolute magnitude $M_V = -18.9$) would become fainter than $m_V = 15.5$ (i.e. fainter than the limit of the SSRS2) already at $z \sim 0.025$. Therefore we do not know if the properties of our Local Group are really "typical", and only looking deeper at VLG fields we can expect to find other groups similar to our own.

In order to construct a statistical sample including, among others, also systems comparable to our Local Group, we have decided to investigate the environment of the VLGs listed in our catalogue defined in Paper I, which represent a volume–limited sample. The first step is to measure redshifts of fainter galaxies in the field of VLGs and determine the membership and velocity dispersion of the systems: in this paper we discuss data concerning the fields of 19 VLGs. In Sect. 2 we define our sample, with the VLG fields we observed at the Observatoire de Haute Provence and the selection of galaxies around VLGs extracted from the 2dFGRS; Sect. 3 presents the individual properties of the systems, while in Sect. 4 we discuss the relation between the VLGs and their environment. Our conclusions are in Sect. 5. In Appendix A we also discuss Arp 127, a pair identified in our preliminary selection as possibly including a VLG, and in Appendix B we give positions, magnitudes and redshifts of 2dFGRS galaxies in our VLG systems.

2. Definition of the sample

Three VLGs were selected from our catalogue of VLGs (see Table 1 in Paper I), while a fourth galaxy satisfying the VLG definition was selected from the CfA catalogue (see Geller & Huchra 1989); the 4 VLG fields were observed at OHP. Other 15 VLG fields were extracted from the 2dFGRS public catalogue, which has an overlap with the SSRS2. While partially imposed by observational constraints (see below), our selection is random with respect to the VLG properties, and should be representative of the whole sample. In fact, one third of the selected VLGs are early–type galaxies, a fraction consistent with that of the total sample published in Paper I.

2.1. Systems observed at OHP

At the Observatoire de Haute–Provence we could observe only galaxies at $\delta > -10°$, while SSRS2 galaxies are south of $\delta = -2.5°$. Among the 12 VLGs in our catalogue which satisfied this declination constraint, we chose three VLGs around which an inspection of DSS images had revealed the presence of galaxies fainter than the VLG but still bright enough to get a useful spectrum at the 1.93 m telescope. The selected VLGs are VLG 061, VLG 068 and VLG 074. In order to cover the whole night, we included also a VLG galaxy selected from the CfA catalogue (VLG 0716+5323), and Arp 127, a galaxy we had included in a preliminary version of the VLG catalogue but finally excluded for its discrepant redshift and the consequent uncertainty on its absolute magnitude. This system is presented in Appendix A.

Our observations were carried out in 1997 at the 1.93 m telescope with the Carelec spectrograph in long slit mode at the Cassegrain focus. The grating dispersion was 260 Å/mm, corresponding to ~7 Å with the 512×512 pixels of the Tektronix CCD. Data reduction was performed with IRAF; calibrations were done using the OHP He–Ar lamps. Redshifts were measured with *xcsao* in the *rvsao* package, using 5 star templates and attributing to each galaxy the redshift given by the best–fitting template (i.e. the one with the highest R parameter, see Tonry & Davis 1979). One velocity standard star and one galaxy with velocity measured from HI observations were also observed and used as a check of the zero–point calibration, cross–correlating them with a subset of our spectra and with our templates: in both cases, the redshifts were consistent within 10 km s^{-1}.

Positions and redshifts of the observed galaxies are listed in Table 1.

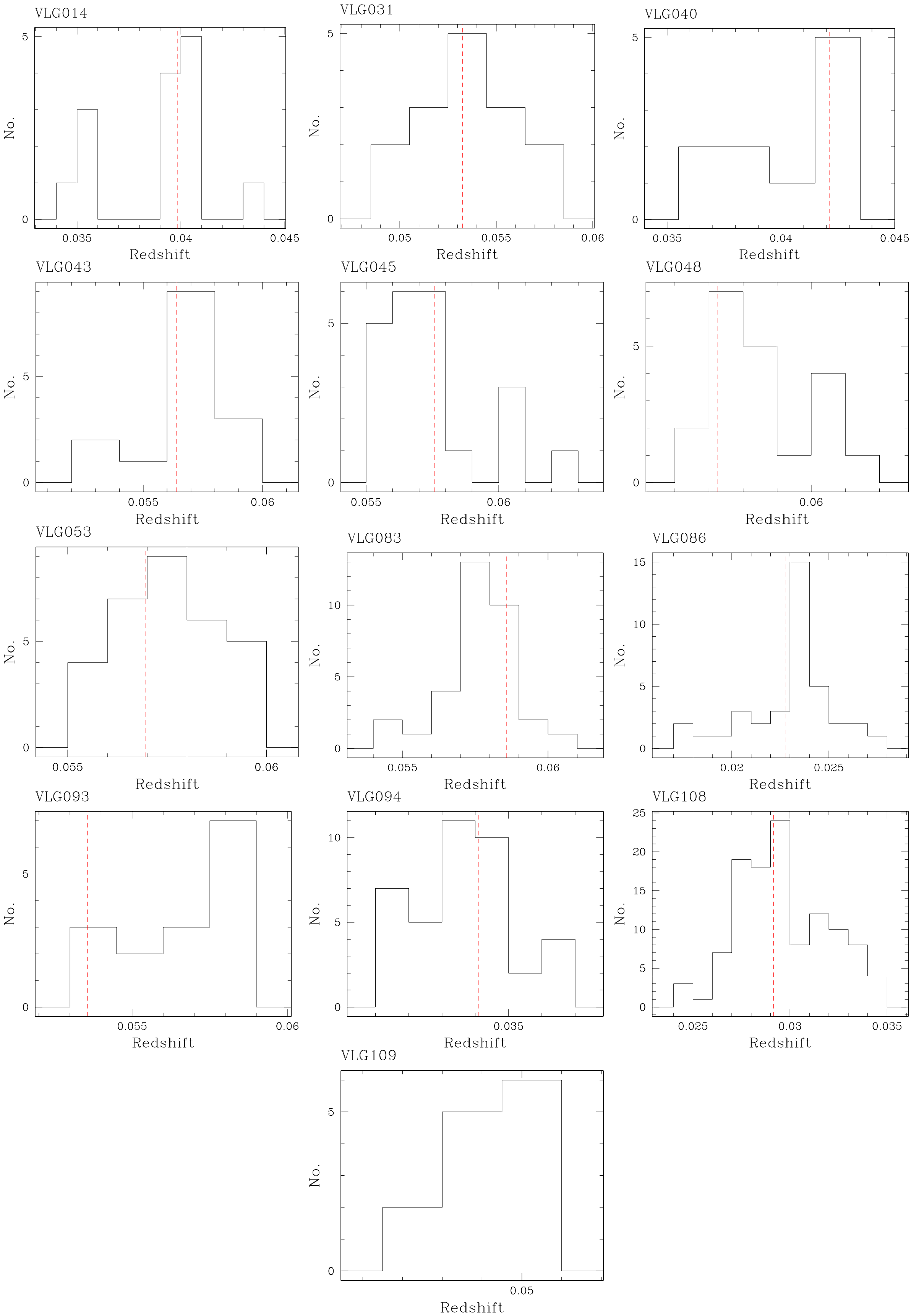

Fig. 3. Redshift histograms of the VLG systems with ≥10 redshifts (dashed line: VLG redshift).

Table 1. Heliocentric redshifts of galaxies in VLG fields.

Iden.	RA (J2000)	Dec (J2000)	V_h (km s^{-1})	Error	Notes
VLG 061	02 30 42.7	–02 56 21	5719	31	
1	02 30 32.1	–02 53 07	5950	24	Emission lines
2	02 30 44.7	–02 53 58	5488	36	
3	02 30 46.4	–02 57 06	5561	28	
4	02 30 47.6	–02 54 32	5870	20	Emission lines
5	02 30 48.9	–02 56 46	5189	91	
6	02 31 11.6	–02 56 35	5847	31	$m = 15.76$
7	02 30 21.9	–02 59 07	12 498	56	
VLG 068	03 25 11.5	–06 10 52	9933	48	$V = 10\,107$ $m = 13.97$
MRK 0609	03 25 25.3	–06 08 38	10 264	57	$V = 10236$
MRK 0610	03 25 31.4	–06 07 43	10 408	55	$V = 10301$
VLG 074a	04 08 07.4	–08 49 45	9930	50	NGC 1516A
VLG 074b	04 08 08.2	–08 50 06	9864	45	NGC 1516B
1	04 07 45.3	–08 44 26	10 073	37	
2	04 07 59.0	–08 50 24	36 482	61	
3	04 08 00.3	–08 49 24	46 248	65	H_β, [OIII]4959 & 5007
4	04 08 06.4	–08 48 04	36 342	101	
5	04 08 12.1	–08 56 11	42 342	95	
6	04 08 21.1	–08 47 20	36 254	45	
VLG 0716+5323	07 16 41.2	53 23 09	19 069	41	$m = 14.0$, $V = 19307$, X–ray
1	07 16 19.9	53 21 51	137	17	Star
2	07 16 21.2	53 21 59	19 048	32	
3	07 16 24.4	53 21 37	19 573	25	
4	07 16 32.0	53 23 45	18 330	44	
5	07 16 38.1	53 15 38	19 781	47	
6	07 16 40.0	53 22 23	19 904	43	
7	07 16 43.1	53 22 55	20 522	73	
8	07 16 47.9	53 22 45	19 066	57	
9	07 17 29.2	53 24 45	19 043	42	

2.2. 2dFGRS data

Part of the SSRS2 region is covered by the 2dFRS (see Colless et al. 2001), and we searched for galaxies around VLG positions in the presently available public catalogue (the "100k" catalogue[1], including more than 102 000 redshifts).

The limiting magnitude of the 2dFGRS is $b_J = 19.45$; within the maximum distance defined by the SSRS2 VLG volume–limited sample (~0.065), the 2dFGRS is volume–limited at $M = -17$ (of course the field incompleteness has to be taken into account).

We selected all galaxies in the 2dFGRS within a projected separation less than $1.5h^{-1}$ Mpc and a velocity difference less than 1500 km s^{-1} with respect to the SSRS2 VLGs. The velocity cut was chosen to limit foreground and background contamination, but large enough to include also marginal members. We also applied a 3–σ clipping (see e.g. Yahil & Vidal 1977) to the velocity distribution. The chosen value of the projected radius corresponds to one Abell radius and it is also used as a criterion for determining the Local Group membership (van den Bergh 1999). We found data for 19 VLG fields: in 4 cases (VLG 003, VLG 008, VLG 054, VLG 075) we could retrieve only one redshift (in addition to the VLG) with our selection limits. Such cases deserve a more careful study and we will not include them in the present work. We simply note here that VLG 075 is in a group identified in the Las Campanas Redshift Survey (Tucker et al. 2000). In the other 15 fields we could obtain at least 5 redshifts (reduced to 3 by the 3σ clipping in the case of VLG 022).

The images of the fields centered on the selected VLGs (30 arcmin size in δ) were retrieved from the Digitized Sky Survey and are shown in Figs. 1 and 2. In Appendix B and in tables available in electronic form we give positions and redshifts of the 2dFGRS galaxies selected according to the criteria defined above.

