SUITES OF DWARFS AROUND NEARBY GIANT GALAXIES

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ABSTRACT

The Updated Nearby Galaxy Catalog (UNGC) contains the most comprehensive summary of distances, radial velocities, and luminosities for 800 galaxies located within 11 Mpc from us. The high density of observables in the UNGC makes this sample indispensable for checking results of N-body simulations of cosmic structures on a ~1 Mpc scale. The environment of each galaxy in the UNGC was characterized by a tidal index Θ1, depending on the separation and mass of the galaxy’s main disturber (MD). We grouped UNGC galaxies with a common MD in suites, and ranked suite members according to their Θ1. All suite members with positive Θ1 are assumed to be physical companions of the MD. About 58% of the sample are members of physical groups. The distribution of suites by the number of members, n, follows a relation N(n) ∼ n−2. The 20 most populated suites contain 468 galaxies, i.e., 59% of the UNGC sample. The fraction of MDs among the brightest galaxies is almost 100% and drops to 50% at MB = −18m. We discuss various properties of MDs, as well as galaxies belonging to their suites. The suite abundance practically does not depend on the morphological type, linear diameter, or hydrogen mass of the MD, the tightest correlation being with the MD dynamical mass. Dwarf galaxies around MDs exhibit well-known segregation effects: the population of the outskirts has later morphological types, richer H I contents, and higher rates of star formation activity. Nevertheless, there are some intriguing cases where dwarf spheroidal galaxies occur at the far periphery of the suites, as well as some late-type dwarfs residing close to MDs. Comparing simulation results with galaxy groups, most studies assume the Local Group is fairly typical. However, we recognize that the nearby groups significantly differ from each other and there is considerable variation in their properties. The suites of companions around the Milky Way and M31, consisting of the Local Group, do not quite seem to be a typical nearby group. The multiplicity of nearby groups of the number of their physical members can be described by the Hirsh-like index hg = 9, indicating that the Local Volume contains nine groups with populations exceeding nine companions to their MDs.

Key words: galaxies: dwarf – galaxies: groups: general – galaxies: interactions

Online-only material: machine-readable table and VO tables

1 INTRODUCTION

The standard LCDM cosmological model, with cold dark matter and dark energy, efficiently explains the observed properties of the universe on large scales (Klypin et al. 2003). Modern cosmological N-body simulations have resolutions good enough to investigate structures with sizes of about or more than 1 Mpc and with individual halos of about 10^7 solar masses (Klypin et al. 2011; Kitaura et al. 2012). However, our advances in matching the simulation results with the observational data on such small scales still look very modest. One reason for this is a limited database on the distances to even the nearest galaxies.

Over the last 10–15 yr, mass measurements of distances to nearby galaxies have been undertaken by several observational teams, relying on the unique resolution of the Hubble Space Telescope (HST). Use of the tip of the red giant branch (TRGB) stars as a “standard candle” (Lee et al. 1993) allows the determination of distances for more than 300 of the nearest galaxies with an error of ~10%. The first summary of the new and old distance estimates was presented in the catalog of galaxies of the Local Volume (Karachentsev et al. 2004), which contains data on 450 galaxies in a sphere of 10 Mpc radius around the Milky Way. Later, the distance estimates and other integral parameters of nearby galaxies were accumulated in the Extragalactic Distance Database (http://edd.ifa.hawaii.edu) by Tully et al. (2008) and the Database on the Local Volume Galaxies (http://www.sao.ru/lv/lvgdb) by Kaisina et al. (2012).

The Updated Nearby Galaxy Catalog (UNGC; Karachentsev et al. 2013) contains the most complete summary of various observable characteristics for ~800 galaxies located within 11 Mpc. The UNGC is currently the most representative and homogeneous sample of neighboring galaxies, most of which have known linear separations, luminosities, and line-of-sight velocities. Unlike most catalogs that are limited by flux, this sample is restricted by distance. It makes the UNGC the most suitable for comparison with N-body simulations on small scales of ~0.1–10 Mpc.