3. Properties of the VLG systems

We have calculated the mean redshift and the velocity dispersion for each VLG system; the main properties are shown in Table 2, where we list in Col. (1) the VLG number, in Col. (2) the VLG morphological type, in Col. (3) the total number of galaxies after applying the 3–σ clipping and used for measuring the mean redshift and velocity dispersion, in Col. (4) the mean heliocentric redshift with its error, in Col. (5) the velocity dispersion, in Col. (6) the system type, when available from the literature.

With respect to the known systems listed in Table 2 of our Paper I, we could associate other 8 VLGs to galaxy

[1] Electronically available at the address
`http://msowww.anu.edu.au/2dFGRS/Public/main.html`

systems, and increase the number of measured velocity dispersions: in fact only VLG 086 (in an Hickson compact group) and VLG 108 (in the ACO cluster A4038) had already an estimate of the velocity dispersion.

In Fig. 3 we show the velocity histograms of the systems with at least 10 measured redshifts. The redshift of the VLG is indicated by a dashed line.

From Table 2, and also taking into account the 4 VLGs not included in this selection, it appears that all VLGs have companions. This is not so surprising, given the known correlation between galaxies, and confirms the idea that there are no truly "isolated" galaxies. Moreover, it is quite striking that in the literature 6 out of the 18 SSRS2 VLGs were not associated to any system, while other 3 were classified simply as binaries: for example, VLG 048 belongs to a system for which we could collect 15 new redshifts from the 2dFGRS. Such a high number of nearby galaxy systems which were not previously identified neither in the optical nor in the X–ray reminds us how poorly known the low–mass end of galaxy systems is. Therefore it is interesting to examine in more detail the nature and environment in which VLGs are found. In the following, we briefly describe the main properties of the selected VLGs and their systems.

– **VLG 014** is an Sbc spiral in a known triplet, which appears to be in a larger system: including the information from the 2dFGRS, we have a total of 14 galaxies with redshift. The 3–σ clipping algorithm does not exclude any of these galaxies, but 5 of them are apparently in foreground and background, contributing to the formally large velocity dispersion of the system, ∼750 km s^{-1}; when considering only the central 9 galaxies (which include the VLG) concentrated at $z \sim 0.04$, the velocity dispersion is only ∼120 km s^{-1}.
– **VLG 022** is an S0 in a known compact group, SCG55, identified with an automated algorithm by Prandoni et al. (1997). Five galaxies are within 1.5 h^{-1} Mpc in projected distance and 1500 km s^{-1} in velocity from the VLG, but two are excluded by the 3σ clipping.
– **VLG 031**, a D galaxy, is the dominant galaxy of A151. In our selection there is only another VLG (VLG108) associated to a rich Abell cluster. The VLG redshift is at the center of the velocity distribution, which is regular and consistent with a Gaussian. For this system we measure a velocity dispersion $\sigma \sim 720$ km s^{-1}.
– **VLG 040** is a spiral in a system with a relatively large velocity dispersion (more than 700 km s^{-1}); however, the velocity histogram shows that this value is probably affected by foreground galaxies. The VLG is in the concentration at $z \sim 0.043$.
– **VLG 043** is an Sb galaxy previously not associated to a known system; now we have identified a group with 15 galaxies having measured redshifts, and a velocity dispersion of ∼470 km s^{-1}. The velocity histogram is not symmetric, with two galaxies which could be in the foreground, having a velocity difference of about 1100 km s^{-1} with respect to the cluster mean.
– **VLG 045** is a spiral classified in our original catalog as an "isolated" galaxy, as no known system was found in the literature. Within the search radius we have found other 20 2dFGRS galaxies, and only one of them was rejected by the 3-σ clipping algorithm. The velocity histogram presents a well defined peak, with 4 galaxies in the background. The velocity dispersion of the system is ∼460 km s^{-1}. All these galaxies are much fainter than the VLG, which has an apparent magnitude of 14.96: the second brightest galaxy has $b_J = 16.66$, while the others are fainter than $b_J = 17$. Notice however that these fainter galaxies have still a significant intrinsic luminosity: the second member has an absolute magnitude brighter than M^*.
– **VLG 048** is an Sbc galaxy member of a known binary system: however, with the 2dFGRS data we have 20 galaxy redshifts for this system. The velocity histogram shows a main peak including the VLG, and a secondary peak in the background.
– **VLG 053** is an S0 galaxy previously not associated to a known system, but looking at the Digital Sky Survey image we had identified a few other bright galaxies. We can now confirm the reality of a group, with other 32 2dFGRS galaxies: its velocity histogram is consistent with a Gaussian distribution, with a velocity dispersion of ∼360 km s^{-1}.
– **VLG 061** is a large spiral galaxy, and also in this case, while it was not associated to any known group or cluster, we had identified many fainter galaxies in the field; 6 of them were selected and observed at OHP, and their redshifts were found to be comparable to that of the VLG. The velocity dispersion of the system is ∼300 km s^{-1}. Galaxy 1 (see Table 1) has a bright HII region outside the nucleus; in its spectrum we have detected H_β in emission, the two [OIII] lines at 4959 and 5007 Å, H_α and [NII] lines (while [OII]3727 is outside our spectral range).
– **VLG 068** was already known to be in a group: we could only measure the redshifts of the three main components. However, we show this system as a further example of how different can be the environment of a VLG from that of a typical cluster. The main companions of the VLG are two Markarian galaxies, already known in the literature. MRK 609 is a Seyfert 1.8, with prominent emission lines (H_β, [OIII] and H_α).
– **VLG 069** is a peculiar spiral galaxy in interaction in a binary system. Its redshift is quite precise, having been measured also in H_α. From the 2dFGRS we have obtained a few other redshifts, but there is some problem with the identification of the binary. At the position of the VLG, the 2dFGRS gives a galaxy with a redshift consistent with the SSRS2, but the magnitude is significantly underestimated. We have kept the SSRS2 measure in the table. The 2dFGRS gives also the redshift of a second nearby galaxy, with coordinate approximately corresponding to the center of the binary system and a bright magnitude (14.09). It could correspond to the companion of the VLG, and we have included it in our table. In conclusion, 8 galaxies are now included as members of the group after the 3–σ clipping. This system has a relatively low velocity dispersion (160 km s^{-1}).

Table 2. Properties of the VLG systems.

Ident.	Type	N_z	$\bar{z}$	σ_r (km s^{-1})	System Type
14	Sbc	14	0.0389 ± 0.0007	747^{+204}_{-114}	Triplet
22	S0	3	0.0570 ± 0.0003	137 ± 66	SCG55
31	D	15	0.0536 ± 0.0007	720^{+188}_{-107}	A151
40	S	10	0.0403 ± 0.0008	724^{+256}_{-127}	—
43	Sb	15	0.0567 ± 0.0004	468^{+123}_{-72}	—
45	S	21	0.0572 ± 0.0004	464^{+97}_{-62}	—
48	Sbc	20	0.0584 ± 0.0003	378^{+82}_{-53}	Binary
53	S0	33	0.0575 ± 0.0002	360^{+57}_{-41}	—
61	SB(rs)c	7	0.0193 ± 0.0004	318^{+177}_{-67}	—
68	S Sy1	3	0.0340 ± 0.0004	236 ± 99	SSRS2 group
69	SB(s)b p	8	0.0376 ± 0.0002	158^{+79}_{-46}	Binary
74	S	3	0.0332 ± 0.0003	104 ± 56	Binary
83	E	31	0.0580 ± 0.0002	319^{+53}_{-38}	S0983
86	SB(s)bc p:Sy	37	0.0231 ± 0.0004	669^{+96}_{-68}	HCG91
93	Sb	15	0.0566 ± 0.0005	550^{+144}_{-83}	—
94	SAB(rs)p	39	0.0336 ± 0.0002	413^{+59}_{-43}	EDCC155
108	cD	114	0.0297 ± 0.0002	659^{+49}_{-41}	A4038
109	E	13	0.0492 ± 0.0003	297^{+89}_{-52}	S1155
VLGN 0716+5323	E	9	0.0645 ± 0.0007	609^{+234}_{-109}	Z1261

- **VLG 074** is in fact a pair of interacting galaxies (NGC 1516 A & B), also detected by IRAS. The redshift was measured by Strauss et al. (1992), attributing the coordinates to the center of the pair. These coordinates and redshifts were included in the SSRS2 and in our VLG catalog. It is possible that the magnitude of the brightest member was not correctly estimated, given the proximity of the two galaxies. We have measured the redshifts of both, which differ by less than 100 km s^{-1} (see Table 1). A third galaxy among those we have observed belongs to the system, while the other, fainter galaxies in the field are in the background, with a concentration at $z \sim 0.121$.
- **VLG 083** is an elliptical galaxy within 0.5 arcmin from the center of the poor Abell cluster S0983. In this field we have found other 30 2dFGRS galaxies: the velocity dispersion of the system is ∼320 km s^{-1}.
- **VLG 086** is a Seyfert galaxy in a Hickson Compact Group (HCG91). The VLG is in interaction with a nearby SB0. This group is quite rich: 37 galaxies have measured redshifts and none of them is rejected by the 3–σ clipping algorithm, giving a quite large velocity dispersion of ∼670 km s^{-1}. However, there is a well defined central peak at $z \sim 0.023$, which corresponds to the mean redshift of the system and also to the redshift of the VLG. This should probably be considered as the main group. Note that we have excluded from our analysis a 2dFGRS galaxy, identified in the NASA Extragalactic Database as 2dFGRS S175Z138, with coordinates ($\alpha = 22^h09^m07.45^s$, $\delta = -27^\circ48'22.8''$), near to –but not coincident with– the VLG center. It might be identified with the VLG or alternatively with the SB0 interacting with the VLG.
- **VLG 093** is an Sb in a field for which we have now 15 redshifts. The 3–σ clipping does not exclude any of these galaxies; however, the histogram is asymmetric, and the VLG, not present in the 2dFGRS catalogue, is in the first velocity bin, while the peak is in the last bin (the velocity difference is ∼1500 km s^{-1}). Therefore we can conclude that there is a group in the field, but it is not clear if it is really associated with the VLG.
- **VLG 094** is a peculiar spiral in a poor cluster listed in the Edinburgh/Durham Cluster Catalog (EDCC155; Lumsden et al. 1992). The redshift of the VLG is comparable to the average redshift and is near the velocity peak. The velocity dispersion, $\sigma \sim 410$ km s^{-1}, is quite typical of a rich group.
- **VLG 108** is the cD galaxy in the Abell cluster A4038. The usually quoted velocity dispersion of this cluster is larger (∼882 km s^{-1} in Struble & Rood 1999) than our estimate of ∼660 km s^{-1}. However, as shown by Fadda et al. (1996), this apparently regular cluster has two different peaks in velocity (the two peaks can also be seen in our velocity histogram, see Fig. 3). Our velocity dispersion is in excellent agreement with the X–ray temperature, $kT = 3.31$ keV (Finoguenov et al. 2001); for example, using the Lubin & Bahcall empirical relation (1993), $\sigma = 10^{2.52}(kT)^{0.6}$, we would expect $\sigma \sim 679$ km s^{-1}.
- **VLG 109** is an elliptical VLG in the poor cluster S1155, which has a velocity dispersion comparable to S0983 (see VLG083), ∼300 km s^{-1}.

– **VLG 0716+5323**, which we selected from the CfA catalog, is another example of an early–type VLG. It is in a Zwicky cluster (Z1261), with an extended X–ray emission centered at 0.5 arcmin from the VLG. This cluster, detected by the Einstein satellite, is also included in the ROSAT Brightest Cluster Sample (Ebeling et al. 1998), with a luminosity $L_X = 0.81 \times 10^{44}$ erg/s. For this cluster there was no previous measured redshift except for the VLG (Gregory & Burns 1982). At OHP we could measure the redshifts of 9 galaxies, VLG included. The resulting velocity dispersion of the system, $\sigma = 609$ km s^{-1}, is typical of a poor cluster. The agreement of the velocity dispersion with the cluster temperature, $kT = 2.8$ keV (Ebeling et al. 1998), is excellent: from the Lubin & Bahcall (1993) fit we would expect $\sigma = 614$ km s^{-1}.

4. The relation between VLGs and their environment

In Paper I we have shown that the correlation function of VLGs approaches that of clusters. Various galaxies discussed above (VLG 045, VLG 048, VLG 053) are within the Pisces–Cetus Supercluster, which appears as a prominent feature near the limiting depth of the SSRS2 volume–limited sample of VLGs (the presence of this structure might explain the excess of the VLG correlation amplitude measured in the SSRS2 with respect to the 2dFGRS). The Pisces–Cetus supercluster is well traced by Abell and ACO clusters (Tully 1986), but none of our VLGs is a member of those clusters. The VLG correlation function is large because VLGs trace large–scale fluctuations just as clusters do, not because they are in rich clusters.

Another interesting issue is the luminosity function of the VLG systems. In principle, merging should have played a major role in the formation of the elliptical VLGs, and the luminosity function of the associated system might be different from those dominated by a spiral VLG. As a preliminary test, we have estimated the composite luminosity functions of early and late VLG dominated systems, excluding both rich clusters and systems with probable field contamination. In this rough comparison, we assume that selection effects are the same for the two types of systems. We have normalized numbers to the total number of galaxies in the two samples (66 for spiral VLG and 71 for elliptical VLG systems). In deriving absolute magnitudes, we applied the mean $K+e$ correction formula $K = 0.03z/(0.01 + z^4)$ adopted by Norberg et al. (2001); at the distances of SSRS2 VLGs (~ 0.05), it is consistent with the correction adopted for the SSRS2 (da Costa et al. 1994; $K = 3z$). As apparent from Fig. 4, taking into account the small number of objects in our samples we cannot find significant differences between the two luminosity functions to $M = -17$, the absolute limiting magnitude at which galaxies around SSRS2 VLGs could still be detected in the 2dFGRS.

There is however a difference when looking at the morphology of the central VLG and the velocity dispersion of the associated system. It is not surprising that the VLGs which are at the center of clusters are giant ellipticals; these clusters have $\sigma \sim 600$ km s^{-1} and an associated X–ray emission at a temperature consistent with their velocity dispersion. Other 3 systems

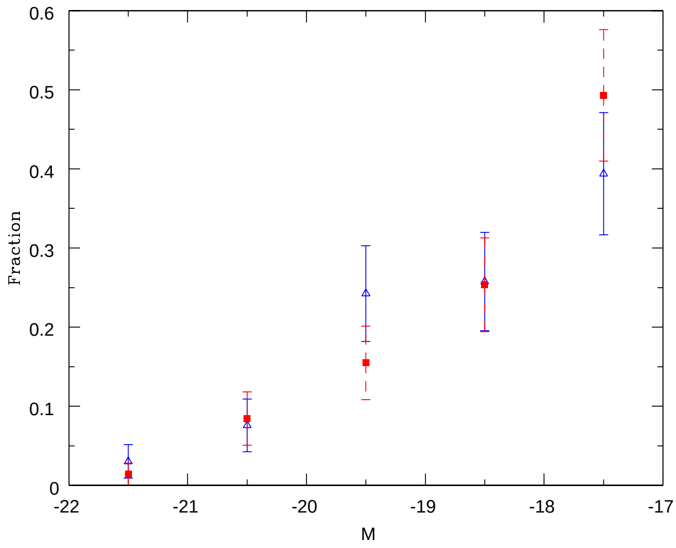

Fig. 4. Normalized luminosity function of systems with an early type VLG (red squares) and a late type VLG (blue triangles), with Poissonian 1σ error bars.

including an early type VLG (one S0 and two ellipticals) have velocity dispersions in the range 300–350 km s^{-1}, and might be considered the low–mass end of galaxy clusters. The remaining S0 in the sample is in a compact group with a small velocity dispersion ($\sim$140 km s^{-1}).

The systems dominated by a spiral VLG have a large spread in velocity dispersion: but as we have seen from the velocity histograms, those with the largest velocity dispersions ($\sim$700 km s^{-1}), VLG 014, VLG 040 and VLG 086, are probably affected by field contamination. Moreover, for these systems no extended X–ray emission is reported in the on–line databases.

Within the limits of the small statistics and lack of completeness, we can conclude that VLGs are in a qualitative agreement with the morphology–density relation: in clusters and rich groups we find only early type VLGs, while among systems originally classified as binaries or triplets, and those with the lowest velocity dispersions (with the exception of the S0 VLG 022) the VLG is a late–type.

The nearby systems we have observed at OHP have lower velocity dispersions, and have probably also a lower richness but the limiting apparent magnitude is also brighter for these systems. The system more similar to our own Local Group is the one associated to VLG 069. It has 10 galaxies with measured redshifts and $M_B \leq -15.5$: even if this is still not a complete sample, the number is comparable to the Local Group, where we find 10 galaxies with $M_V \leq -15.5$. VLG 069 is the main member of a binary system, as Andromeda and the Milky Way; moreover, the VLG 069 system has also a relatively low velocity dispersion, $\sigma \sim 160$ km s^{-1}, still somewhat higher than the velocity dispersion of the Local Group, $\sigma = 61 \pm 8$ km s^{-1} (van den Bergh 1999, 2000), which is indeed lower than the observed range of our VLG systems. However, our observational errors would not allow us to measure accurately such a low velocity dispersion.

Our optical classification of VLG systems can be compared to the X–ray based classification of galaxy groups by

Zabludoff & Mulchaey (1998), who distinguish groups with a bright, central elliptical galaxy and smooth X–ray emission from the hot IGM, and groups without X–ray emission, a few bright late–type galaxies with fainter members, like our Local Group. Our systems with an early–type VLG have generally velocity dispersion and richness comparable to the values found by ZM98 for their 9 poor groups with diffuse X–ray emission. They also find that the 3 groups without X–ray emission have a lower number of members, which seems also consistent with what we find. Zabludoff (2000) has suggested the possibile existence of a third class of groups in a transition phase, but it has still to be demonstrated that the differences between the two classes might be due to evolution instead of their different formation processes.

5. Discussion and conclusions

The number density of galaxies is dominated by faint, small systems. As an example, let us assume a Schechter luminosity function with $M^*_{b_J} = -19.6$, $\alpha = -1.22$ and $\phi^* = 0.02$ (Zucca et al. 2000). The fraction of galaxies brighter than L^* is in fact less than 2% of all galaxies with $M_{b_J} \leq -12.5$. The brightest galaxies with $M_{b_J} \leq -21$ are only 3 out of 10 000. Among these galaxies, we find M 31 and probably the Milky Way (see e.g. van den Berg 1999), which are therefore not typical galaxies, but very special systems. Nevertheless, when looking at the luminosity (mass) density, the contribution of Very Luminous Galaxies (VLGs) with $M_B \leq -21$ to the luminosity density increases to 1.6% and that of M_* galaxies to nearly 30%. VLGs are extremely interesting from the point of view of galaxy formation and large–scale structure. They are visible at large distances ($D_{\max} \sim 170h^{-1}$ Mpc at the limiting magnitude of the SSRS2 $m_B = 15.5$) and their distribution is biased with respect to galaxies of lower luminosity.

There is a common misconception according to which optically very luminous galaxies selected with a large correlation amplitude are early–type galaxies in clusters. In this work we have shown that, at least choosing galaxies in the blue passband, this is not the case. We have presented our observations and 2dFGRS data concerning fields centered on SSRS2 VLGs: we have found clear evidence that VLGs are the brightest members of galaxy systems which can escape standard group finding methods, except of course for the minority of early–type VLGs in rich groups or clusters. VLGs have clustering properties similar to clusters, but most of them are in systems with a galaxy population comparable to loose groups, and some of them are probably comparable to our Local Group. The large correlation amplitude suggests that VLGs are in high density regions; most of them, being spirals, cannot have accreted more than a few percent of their mass through major merging episodes (Tóth & Ostriker 1992), so we have to suppose that these systems already formed with a large, central massive galaxy and low mass companions. On the other hand, the merging of two late–type VLGs could evolve into an early type system, analogously to what was suggested for poor groups by Zabludoff & Mulchaey (2000).

Other recent works appear to confirm the general properties of VLGs which we have found from the analysis of the SSRS2. Giuricin et al. (2001) have analysed the Nearby Optical Galaxy sample, finding a similar trend for the luminosity segregation, and that only 10% of their VLGs reside in clusters; they also find that, while the fraction of very luminous early–type galaxies is larger than the corresponding fraction for the total sample, it is still only 29%, less than than the fraction of Scd galaxies (39%). Moreover, from the analysis of the 2dFGRS Norberg et al. (2002) confirm that "luminosity, and not type, is the dominant factor in determining how the clustering strength of the whole galaxy population varies with luminosity".

The amount of mass associated to VLG systems is still an open question. For example, the lower correlation amplitude for VLGs found in the 2dFGRS would indicate that VLGs are associated to dark halos less massive than typical halo clusters. The increase in local overdensity of galaxies around VLGs should also be better determined. In a recent paper Hogg et al. (2003) analyse the Sloan Digital Sky Survey and find the intriguing results that blue luminous galaxies with $L < 3L^*$ are not apparently found in overdensities, but VLGs have even larger luminosities.

Therefore only further and deeper observations devoted to the detailed study of VLGs, determining the luminosity function of these systems and the dynamics of satellites around the VLGs, together with observations in redder passbands (more representative of the mass of the systems) will shed more light on the properties of VLGs and their environment, and their implications for galaxy formation and evolution.

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Appendix A: The discrepant redshift of Arp 127

The Arp 127 pair (Arp 1966) is made by NGC 0191, a spiral classified as SAB(rs)c: pec, and IC 1563, an S0 pec sp. A third, more compact object is seen among the two galaxies (see Fig. A.1). According to the literature, the redshifts of NGC 0191 and IC 1563 are respectively $v = 5065 \pm 141$ km s^{-1} and $v = 13\,652 \pm 141$ km s^{-1} (Huchra et al. 1993), a surprising difference given the apparent signs of interactions; for this reason IC 1563 was not included in our final catalogue, even if according to the quoted redshift and the apparent magnitude ($m = 14.74$) it should be considered a VLG.