2 ENVIRONMENT OF NEARBY GIANT GALAXIES

For each of the 869 galaxies in the UNGC (Karachentsev et al. 2013), we determined the “tidal index” (Karachentsev & Makarov 1999)

\[ \Theta_1 = \max \left[ \log \left( \frac{L_n}{D_n^3} \right) \right] + C, \quad n = 1, 2, \ldots, N, \quad (1) \]

where \( L_n \) is the K-band luminosity of the neighboring galaxy and \( D_n \) is its spatial separation from the considered galaxy. Ranking the surrounding galaxies by the value of their tidal force \( F_n \sim L_n/D_n^3 \), we are looking for the most significant, influential neighbor, which is designated as the main disturber (MD). We assume that the total mass of the galaxy is proportional to its luminosity in the K band, and that the mass-to-light ratio does not depend on the luminosity and morphology. The constant \( C = -10.96 \) in Equation (1) has been chosen so that the galaxy
with $\Theta_1 = 0$ locates on the “zero velocity sphere” relative to its MD. In other words, the galaxy with $\Theta_1 > 0$ is considered to be causally connected with its MD, since the crossing time for this pair is shorter than the age of the universe $H_0^{-1}$, where $H_0 = 72$ km s$^{-1}$ Mpc$^{-1}$ is the Hubble parameter. Accordingly, a galaxy with a negative $\Theta_1$ should be considered as physically not bound with its neighbors. Such objects are usually referred to as the “field” galaxies. Evidently, this approach is only justified for the close volume, where all the fairly massive galaxies are already discovered and their distances have been measured.

In Tables 1 and 2 of the UNGC (Karachentsev et al. 2013), we presented the observing and physical characteristics of 869 of the Local Volume galaxies, taking into account corrections for external and internal extinction. We excluded from this sample 75 galaxies with distance estimates of $D > 11.0$ Mpc and united all the remaining objects in associations with their common MD. We call the set of galaxies with one common MD the MD “suite.” Within each suite, the members were ranked by highest tidal index $\Theta_1$. We determine a sub-sample of members of the suite with $\Theta_1 \geq 0$ to be a physical group, where the MD is the dominant galaxy by mass. In almost all cases, the groups of galaxies formed this way matched with the list of nearby groups by Karachentsev (2005).

The suites around the MDs themselves were ranked according to the number of suite members $n_s$ from the maximum of $n_s = 53$ for the suite around M81 to $n_s = 1$. The sample of galaxies of the Local Volume reorganized this way is presented in Table 1, the full version of which is available in the online journal and at the LVG page on the Web site of the Special Astrophysical Observatory of the Russian Academy of the Sciences (http://www.sao.ru/lv/lvgdb).

The table columns contain the following data:

1. the name of the galaxy;
2. the linear diameter of the galaxy in kpc, determined at Holmberg’s isophote (26.5 mag arcsec$^{-2}$);
3. the absolute magnitude of the galaxy in the $B$ band corrected for extinction;
4. the logarithm of the stellar mass in solar units;
5. the logarithm of the indicative (dynamic) mass within the Holmberg diameter, $\log (M_{26}/M_\odot) = 2 \log V_m + \log a_{26} + \log D + 4.52$, where the rotation velocity $V_m$ is expressed in km s$^{-1}$, the Holmberg diameter $a_{26}$ in angular minutes, and the distance $D$ in Mpc;
6. the logarithm of the hydrogen mass in solar units;
7. the tidal index $\Theta_1$;
8. the MD’s name;
9. the distance to the galaxy in Mpc;
10. the line-of-sight velocity of the galaxy (in km s$^{-1}$) relative to the velocity of the MD;
11. the number of members in the suite of the MD to which the galaxy belongs.

The distribution of the number of suites around the MDs by the number of suite members is demonstrated in Figure 1 in the logarithmic scale. Open circles in the figure correspond to the total number of galaxies in the suite with any tidal indices. The filled circles show the number of bound companions satisfying $\Theta_1 \geq 0$. Standard errors $\sqrt{N}$ are depicted by vertical bars. In general, the distribution of suites by the number of galaxies in them is represented quite well by the power law $N(n) \propto n^{-2}$, which corresponds to the straight line in the figure.

Among the 794 galaxies of the Local Volume, 457 galaxies, or 58%, have $\Theta_1 \geq 0$ values. In other words, they are members of physical groups of different multiplicity. It should be noted

![Figure 1](image_url)

**Figure 1.** Number of suites in the Local Volume depending on the number of suite members (open circles) and the number of dynamically bound companions with $\Theta_1 > 0$ (filled circles). The straight line corresponds to the $N(n) \propto n^{-2}$ relation.
that according to Makarov & Karachentsev (2011), for ~11,000 galaxies of the Local Universe located within the sphere of \( D \sim 50 \) Mpc radius, the relative number of galaxies in groups is 52%. Thus, the abundance of galaxy group members in small and large volumes is almost the same. The agreement of these quantities can be considered as evidence of the representativeness of the Local Volume in terms of structure and dynamics of galaxy systems.