Our measurements for NGC 0191 and IC 1563 are reported in Table A.1, and show that there is no discrepancy: the binary system Arp 127 is at $z \sim 6150$ km s^{-1}, and the two galaxies have a velocity difference of only $\sim$60 km s^{-1} –, i.e. they have the same velocity taking into account the errors. These two galaxies are clearly interacting, as shown by the tidal distortion in NGC 0191.

We suggest that the redshift of 13 652 km s^{-1} should be attributed to the round object between the two galaxies. In fact Beers et al. (1991) report that value for the redshift giving the coordinates of the round object, but identify it as IC 1563, while

Table A.1. Heliocentric redshifts of galaxies in Arp 127.

Iden.	RA (2000)	Dec (2000)	V_h (km s^{-1})	Error	B_t Notes
NGC 0191	00 38 59.3	–09 00 09	6076	32	12.5 [13.68]
IC 1563	00 39 00.2	–09 00 53	6138	39	14.74 [14.39]
0039-0931	00 39 02.0	–09 00 31	13 652	141	

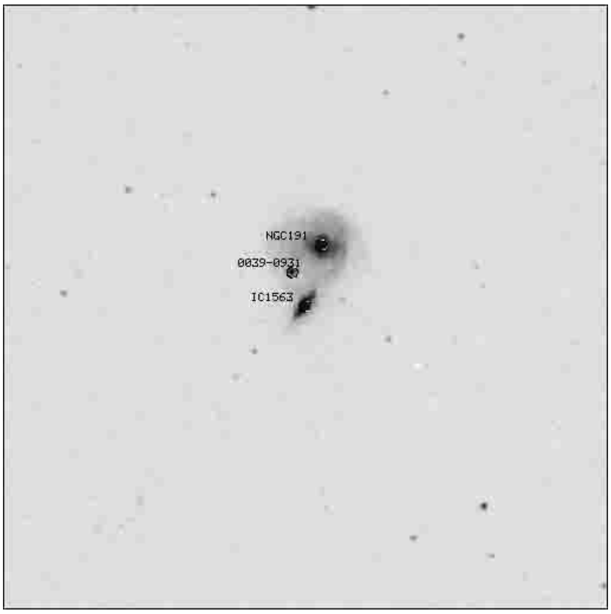


Fig. A.1. Arp 127: finding chart (the scale is 8 × 8 square arcmin).

Huchra et al. (1993) give the approximate coordinates of the Arp 127 system for both NGC 0191 and IC 1563. The velocity of the round object is in the lower part of the velocity range of the A85 galaxy cluster (see Durret et al. 1998) and at an angular distance of 44 arcmin from its center, and it might be a galaxy member of the cluster.

The new redshift for IC 1563 means that this galaxy has $M = -19.2$, i.e. it is a typical M^* galaxy and not a VLG. In Table A.1 we report also the photometric observations of Reshetnikov & Combes (1996).

References

Abell, G. O. 1958, ApJS, 3, 211
Alonso, M. V., da Costa, L. N., Pellegrini, P. S., & Kurtz, M. J. 1993, AJ, 106, 676
Alonso, M. V., da Costa, L. N., Latham, D. W., Pellegrini, P. S., & Milone, A. A. E. 1994, AJ, 108, 1987
Arp, H. 1966, ApJS, 14, 1
Bardeen, J. R., Bond, J. R., Kaiser, N., & Szalay, A. S. 1986, ApJ, 314, 15
Beers, T. C., Forman, W., Huchra, J. P., Jones, C., & Gebhardt, K. 1991, AJ, 102, 1581
Benoist, C., Cappi, A., da Costa, L. N., et al. 1999, ApJ, 514, 563
Benoist, C., Maurogordato, S., da Costa, L. N., Cappi, A., & Schaeffer, R. 1996, ApJ, 472, 452
Cappi, A., Benoist, C., da Costa, L. N., & Maurogordato, S. 1998, AA, 335, 779 (Paper I)
Cappi, A., da Costa, L. N., Benoist, C., Maurogordato, S., & Pellegrini, P. S. 1998, AJ, 115, 2250
Cappi, A., & Maurogordato, S. 1995, ApJ, 438, 507
Colless, M., Dalton, G., Maddox, S., et al. 2001, MNRAS, 328, 1039
da Costa, L. N., Geller, M. J., Pellegrini, P. S., et al. 1994, ApJ, 424, L1
Durret, F., Felenbok, P., Lobo, C., & Slezak, E. 1998, AAS, 129, 281
Ebeling, H., Edge, A. C., Böhringer, H., et al. 1998, MNRAS, 301, 881
Fadda, D., Girardi, M., Giuricin, G., Mardirossian, F., & Mezzetti, M. 1996, ApJ, 473, 670
Finoguenov, A., Arnaud, M., & David, L. P. 2001, ApJ, 555, 191
Geller, M. J., & Huchra, J. P. 1989, Science, 246, 897
Giuricin, G., Samurović, S., Girardi, M., Mezzetti, M., & Marinoni, C. 2001, ApJ, 554, 857
Gregory, S. A., & Burns, J. O. 1982, ApJ, 255, 373
Hamilton, A. J. S. 1988, ApJ, 331, L59
Hickson, P. 1982, ApJ, 255, 382
Hogg, D. W., Blanton, M. R., Eisenstein, D. J., et al. 2003, ApJ, 585, L5
Huchra, J., Latham, D. W., da Costa, L. N., Pellegrini, P. S., & Willmer, C. N. A. 1993, AJ, 105, 1637
Kaiser, N. 1984, ApJ, 284, L9
Lubin, L. M., & Bahcall, N. A. 1993, ApJ, 415, L17
Lumsden, S. L., Nichol, R. C., Collins, C. A., & Guzzo, L. 1992, MNRAS, 258, 1
Maddox, S. J., Efstathiou, G., Sutherland, W. J., & Loveday, J. 1990a, MNRAS, 243, 692
Maddox, S. J., Efstathiou, G., Sutherland, W. J., & Loveday, J. 1990b, MNRAS, 246, 433
Maddox, S. J., Efstathiou, G., Sutherland, W. J., & Loveday, J. 1996, MNRAS, 283, 1227
Moore, B., Ghigna, S., Governato, F., et al. 1999, ApJ, 524, L19
Mulchaey, J. S., & Zabludoff, A. I. 1998, ApJ, 496, 73
Norberg, P., Baugh, C. M., Hawkins, Ed, et al. (the 2dFGRS collaboration) 2001, MNRAS, 328, 64
Norberg, P., Baugh, C. M., Hawkins, Ed, et al. (the 2dFGRS collaboration) 2002, MNRAS, 332, 827
Norberg, P., Cole, S., Baugh, C. M., et al. (the 2dFGRS collaboration) 2002, MNRAS, 336, 907
Prandoni, I., Iovino, A., & MacGillivray, H. T. 1994, AJ, 107, 1235
Reshetnikov, V., & Combes, F. 1996, AAS, 116, 417
Strauss, M. A., Huchra, J. P., Davies, M., et al. 1992, ApJS, 83, 29
Tonry, J., & Davis, M. 1979, AJ, 84, 1511
Tóth, G., & Ostriker, J. P. 1992, ApJ, 389, 5
Tucker, D. L., Oemler, A. Jr., Hashimoto, Y., et al. 2000, ApJS, 130, 237
Tully, R. B. 1986, ApJ, 303, 25
van den Bergh, S. 1999, A&ARv, 9, 273
van den Bergh, S. 2000, PASP, 112, 529
White, R. A., Bliton, M., Bhavsar, S. P., et al. 1999, AJ, 118, 2014
Willmer, C. N. A., da Costa, L. N., & Pellegrini, P. S. 1998, AJ, 115, 869
Yahil, A., & Vidal, N. V. 1977, ApJ, 214, 347
Zabludoff, A. I. 1999, in The Stellar Content of Local Group Galaxies, ed. P. Whitelock, & R. Cannon, IAU Symp., 192, 433
Zabludoff, A. I., & Mulchaey, J. S. 1998, ApJ, 496, 39
Zabludoff, A. I., & Mulchaey, J. S. 2000, ApJ, 539, 136
Zucca, E., Zamorani, G., Vettolani, G., et al. 1997, A&A, 326, 477

Online Material

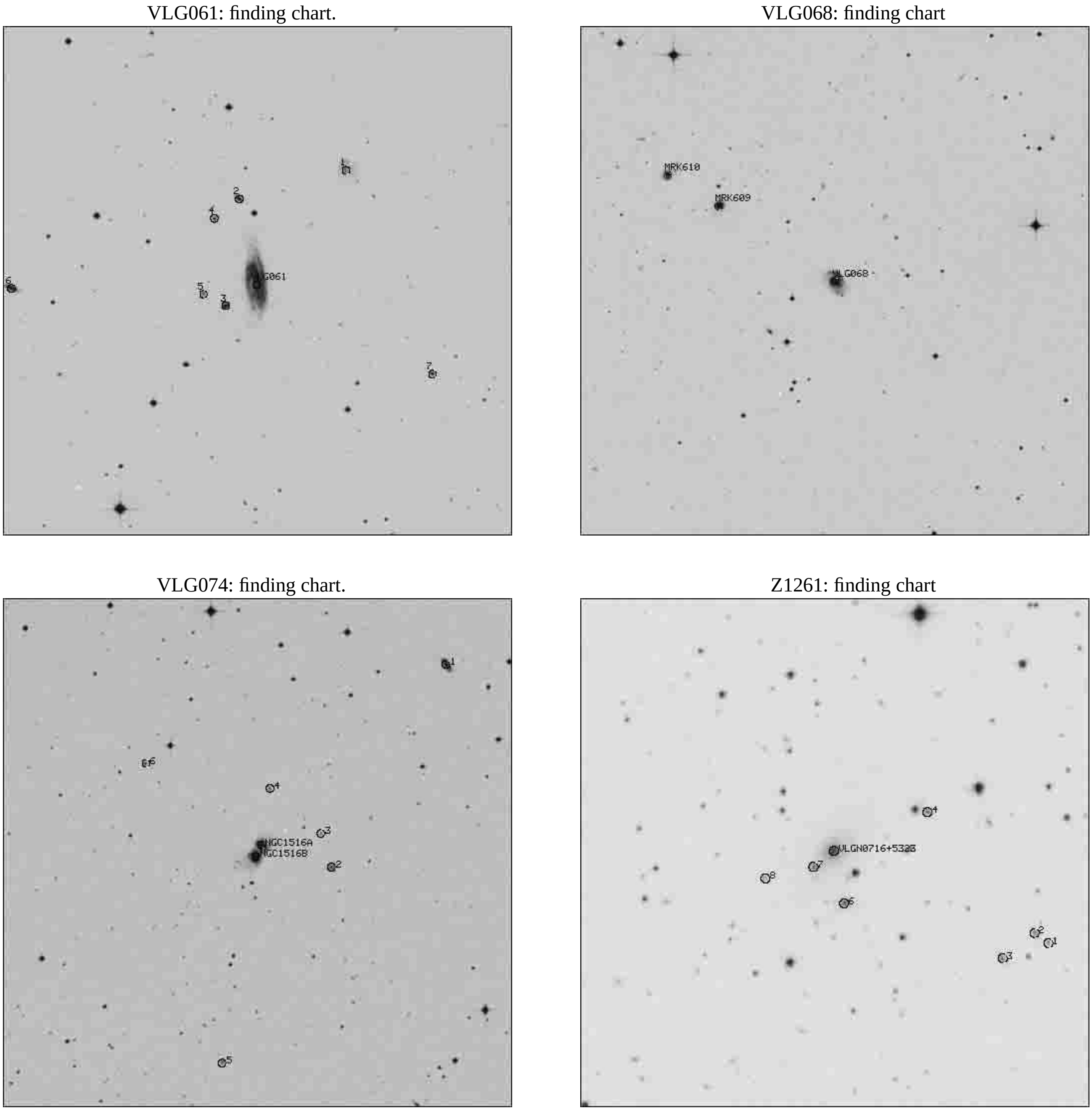


Fig. 1. Finding charts of the VLG fields observed at OHP (the scale is approximately 30×30 square arcmin).

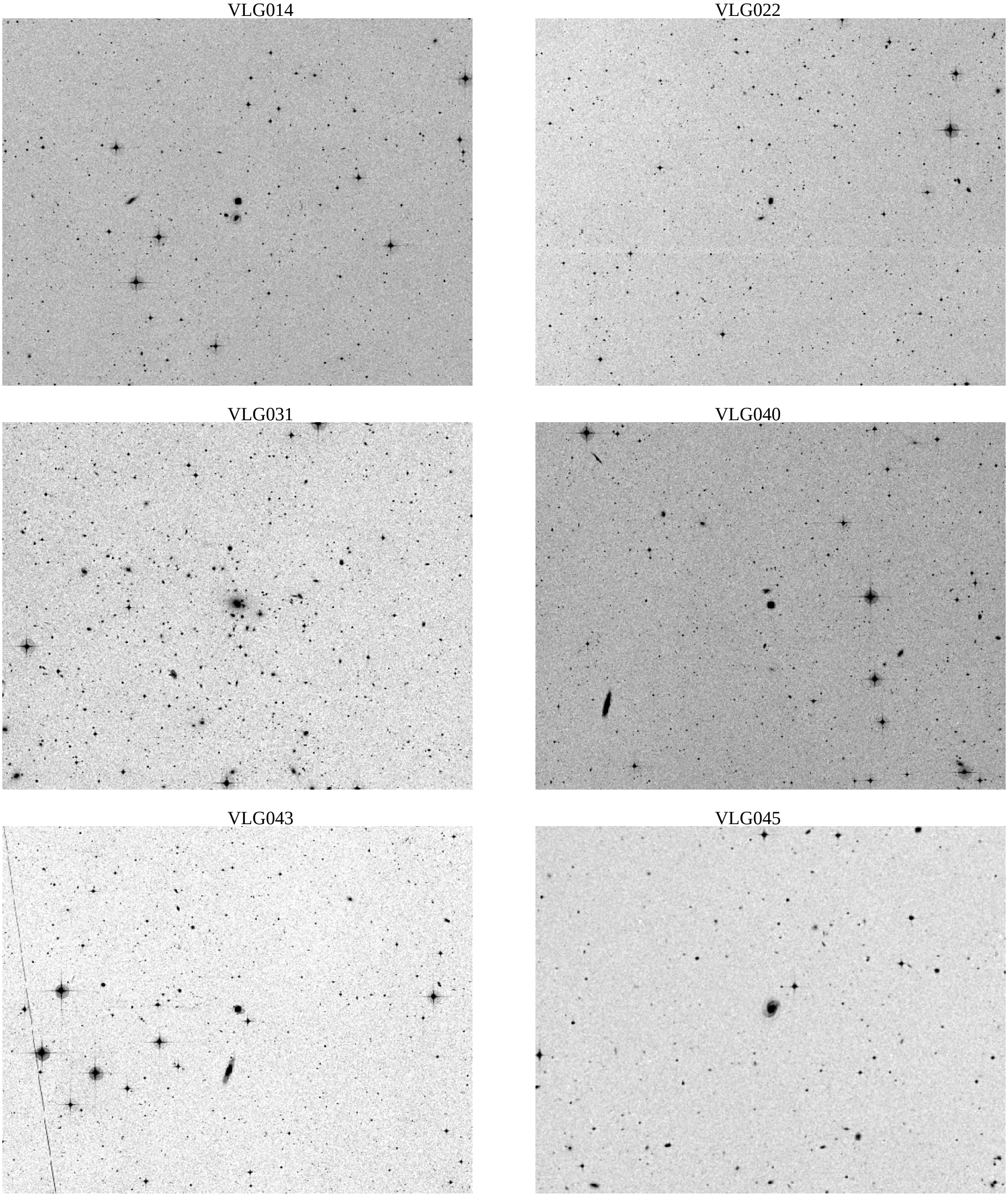
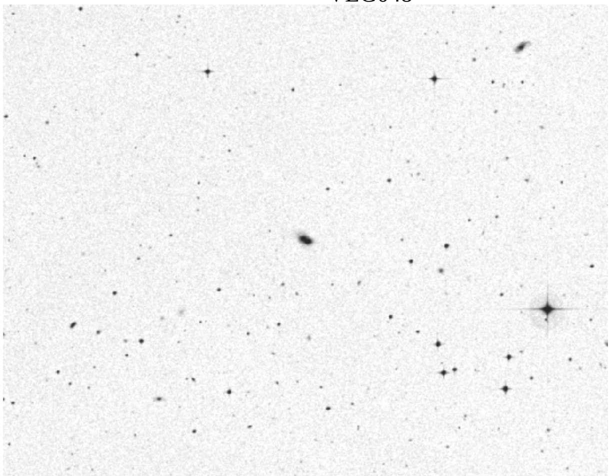
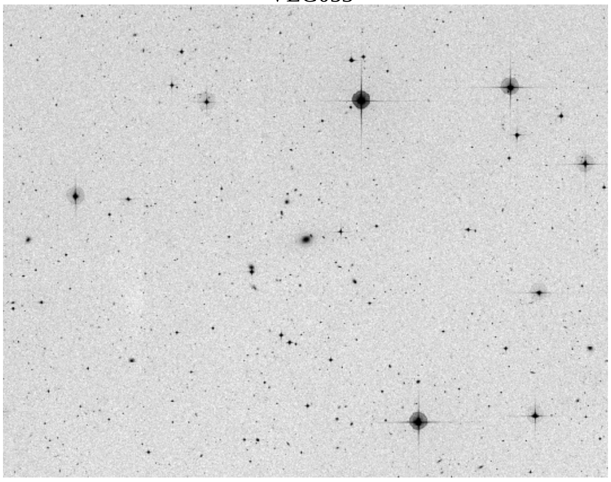


Fig. 2. Finding charts of the VLG fields selected from the 2dFGRS (the scale is approximately 40×30 square arcmin).