The data in Table 1 show that most of the galaxies in the Local Volume are concentrated in suites around a small number of the most massive galaxies. Thus, 20 of the most significant neighbors of the Local Volume are located in a field of gravitational influence. However, that not all of the distances of the galaxies of the Local Volume were measured with high accuracy. Therefore, the status: both the group members and field galaxies.

Some parameters of these 20 structures and properties of their main galaxies are presented in Table 2 with columns containing: (1) the abbreviated name of the main galaxy (MD); (2) the distance to the MD in Mpc, by which the list of suites is ordered; (3) the total number of galaxies in the MD suite, including the field objects; (4) the number of physical group members with \( \Theta_1 \geq 0 \); (5) the number of “bright” bound companions of the main galaxy with absolute magnitudes \( M_B \) brighter than \(-11^m\); (6) the absolute magnitude of the main galaxy; (7) and (8) its stellar mass and dynamical masses within the Holmberg diameter in solar masses; (9) the linear Holmberg diameter of the MD in kpc; (10) and (11) the hydrogen mass and morphological type of the main galaxy by de Vaucouleurs classification; (12)–(14) tidal indices, characterizing the MD environment: \( \Theta_1 \)—tidal index determined by the most significant neighbor; \( \Theta_3 \)—tidal index determined by the total contribution of the five most significant neighbors, \( \Theta_3 = \log(\sum_{i=1}^{5} M_B / D_{15}^3) + C \); and \( \Theta_5 \) = \( \log(j_{11} \text{Mpc} / j_{\text{global}}) \)—logarithm of the mean density of stellar mass around the galaxy (excluding the galaxy itself) within a 1 Mpc radius, expressed in units of the global mean density \( 4.28 \times 10^8 M_\odot \text{Mpc}^{-3} \) (Jones et al. 2006).

The distribution of members of the 20 most populated suites by the tidal index \( \Theta_1 \) is shown in Figure 2. As follows from it, about 60% of members of these suites have \( \Theta_1 \geq 0 \), i.e., are physically bound with the main galaxy. It should be noted, however, that not all of the distances of the galaxies of the Local Volume were measured with high accuracy. Therefore, the \( \Theta_1 = 0 \pm 0.5 \) boundary strip may contain galaxies of different status: both the group members and field galaxies.

We noted above that more than half of the total population of the Local Volume is located in a field of gravitational influence of only 20 giant galaxies. Figure 3 represents the distribution of galaxies of the Local Volume by the absolute \( B \)-band magnitude. The inset picture shows the fraction of MDs as function of the absolute magnitude.

The relative number of MDs among the brightest galaxies is close to 100%. As might be expected, the fraction of MDs decreases toward the low-luminosity galaxies, dropping below 50% at \( M_B \approx -18^m \). A similar pattern was noted by