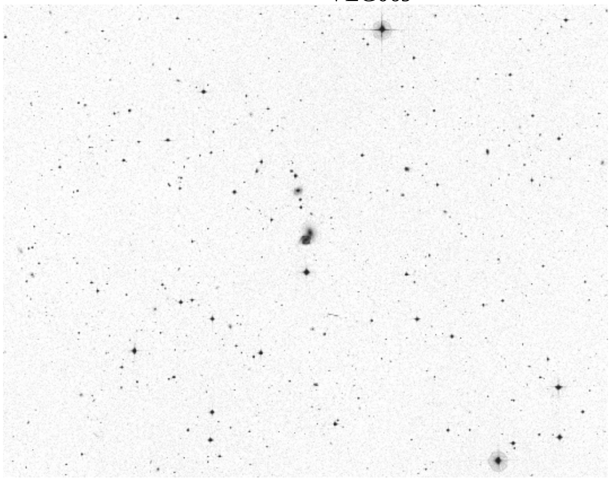
VLG048



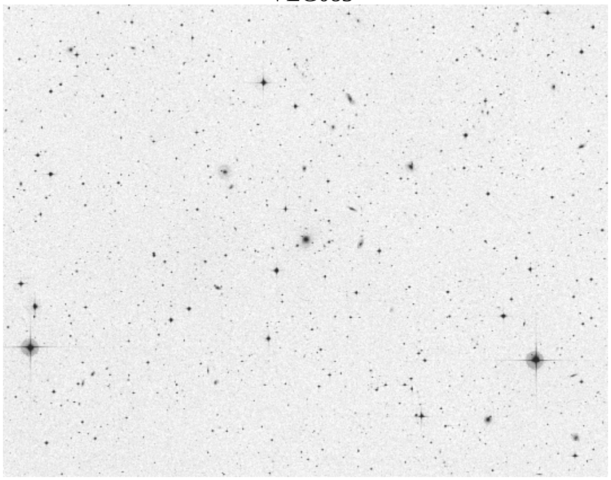
VLG053



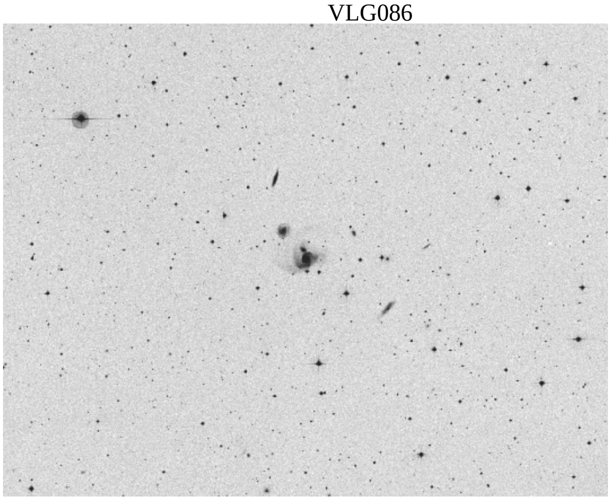
VLG069



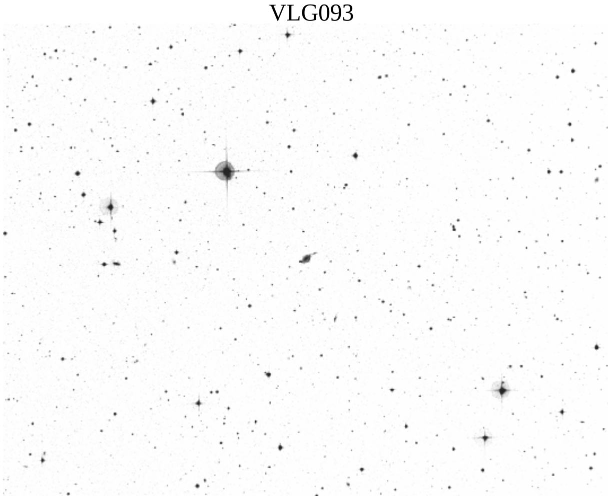
VLG083



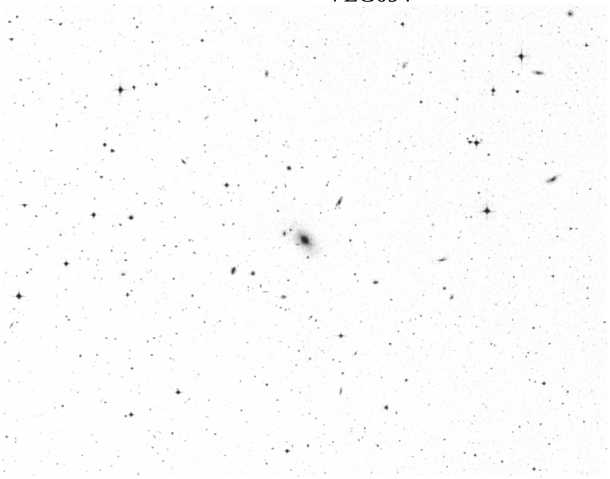
VLG086



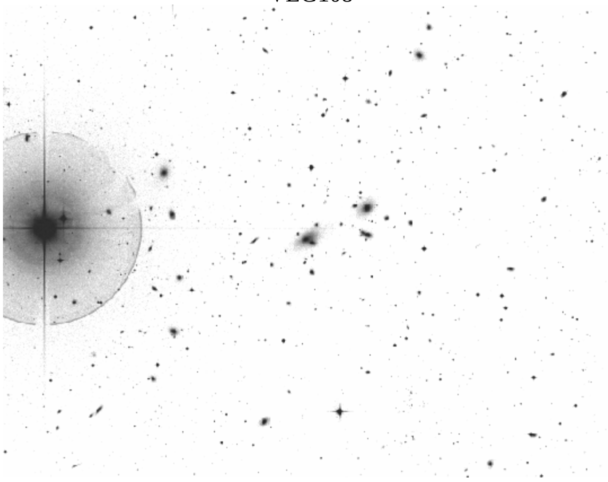
VLG093



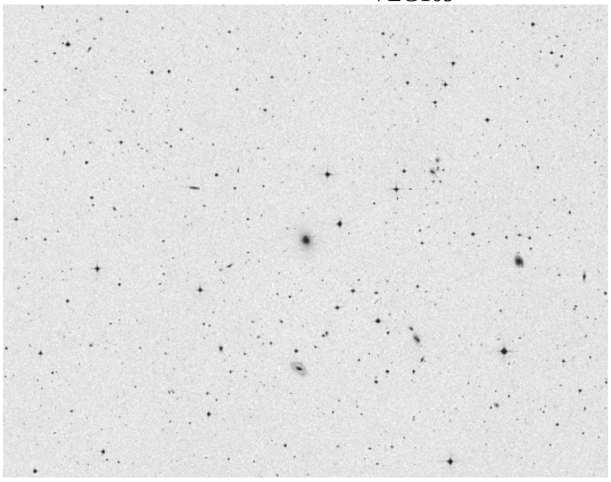
VLG094



VLG108



VLG109



Appendix B: 2dFGRS data

In the following tables we list the 2dFGRS galaxies which we have selected as members of VLG systems. We give in Col. (1) our identification number, in Cols. (2) and (3) respectively right ascension and declination, in Col. (4) the b_J magnitude, and in Col. (5) the redshift.

We have listed the 2dFGRS data on the VLG when available, otherwise we have reported the SSRS2 data.

We could compare magnitudes and redshifts of the 2dFGRS and SSRS2 for 5 VLGs with 2dFGRS data (VLG 014, VLG 022, VLG 043, VLG 045, VLG 048, VLG 109): we find an average velocity difference $< V(2dF) - V(SSRS2) >= 118$ km s^{-1} with an rms of 155 km s^{-1} and an average magnitude difference $< b_J(2dF) - m_B(SSRS2) >= 0.20$, with an rms of 0.46. The magnitude difference is consistent with the ~ 0.2 zero–point shift expected between the blue magnitudes of the SSRS2 (Alonso et al. 1993, 1994; da Costa et al. 1994) and the APM b_J magnitudes on which the 2dFGRS is based (Maddox et al. 1990, 1990, 1996). Note that for bright galaxies, magnitudes are not very precise: the APM b_J magnitudes have a precision of 0.2 in the range 17–19.5 but are significantly affected by saturation at magnitudes brighter than $b_J = 16$ (Norberg et al. 2002).

Table B.1. VLG 014 system.

Iden.	RA (J2000)	DEC (J2000)	b_J	Redshift	
1	00 49 16.58	-27 15 02.3	17.04	0.03514	
2	00 49 32.12	-27 40 00.1	18.14	0.04093	
3	00 49 45.62	-27 45 15.2	16.65	0.04012	
4	00 49 57.81	-26 55 11.7	18.86	0.04342	
5	00 50 20.18	-27 47 36.3	17.41	0.03942	
6	00 50 21.56	-27 37 15.5	18.74	0.04076	
7	00 51 03.74	-27 41 06.2	17.43	0.03996	
8	00 51 27.98	-27 38 24.5	16.89	0.04005	
9	00 52 15.02	-27 19 41.4	15.17	0.03983	VLG014
10	00 52 15.58	-27 01 35.9	18.13	0.03534	
11	00 52 15.64	-27 20 58.1	15.62	0.04005	
13	00 52 25.52	-26 59 17.6	16.96	0.03553	
13	00 52 40.97	-27 15 51.2	18.21	0.03498	
14	00 53 11.23	-26 47 31.7	19.32	0.03946	

Table B.2. VLG 022 system.

Iden.	RA (J2000)	DEC (J2000)	b_J	Redshift	
1	00 58 52.33	-28 18 11.9	15.64	0.05753	VLG022
2	00 58 55.81	-28 19 30.2	16.53	0.05703	
3	01 00 58.93	-28 21 39.9	19.28	0.05640	

Table B.3. VLG 031 system.

Iden.	RA (J2000)	DEC (J2000)	b_J	Redshift	
1	01 07 17.22	-15 04 48.0	18.55	0.05560	
2	01 07 41.81	-14 54 56.7	18.06	0.05044	
3	01 08 09.82	-15 12 18.7	17.13	0.05197	
4	01 08 16.05	-14 52 07.8	17.05	0.05272	
5	01 08 30.64	-14 57 04.7	16.07	0.05112	
6	01 08 32.40	-15 03 10.4	18.21	0.05184	
7	01 08 32.44	-15 08 54.6	18.26	0.05371	
8	01 08 50.70	-15 24 32.2	14.36	0.05326	VLG031; data from SSRS2
9	01 09 40.52	-14 55 50.5	17.47	0.05813	
10	01 10 15.95	-15 18 17.3	17.28	0.05563	
11	01 10 20.67	-15 18 08.1	17.44	0.05439	
12	01 10 21.68	-15 15 22.1	18.09	0.05634	
13	01 10 25.17	-15 15 24.8	15.39	0.05666	
14	01 10 26.38	-15 18 57.4	17.59	0.05309	
15	01 10 27.46	-15 06 43.1	17.58	0.04893	

Table B.4. VLG 040 system.

Iden.	RA (J2000)	DEC (J2000)	b_J	Redshift	
1	01 37 40.78	-28 37 01.9	16.83	0.04254	
2	01 38 20.37	-28 38 58.5	17.61	0.04307	
3	01 38 40.39	-28 57 17.6	19.23	0.04067	
4	01 38 56.46	-28 35 08.7	18.96	0.04261	
5	01 38 59.71	-28 34 21.2	14.64	0.04212	VLG040; data from SSRS2
6	01 39 21.29	-29 00 42.2	17.28	0.04205	
7	01 41 07.26	-29 07 42.7	18.16	0.03683	
8	01 41 47.60	-28 12 26.4	19.37	0.03812	
9	01 41 48.65	-28 31 28.7	17.00	0.03724	
10	01 41 55.43	-28 32 53.0	15.77	0.03768	

Table B.5. VLG 043 system.

Iden.	RA (J2000)	DEC (J2000)	b_J	Redshift	
1	01 38 44.44	-27 50 47.4	16.50	0.05666	
2	01 39 17.85	-27 49 05.0	17.17	0.05702	
3	01 39 21.51	-27 48 47.1	19.21	0.05596	
4	01 39 36.50	-28 25 41.6	19.14	0.05888	
5	01 39 51.04	-27 48 51.9	19.00	0.05674	
6	01 39 57.12	-27 57 21.7	15.63	0.05640	VLG043
7	01 40 03.08	-27 59 04.0	18.05	0.05652	
8	01 40 31.09	-28 04 36.2	19.14	0.05924	
9	01 40 39.96	-27 28 58.6	18.82	0.05372	
10	01 40 55.41	-27 49 40.2	18.62	0.05915	
11	01 41 30.07	-27 46 31.8	17.52	0.05704	
12	01 41 37.09	-27 45 33.0	18.61	0.05658	
13	01 41 42.11	-27 40 18.1	17.03	0.05687	
14	01 41 44.35	-28 07 23.1	19.43	0.05319	
15	01 42 19.91	-27 59 36.8	18.75	0.05674	

Table B.6. VLG 045 system.

Iden.	RA (J2000)	DEC (J2000)	b_J	Redshift	
1	01 48 02.03	-28 49 30.2	19.00	0.05580	
2	01 48 37.65	-29 03 18.1	18.34	0.06024	
3	01 49 00.27	-28 36 28.9	17.32	0.05612	
4	01 49 05.17	-28 33 57.5	17.00	0.05547	
5	01 49 12.19	-28 37 10.2	18.86	0.05607	
6	01 49 22.26	-28 57 38.4	18.04	0.05604	
7	01 49 40.19	-29 15 21.7	19.04	0.05552	
8	01 50 05.55	-28 49 54.0	18.56	0.05576	
9	01 50 06.99	-28 49 17.0	18.36	0.05756	
10	01 50 08.49	-28 45 46.1	18.20	0.05769	
11	01 50 14.15	-28 52 18.0	14.96	0.05759	VLG045
12	01 50 20.74	-29 05 32.0	18.83	0.05736	
13	01 50 43.56	-28 58 56.4	17.04	0.05606	
14	01 50 44.60	-29 11 10.0	17.92	0.06084	
15	01 51 00.56	-28 54 27.9	16.66	0.05802	
16	01 51 01.84	-29 15 35.9	18.64	0.05592	
17	01 51 04.92	-28 59 50.8	19.41	0.05723	
18	01 51 11.10	-28 54 42.2	17.54	0.05622	
19	01 51 32.85	-28 29 32.6	18.04	0.05681	
20	01 51 35.00	-28 55 42.8	18.70	0.06092	
21	01 51 39.92	-28 30 14.8	19.09	0.05707	

Table B.7. VLG 048 system.

Iden.	RA (J2000)	DEC (J2000)	b_J	Redshift	
1	01 53 13.63	-27 54 33.2	19.06	0.05883	
2	01 53 16.97	-27 49 32.7	17.14	0.06007	
3	01 53 34.87	-28 34 07.0	17.54	0.05741	
4	01 53 55.02	-28 14 37.4	19.32	0.05816	
5	01 54 11.90	-28 23 02.1	17.01	0.05745	
6	01 54 12.78	-27 51 57.1	16.90	0.06024	
7	01 54 13.11	-27 52 19.7	17.94	0.05717	
8	01 54 26.25	-27 47 43.0	18.43	0.06103	
9	01 54 27.30	-27 51 08.0	19.30	0.06021	
10	01 54 29.09	-28 27 22.4	17.76	0.05686	
11	01 54 39.87	-27 59 20.8	18.40	0.06010	
12	01 54 41.67	-28 10 10.2	19.31	0.05614	
13	01 54 48.16	-28 11 45.5	19.13	0.05954	
14	01 54 48.72	-28 08 56.8	15.66	0.05726	VLG048
15	01 55 03.18	-28 12 57.9	18.96	0.05750	
16	01 55 09.03	-27 41 35.3	19.45	0.05734	
17	01 55 15.56	-28 11 37.6	18.81	0.05818	
18	01 55 39.26	-27 53 56.5	19.10	0.05897	
19	01 55 49.42	-28 00 13.2	17.53	0.05813	
20	01 56 35.77	-27 55 39.7	19.32	0.05789	

Table B.8. VLG 053 system.

Iden.	RA (J2000)	DEC (J2000)	b_J	Redshift	
1	02 11 25.59	-26 49 51.0	17.93	0.05572	
2	02 11 48.77	-26 35 24.5	18.28	0.05744	
3	02 12 07.18	-26 46 18.8	16.03	0.05566	
4	02 12 07.92	-26 49 38.9	17.72	0.05555	
5	02 12 27.64	-26 38 18.4	18.76	0.05903	
6	02 12 36.11	-26 30 03.9	17.25	0.05513	
7	02 12 36.71	-26 38 29.8	18.46	0.05650	
8	02 12 40.02	-26 29 11.6	18.10	0.05770	
9	02 12 40.28	-26 45 21.8	19.04	0.05890	
10	02 12 43.66	-26 09 50.9	17.70	0.05882	
11	02 12 44.45	-26 27 28.1	19.16	0.05765	
12	02 12 49.00	-26 27 35.0	15.16	0.05695	VLG053; data from SSRS2
13	02 12 51.77	-26 24 39.8	18.56	0.05715	
14	02 12 52.89	-26 47 58.4	15.15	0.05634	
15	02 12 53.46	-26 39 42.3	18.70	0.05724	
16	02 12 54.13	-26 25 20.2	17.02	0.05721	
17	02 12 57.90	-26 42 24.9	18.37	0.05536	
18	02 13 04.47	-26 40 04.4	18.56	0.05652	
19	02 13 08.44	-26 30 11.9	18.62	0.05749	
20	02 13 27.83	-26 48 41.7	18.38	0.05891	
21	02 13 31.14	-26 25 39.3	19.21	0.05916	
22	02 13 35.09	-26 34 47.2	17.00	0.05752	
23	02 13 38.35	-26 50 23.4	19.34	0.05890	
24	02 13 45.41	-26 49 17.1	18.78	0.05958	
25	02 13 46.08	-26 46 12.7	17.96	0.05881	
26	02 14 02.66	-26 27 38.3	16.82	0.05832	
27	02 14 06.69	-26 31 21.9	18.30	0.05605	
28	02 14 07.28	-26 29 43.4	18.80	0.05658	
29	02 14 22.41	-26 39 48.9	16.69	0.05909	
30	02 14 33.71	-26 28 02.9	18.24	0.05676	
31	02 14 46.39	-26 35 14.0	18.70	0.05941	
32	02 14 51.04	-26 39 37.1	15.77	0.05784	
33	02 14 58.37	-26 16 18.9	18.87	0.05661	

Table B.9. VLG 069 system.

Iden.	RA (J2000)	DEC (J2000)	b_J	Redshift	
1	03 29 13.06	-28 07 47.8	19.37	0.03771	
2	03 29 20.35	-28 09 10.5	18.78	0.03778	
3	03 29 20.92	-28 08 00.9	14.22	0.03773	
4	03 29 32.13	-28 09 35.4	16.55	0.03818	
5	03 29 56.13	-28 46 14.5	14.09	0.03647	companion of the VLG?
6	03 29 56.79	-28 46 29.8	13.95	0.03687	VLG069; data from SSRS2
7	03 29 58.84	-28 43 35.5	15.23	0.03830	
8	03 30 11.98	-28 59 49.0	19.20	0.03778	

Table B.10. VLG 083 system.

Iden.	RA (J2000)	DEC (J2000)	b_J	Redshift	
1	21 58 44.19	-19 05 08.0	17.22	0.05913	
2	21 58 49.05	-19 09 46.3	18.51	0.05877	
3	21 58 55.66	-19 03 13.7	19.04	0.05817	
4	21 58 57.89	-19 20 14.5	17.03	0.05751	
5	21 59 10.30	-19 17 13.3	17.78	0.05682	
6	21 59 10.32	-19 24 23.5	18.91	0.05777	
7	21 59 19.18	-19 22 53.1	15.76	0.05814	
8	21 59 31.49	-19 06 59.1	18.34	0.05715	
9	21 59 36.35	-19 22 03.7	18.45	0.05788	
10	21 59 40.51	-19 10 40.1	18.32	0.05752	
11	21 59 43.73	-19 16 26.5	19.16	0.05901	
12	21 59 48.86	-19 20 01.8	18.14	0.05814	
13	21 59 52.95	-19 04 50.0	18.70	0.05691	
14	21 59 56.81	-19 06 06.6	19.01	0.05808	
15	22 00 04.31	-19 09 58.3	19.18	0.05778	
16	22 00 05.40	-19 12 16.0	15.48	0.05858	VLG083; data from SSRS2
17	22 00 07.52	-19 12 38.5	17.93	0.05731	
18	22 00 10.74	-19 02 48.0	18.20	0.05872	
19	22 00 13.16	-18 50 12.4	19.19	0.05848	
20	22 00 22.42	-18 43 14.8	18.99	0.05777	
21	22 00 24.22	-19 09 11.0	16.90	0.05830	
22	22 00 49.05	-19 00 57.6	17.65	0.05588	
23	22 00 55.20	-19 19 58.5	18.74	0.05701	
24	22 00 56.22	-19 09 11.8	19.15	0.05646	
25	22 01 04.69	-19 01 04.6	16.84	0.05713	
26	22 01 28.62	-19 23 53.1	17.34	0.05860	
27	22 01 34.80	-19 26 41.1	18.37	0.05715	
28	22 01 43.74	-19 19 19.4	17.46	0.05709	
29	22 01 56.98	-19 22 54.9	17.99	0.05755	
30	22 02 05.65	-19 23 45.2	17.24	0.05694	

Table B.11. VLG 086 system.

Iden.	RA (J2000)	DEC (J2000)	b_J	Redshift	
1	22 03 38.55	-27 58 32.7	18.02	0.02329	
2	22 03 41.79	-27 56 07.2	15.03	0.02014	
3	22 03 45.74	-27 47 52.5	15.50	0.02327	
4	22 03 54.11	-27 51 30.5	19.14	0.02155	
5	22 04 03.25	-27 29 38.5	16.18	0.02316	
6	22 04 57.79	-28 05 18.4	19.01	0.02291	
7	22 06 14.11	-27 57 14.8	14.32	0.02400	
8	22 06 21.29	-27 35 22.0	17.69	0.02014	
9	22 06 34.06	-27 59 30.8	14.99	0.02287	
10	22 06 36.75	-27 48 05.3	18.89	0.02312	
11	22 06 38.17	-27 57 24.7	17.65	0.02331	
12	22 07 27.04	-27 55 34.9	18.67	0.02309	
13	22 07 33.04	-27 44 51.8	18.98	0.02066	
14	22 07 57.11	-28 15 01.2	16.43	0.02593	
15	22 08 12.28	-27 05 56.1	16.83	0.01956	
16	22 08 26.36	-28 13 07.7	19.21	0.02689	
17	22 08 33.09	-27 56 12.1	18.88	0.02331	
18	22 08 50.20	-26 54 05.3	18.25	0.01885	
19	22 09 07.45	-27 48 22.8	14.19	0.02298	
20	22 09 07.68	-27 48 34.1	13.05	0.02279	VLG086; data from SSRS2
21	22 09 13.08	-27 34 03.9	15.70	0.02352	
22	22 09 14.08	-27 46 57.1	14.66	0.02431	
23	22 09 14.28	-27 24 11.8	14.98	0.02373	
24	22 09 16.29	-27 43 50.0	15.09	0.02398	
25	22 09 38.77	-27 33 18.2	19.00	0.02481	
26	22 09 43.74	-27 35 56.1	18.48	0.02359	
27	22 09 47.10	-26 53 02.7	18.91	0.02141	
28	22 09 50.52	-27 32 06.0	15.18	0.02450	
29	22 09 52.15	-27 37 53.8	19.03	0.02586	
30	22 11 52.69	-27 18 45.2	19.15	0.02410	
31	22 12 20.97	-27 29 17.1	15.93	0.02374	
32	22 12 29.62	-27 54 17.8	18.65	0.02740	
33	22 13 23.04	-27 56 01.9	18.34	0.02404	
34	22 13 23.52	-27 13 10.6	14.00	0.02375	
35	22 13 28.77	-28 07 17.6	19.05	0.02691	
36	22 13 56.58	-27 30 31.3	17.21	0.01765	
37	22 14 39.41	-27 27 52.0	13.97	0.01789	

Table B.12. VLG 093 system.

Iden.	RA (J2000)	DEC (J2000)	b_J	Redshift	
1	22 29 45.57	-30 28 30.1	18.88	0.05894	
2	22 29 49.89	-30 12 24.9	18.62	0.05316	
3	22 29 50.60	-30 31 02.9	14.73	0.05356	VLG093; data from SSRS2
4	22 29 55.77	-30 32 39.7	18.06	0.05389	
5	22 30 11.21	-30 21 19.5	19.32	0.05700	
6	22 30 15.05	-30 47 03.4	18.35	0.05868	
7	22 30 17.94	-30 44 42.8	17.93	0.05788	
8	22 30 21.04	-30 51 48.2	19.14	0.05832	
9	22 30 23.39	-30 40 56.3	18.69	0.05686	
10	22 30 29.91	-30 59 31.5	18.07	0.05709	
11	22 30 36.86	-30 16 37.8	19.21	0.05513	
12	22 30 37.17	-30 37 41.3	17.81	0.05815	
13	22 30 41.06	-30 26 09.7	18.83	0.05492	
14	22 30 50.02	-30 24 01.5	19.06	0.05778	
15	22 31 02.16	-30 43 12.8	18.28	0.05793	

Table B.13. VLG 094 system.