### Table 2

Properties of the 20 Most Populated Suites in the LV

| MD     | \( D \) | \( n_1 \) | \( n_2 \) | \( n_0 \) | \( M_B \) | \( \lg M_\star \) | \( \lg M_{26} \) | \( A_{26} \) | \( \lg M_{H1} \) | \( T \) | \( \Theta_1 \) | \( \Theta_3 \) | \( \Theta_5 \) |
|--------|--------|--------|--------|--------|--------|---------------|---------------|--------|-------------|--------|--------|--------|--------|
| M.Way  | 0.01   | 38     | 29     | 5      | -20.8  | 10.5          | 11.3          | 25     | 9.5         | 4      | 2.8    | 2.9    | 1.6    |
| M31    | 0.77   | 42     | 39     | 10     | -21.40 | 10.73         | 11.50         | 43.4   | 9.73        | 3      | 4.9    | 4.9    | 1.4    |
| IC 342 | 3.28   | 10     | 9      | 9      | -20.69 | 10.60         | 11.15         | 34.2   | 10.16       | 6      | 0.1    | 0.5    | 1.7    |
| M81    | 3.63   | 53     | 37     | 22     | -20.92 | 10.93         | 11.27         | 31.4   | 9.44        | 3      | 2.5    | 2.6    | 1.5    |
| N 5128 | 3.75   | 37     | 26     | 16     | -20.78 | 10.91         | 11.70         | 42.6   | 8.46        | -2     | 0.7    | 1.0    | 1.6    |
| N 253  | 3.94   | 25     | 8      | 7      | -21.29 | 11.04         | 11.24         | 40.8   | 9.15        | 5      | -0.4   | -0.3   | 0.7    |
| N 4828 | 4.37   | 11     | 3      | 3      | -19.51 | 10.48         | 10.70         | 17.8   | 8.26        | 2      | -0.8   | -0.5   | -1.0   |
| N 4736 | 4.66   | 31     | 15     | 12     | -19.86 | 10.61         | 10.73         | 20.7   | 8.32        | 2      | -0.6   | -0.1   | 0.8    |
| N 5236 | 4.92   | 28     | 15     | 14     | -20.64 | 10.86         | 11.32         | 28.2   | 10.00       | 5      | -0.5   | 0.0    | 0.0    |
| M 101  | 7.38   | 11     | 6      | 5      | -21.12 | 10.85         | 11.35         | 65.2   | 9.91        | 6      | 0.4    | 0.5    | 0.2    |
| N 4631 | 7.38   | 16     | 5      | 4      | -20.28 | 10.49         | 10.41         | 33.7   | 9.72        | 7      | 1.8    | 1.9    | 1.0    |
| N 2683 | 7.73   | 13     | 2      | 2      | -20.36 | 10.60         | 11.14         | 29.5   | 8.94        | 3      | 0.0    | 0.2    | -1.3   |
| N 4258 | 7.83   | 31     | 19     | 17     | -21.20 | 10.94         | 11.33         | 41.5   | 9.64        | 4      | 1.1    | 1.3    | 0.6    |
| N 6744 | 8.30   | 12     | 6      | 6      | -20.96 | 10.79         | 11.35         | 52.8   | 10.19       | 4      | 2.0    | 2.0    | 1.2    |
| N 2903 | 8.87   | 15     | 4      | 4      | -20.89 | 10.82         | 11.13         | 32.4   | 9.44        | 4      | 1.7    | 1.7    | -0.8   |
| N 5055 | 8.99   | 11     | 5      | 5      | -20.98 | 10.99         | 11.34         | 42.2   | 9.62        | 4      | -0.1   | 0.1    | -0.9   |
| N 4594 | 9.30   | 32     | 10     | 10     | -21.82 | 11.30         | 11.76         | 32.5   | 8.36        | 1      | 2.5    | 2.6    | -0.4   |
| N 3115 | 9.68   | 12     | 7      | 7      | -20.77 | 10.95         | 10.50         | 24.0   | 8.75        | -1     | 2.3    | 2.6    | 0.2    |
| N 2784 | 9.82   | 9      | 6      | 6      | -19.65 | 10.80         | ...           | 19.3   | 8.0         | -2     | 3.1    | 3.2    | 1.0    |
| N 3368 | 10.42  | 31     | 31     | 31     | -20.40 | 10.83         | 11.14         | 27.2   | 9.18        | 3      | 1.1    | 1.5    | 2.1    |

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3 We have not included in this list a suite of 12 galaxies around NGC 4414, which lies outside the LV at a distance of 18 Mpc, or the suite of 10 galaxies around NGC 1291, the distance to which is very uncertain.

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![Figure 2](image-url)
Wang & White (2012) according to SDSS data. MDs are also presented on the faint end of the luminosity function. They can be conditionally divided into two categories: (1) dwarf companions located close to a giant galaxy (an example is the dwarf spheroidal system SagdSph, semi-disrupted by the tidal influence of the Milky Way), (2) tight pairs of dwarf galaxies, for example, UGCA 319+DDO 161, KK 78+DDO 64, and KK 65+DDO 47, where each component of the pair is an MD for the second component. A list of similar isolated multiple dwarf galaxies in the volume of ~50 Mpc radius was compiled by Makarov & Uklein (2012).

It should be stressed that the considered sample of nearby galaxies suffers with different selection effects. Clearly, these are very complex and variable due to the heterogeneous nature of many of the surveys that contribute to the UNGC catalog. For instance, there is a luminosity bias with distance, an H I bias over the sky because of the declination horizon and limited angular resolution for radio telescopes, etc. In particular, blind H I surveys, like HIPASS and ALFALFA, are efficient in revealing gas-rich irregular dwarfs in the Zone of Avoidance, which are practically invisible in optical surveys, but the radio surveys are nearly insensitive in detecting dwarf spheroidal objects.

3. SOME PROPERTIES OF THE MAIN DISTURBERS

Returning to Table 2 data, we note some features of the main galaxies in the suites, which foster the presence of a large number of companions around MDs. The four panels of Figure 4 show the dependence of the number of physical members of the suite (i.e., members of group), $n_{p}$, on the stellar and dynamical mass of the MD, as well as its linear diameter and hydrogen mass. As one can see, the most obvious relationship occurs for the dynamic mass of the main galaxy $M_{25}$, which was earlier noted by Karachentsev & Kasparova (2005). It should be noted, however, that due to the selectivity by luminosity, the suites of nearby MDs look more populated than the suites of their distant counterparts. To reduce the selectivity effect with distance, we have excluded from our analysis the dwarf galaxies with absolute magnitudes $M_{B} > -11^{m}0'$. The reduced number of bright physical companions is indicated in Table 2 as $n_{b}$.

Considering each parameter in Table 2 as a feature that may affect the number of members of the suite, we calculated the correlation coefficients of these parameters with the total number of galaxies in the suite $n_{t}$, the number of physical members $n_{p}$, and the number of bright physical companions $n_{b}$. The results are shown in Table 3.

If we assume that the correlation coefficients larger than 0.25 by modulus are significant, then the data in Table 3 leads to the following conclusions. (1) The linear diameter of the main galaxy, its hydrogen mass, and morphological type have practically no effect on the population of a suite. (2) The total number of members of the suite $n_{t}$ and the number of bound companions $n_{b}$ show a positive correlation with the luminosity of the main galaxy, its dynamical mass $M_{25}$, and all three tidal indices $\Theta_{1}$, $\Theta_{5}$, and $\Theta_{j}$; however, the presence of a significant correlation between $n_{t}$ and $n_{b}$ with distance indicates the effect of observational selection as the cause of the listed correlations. (3) For bright physical group members, $n_{b}$, the correlation with distance $D$ virtually disappears. The number of $n_{b}$ is significantly influenced by the value of the stellar dynamic mass of the MD, and by the stellar density contrast of the environment, $\Theta_{j}$. However, the last circumstance is almost trivial, since it is the abundance of the MD’s companions that determines the density contrast $\Theta_{j}$. The above trends may shed some light on the conditions of the formation and evolution of massive galactic halos surrounded by small sub-halos.

4. PROPERTIES OF GALAXIES IN MD SUITES

We know that groups and clusters of galaxies reveal segregation effects along the radius by the luminosity, morphological type, and other characteristics. The tidal index $\Theta_{1}$ is an indicator of the distance of the suite member from its main galaxy, normalized to the MD mass. This allows us to rank the members of different suites by $\Theta_{1}$ to form a synthetic unified suite.

Figure 5 presents the distribution of several parameters of galaxies in the 20 most populated suites (Table 2) along the $\Theta_{1}$ scale. In the top left panel, the absolute magnitude of galaxies of the synthetic suite is clearly correlated with $\Theta_{1}$. However, exclusion of galaxies fainter than $-11^{m}0'$ (above the dashed horizontal line), Andromeda and M81, mainly found in the vicinity of the Milky Way, makes this correlation insignificant. The top right panel of the figure shows the hydrogen-to-stellar mass ratio as a function of $\Theta_{1}$. The open circles mark the objects where only the upper limit of the H I flux is estimated. Despite a large dispersion of $M_{HI}/M_{*}$ ratios, its mean value systematically decreases from the field galaxies toward members of the groups. This known effect is usually explained by a sweeping out of the gas of dwarf galaxies in groups as they pass through the dense halo regions of a massive galaxy (Slater & Bell 2013). Note, however, that among the field galaxies with $\Theta_{1} < 0$ there are objects with low hydrogen abundances per stellar mass unit. To explain these cases, we need to employ some other mechanisms of gas loss by dwarf galaxies, for example, the “cosmic web stripping” (Benitez-Llambay et al. 2013).