Iden.	RA (J2000)	DEC (J2000)	b_J	Redshift	
1	22 29 36.48	-25 01 38.5	17.52	0.03260	
2	22 29 42.08	-25 27 31.0	19.13	0.03231	
3	22 30 04.41	-24 59 05.2	17.98	0.03186	
4	22 30 07.11	-24 58 22.4	14.56	0.03116	
5	22 30 12.09	-25 18 47.6	19.25	0.03302	
6	22 30 23.82	-25 28 10.0	18.24	0.03317	
7	22 30 35.88	-24 36 56.9	17.77	0.03363	
8	22 30 44.70	-25 43 14.6	18.85	0.03620	
9	22 30 57.29	-25 10 45.9	15.75	0.03384	
10	22 31 02.76	-25 20 34.8	15.12	0.03296	
11	22 31 17.61	-24 58 07.8	19.26	0.03129	
12	22 31 17.97	-24 43 58.5	15.98	0.03410	
13	22 31 27.37	-25 15 41.5	18.41	0.03502	
14	22 31 31.09	-25 53 13.0	15.03	0.03458	
15	22 31 32.05	-25 25 12.9	15.79	0.03376	
16	22 31 41.06	-25 13 36.6	16.67	0.03378	
17	22 31 41.66	-25 30 21.0	18.84	0.03589	
18	22 31 49.74	-25 26 28.5	16.57	0.03190	
19	22 31 55.43	-25 30 39.9	17.04	0.03163	
20	22 31 58.81	-25 21 39.3	15.40	0.03617	
21	22 31 59.49	-25 32 55.6	16.05	0.03310	
22	22 32 03.77	-25 38 47.8	18.83	0.03435	
23	22 32 07.45	-25 24 53.4	18.35	0.03132	
24	22 32 08.10	-25 23 51.0	13.92	0.03409	VLG094; data from SSRS2
25	22 32 11.88	-26 00 19.7	18.77	0.03234	
26	22 32 13.43	-25 23 27.7	16.52	0.03406	
27	22 32 17.26	-25 13 57.4	16.99	0.03179	
28	22 32 17.77	-25 18 49.4	18.46	0.03668	
29	22 32 25.17	-25 20 33.0	18.53	0.03347	
30	22 32 26.99	-25 25 35.3	15.76	0.03632	
31	22 32 33.25	-25 16 29.4	17.15	0.03415	
32	22 32 55.19	-26 02 16.9	18.10	0.03246	
33	22 34 29.62	-25 43 07.3	15.20	0.03330	
34	22 34 49.05	-25 14 29.0	16.51	0.03396	
35	22 34 49.93	-25 36 01.7	17.20	0.03463	
36	22 35 10.71	-25 02 56.7	16.75	0.03465	
37	22 35 18.30	-25 06 56.8	15.76	0.03323	
38	22 35 26.06	-25 04 29.3	14.65	0.03409	
39	22 35 39.69	-25 06 35.8	18.45	0.03474	

Table B.14. VLG 108 system.

Iden.	RA (J2000)	DEC (J2000)	b_J	Redshift
1	23 43 15.45	-28 14 26.7	17.35	0.02836
2	23 43 23.27	-28 11 17.9	17.80	0.02845
3	23 43 35.67	-28 06 04.0	16.67	0.02974
4	23 44 22.30	-28 11 44.6	17.69	0.02787
5	23 44 38.81	-27 39 34.5	15.93	0.03031
6	23 45 03.76	-27 59 11.9	17.99	0.02987
7	23 45 03.84	-27 20 41.4	16.80	0.02782
8	23 45 16.64	-27 18 57.1	18.02	0.02784
9	23 45 28.01	-27 57 49.0	16.63	0.03058
10	23 45 32.63	-27 37 21.8	19.36	0.02647
11	23 45 34.49	-28 10 48.0	17.67	0.02811
12	23 45 40.30	-27 51 48.8	16.91	0.02876
13	23 45 41.19	-27 48 27.8	17.65	0.03093
14	23 45 52.57	-28 02 53.0	17.86	0.03008
15	23 45 55.71	-28 13 52.1	18.53	0.02636
16	23 46 00.76	-27 53 44.3	17.30	0.02871
17	23 46 16.09	-27 30 37.3	15.99	0.02933
18	23 46 22.83	-28 00 18.4	15.34	0.02696
19	23 46 38.39	-28 15 11.4	16.81	0.02665
20	23 46 41.44	-27 58 04.4	18.95	0.02947
21	23 46 43.40	-27 56 01.9	18.23	0.03097
22	23 46 44.02	-27 50 29.2	17.93	0.03259
23	23 46 45.76	-27 49 23.7	18.60	0.03180
24	23 46 47.33	-27 33 21.2	17.88	0.02878
25	23 46 49.87	-28 10 08.9	16.02	0.03251
26	23 46 50.07	-27 57 29.1	17.96	0.03142
27	23 46 53.00	-27 34 47.8	16.68	0.03142
28	23 46 54.99	-28 21 42.6	15.62	0.02425
29	23 46 58.15	-28 02 55.6	17.71	0.02706
30	23 47 11.34	-28 14 25.5	18.00	0.02472
31	23 47 12.08	-27 55 48.4	15.98	0.02963
32	23 47 13.29	-28 01 03.0	16.63	0.03345
33	23 47 14.15	-28 01 48.9	17.72	0.02826
34	23 47 14.39	-28 11 35.7	16.62	0.02922
35	23 47 14.80	-27 57 27.9	14.65	0.02884
36	23 47 17.39	-28 13 37.9	18.08	0.03289
37	23 47 20.14	-28 03 46.7	17.08	0.02787
38	23 47 22.36	-27 58 32.6	16.79	0.02475
39	23 47 23.22	-28 07 09.0	16.36	0.03283
40	23 47 27.39	-27 27 56.1	16.80	0.02838

Table B.14. VLG 108 system (continued).

Iden.	RA (J2000)	DEC (J2000)	b_J	Redshift	
41	23 47 28.56	-28 06 33.3	14.76	0.02792	
42	23 47 28.84	-28 08 08.3	14.81	0.02799	
43	23 47 30.17	-27 39 44.0	15.43	0.02887	
44	23 47 30.63	-28 02 35.5	17.28	0.02780	
45	23 47 30.77	-27 56 05.3	18.56	0.02733	
46	23 47 31.80	-28 06 26.1	16.43	0.02783	
47	23 47 34.67	-28 09 16.0	17.62	0.03218	
48	23 47 38.14	-27 44 45.2	18.45	0.03141	
49	23 47 41.98	-28 04 51.4	19.36	0.03049	
50	23 47 42.10	-28 07 33.8	17.25	0.02946	
51	23 47 42.33	-27 59 54.0	17.56	0.02943	
52	23 47 44.71	-27 29 13.9	14.86	0.02976	
53	23 47 45.00	-28 08 27.0	13.78	0.02916	VLG108; data from SSRS2
54	23 47 45.53	-27 49 49.3	17.98	0.03149	
55	23 47 47.16	-28 08 06.5	17.61	0.02699	
56	23 47 49.34	-28 17 28.7	17.92	0.02979	
57	23 47 49.54	-28 05 12.4	17.31	0.03214	
58	23 47 49.54	-28 12 13.8	16.99	0.03178	
59	23 47 50.41	-28 09 08.8	17.74	0.03289	
60	23 47 52.55	-28 06 13.8	18.45	0.03336	
61	23 47 55.83	-28 14 25.8	18.66	0.03174	
62	23 47 58.53	-27 56 11.5	18.94	0.03119	
63	23 48 00.86	-28 09 22.9	19.18	0.03220	
64	23 48 03.81	-27 53 01.7	18.39	0.03051	
65	23 48 05.68	-27 43 42.6	19.04	0.02868	
66	23 48 11.40	-27 55 58.6	18.54	0.03402	
67	23 48 20.23	-27 55 11.6	18.26	0.03406	
68	23 48 26.86	-27 51 20.1	17.41	0.02998	
69	23 48 27.14	-27 47 44.5	18.97	0.03304	
70	23 48 40.31	-27 52 31.3	18.78	0.03192	
71	23 48 48.75	-27 41 58.5	17.98	0.03400	
72	23 48 54.69	-27 49 03.6	17.13	0.03410	
73	23 49 05.07	-27 44 47.4	18.94	0.02661	
74	23 49 05.47	-28 50 12.3	18.87	0.02953	
75	23 49 11.19	-27 39 06.2	18.05	0.02890	
76	23 49 21.48	-28 32 30.2	16.60	0.02913	
77	23 49 33.91	-28 27 25.6	18.22	0.02695	
78	23 49 44.75	-28 15 41.9	17.65	0.02861	
79	23 49 44.76	-28 00 20.0	18.30	0.03121	
80	23 49 51.09	-27 57 01.2	14.54	0.02996	

Table B.14. VLG 108 system (continued).

Iden.	RA (J2000)	DEC (J2000)	b_J	Redshift
81	23 49 57.42	-27 58 49.0	18.05	0.03364
82	23 50 00.20	-28 11 26.1	17.02	0.03199
83	23 50 00.69	-27 55 46.3	19.22	0.03025
84	23 50 06.33	-27 25 46.2	18.79	0.03349
85	23 50 20.04	-27 38 49.0	17.57	0.02885
86	23 50 21.56	-28 20 36.1	18.60	0.02506
87	23 50 24.70	-27 56 25.8	15.42	0.02916
88	23 50 27.55	-28 20 23.2	18.53	0.02739
89	23 50 30.75	-27 32 13.1	16.91	0.03411
90	23 50 35.11	-27 47 45.2	15.62	0.02959
91	23 50 35.65	-28 07 42.8	16.59	0.02858
92	23 50 37.30	-28 35 54.3	18.28	0.02799
93	23 50 37.95	-28 26 04.5	14.86	0.02839
94	23 50 53.02	-28 03 29.9	17.44	0.02771
95	23 51 00.47	-27 56 17.1	15.82	0.02982
96	23 51 02.82	-27 47 51.3	16.78	0.02912
97	23 51 03.64	-28 21 00.8	16.41	0.02757
98	23 51 06.50	-28 09 05.5	18.04	0.02742
99	23 51 07.01	-27 48 44.0	17.61	0.02978
100	23 51 11.37	-28 06 06.2	19.29	0.02951
101	23 51 19.10	-27 58 27.8	15.45	0.03360
102	23 51 24.97	-28 35 44.8	17.11	0.02897
103	23 51 25.67	-28 28 51.1	17.39	0.02705
104	23 51 26.91	-28 03 07.9	17.28	0.03219
105	23 51 35.63	-28 17 13.5	17.48	0.02817
106	23 51 36.69	-28 21 53.2	14.40	0.02758
107	23 51 39.58	-28 35 32.1	16.65	0.02789
108	23 51 41.85	-28 04 26.7	18.91	0.03285
109	23 51 48.02	-28 18 46.9	17.55	0.02933
110	23 51 50.29	-28 17 37.6	17.21	0.02777
111	23 51 50.36	-27 57 55.1	15.11	0.02927
112	23 51 54.42	-27 55 48.3	14.55	0.02921
113	23 51 54.55	-27 59 03.6	18.22	0.03317
114	23 52 02.00	-28 11 34.5	17.41	0.03109

Table B.15. VLG 109 system.

Iden.	RA (J2000)	DEC (J2000)	b_J	Redshift	
1	23 47 48.41	-28 56 38.9	18.62	0.04815	
2	23 47 56.85	-29 18 08.3	17.82	0.04885	
3	23 49 21.95	-29 10 22.2	17.46	0.04869	
4	23 49 39.21	-28 56 30.1	16.53	0.04731	
5	23 49 44.29	-29 16 23.6	19.05	0.05044	
6	23 49 52.57	-28 49 41.2	18.51	0.04989	
7	23 50 13.62	-29 00 32.3	14.31	0.04973	VLG 109
8	23 50 15.62	-29 08 09.2	15.08	0.05062	
9	23 50 16.65	-28 59 50.2	18.88	0.05058	
10	23 50 26.60	-29 06 16.6	18.71	0.04857	
11	23 50 34.41	-29 02 03.2	17.16	0.04920	
12	23 50 36.89	-29 06 58.4	16.80	0.04977	
13	23 50 43.89	-28 57 24.8	16.11	0.04778	