The lower left panel reproduces the specific star formation rate (SFR) in the galaxies of the synthetic suite as a function of $\Theta_{1}$. The SFR was estimated by the Hα flux and the far-UV flux measured with Galaxy Evolution Explorer. Empty symbols correspond to the upper limit of the Hα and far-UV fluxes. The smallest scatter in SFR/$M_{*}$ occurs in the galaxies in the outskirts of the suites. With the growth of $\Theta_{1}$, there are many cases of depressed star formation. As for the hydrogen-to-stellar mass ratio, $M_{HI}/M_{*}$, the decrease in specific SFR, SFR/$M_{*}$, in the densest regions is apparently caused by the effects of
Figure 4. Number of physical companions in the MD suites as a function of the MD global parameters: dynamic mass $M_{26}$, stellar mass $M_*$, linear diameter $A_{26}$, and hydrogen mass $M_{HI}$. The Milky Way and M31 suites are depicted by larger symbols.

Table 3

| $D$ | $M_B$ | $\lg M_*$ | $\lg M_{26}$ | $\lg A_{26}$ | $\lg M_{HI}$ | $T$ | $\Theta_1$ | $\Theta_3$ | $\Theta_j$ |
|-----|-------|-----------|--------------|--------------|--------------|-----|------------|------------|------------|
| $n_1$ | -0.48 | -0.37 | 0.23 | 0.41 | 0.03 | -0.02 | -0.06 | 0.29 | 0.27 | 0.44 |
| $n_2$ | -0.48 | -0.31 | 0.17 | 0.39 | 0.08 | 0.12 | -0.11 | 0.43 | 0.39 | 0.74 |
| $n_0$ | -0.08 | -0.24 | 0.42 | 0.33 | 0.07 | 0.05 | -0.17 | 0.17 | 0.12 | 0.63 |

gas sweeping out from the shallow potential well of the dwarf galaxies.

The bottom right panel of Figure 5 shows the distribution of galaxies of the synthetic suite by morphological types in the de Vaucouleurs classification at different $\Theta_1$. Again, the gas-rich late-type dwarf galaxies, $T = 10, 9$ (Ir, Im, and BCD), prevail in the low-density regions with $\Theta_1 < 0$, while the early-type objects, $T < 0$ (E, S0, and dSph), are found mainly in the dense central parts of the suites. Note that in this panel there are three objects marked with the type $T = 11$. We have classified in this category the intergalactic H I clouds without any signs of stellar population. The fact that two of them have $\Theta_1 > 0$ values is likely determined by a selectivity effect: in the regions of nearby groups, the H I surveys are as a rule performed to a deeper extent than in the vast areas between the groups.

Despite the presence of a quite evident morphological segregation of galaxies along the radius of the groups, the lower left corner of the $T \propto \Theta_1$ diagram hosts a number of galaxies with the characteristics $T < 0$ and $\Theta_1 \leq 0$. These galaxies can be critical when testing different scenarios of formation of early-type galaxies. Twelve of them are shown in Table 4 in order of increasing $\Theta_1$. The first column shows the name of the galaxy, and the second indicates its morphological type with detailed classification of dwarf galaxies (Karachentsev et al. 2013). The designations of parameters in the subsequent columns are the same as in Table 2. The penultimate column shows the difference between the line-of-sight velocities of the suite galaxy and its MD. Some objects from the list (KKR 8, KKH 65, KK 258, and KK 227) coincide with the list of isolated early-type galaxies in the Local Supercluster (Karachentseva et al. 2010).

As we can see from Table 4, this list contains only the dwarf systems with linear diameters of less than 4 kpc and absolute magnitudes not brighter than $-16^{m}5$. We have classified half of them as transition objects (Tr) between dIrr and dSph. Three dwarf galaxies of S0 and E types, NGC 4600, NGC 404, and NGC 59, reveal a gas content according to the optical emission spectra and H I fluxes. In fact, only 4 out of
12 galaxies, KKR 8, KKH 65, KKR 25, and UGC 8882, remain well-founded representatives of isolated early-type galaxies. Moreover, only one of them, KKR 25, was studied in detail in the optical and radio ranges (Makarov et al. 2012) and has a reliable distance estimate by the TRGB method (Karachentsev et al. 2001).

From the aspect of the evolution of dwarf galaxies, of great interest here are not only the isolated early-type galaxies, but also the gas-rich dwarfs of Ir, Im, and BCD types, which are located close to the massive galaxies. They occupy the opposite diagonal corner on the \( \{T, \Theta_1\} \) diagram with respect to the isolated early-type objects. Table 5 lists the data on 18 irregular dwarf galaxies, \( T = 9, 10 \) types, with tidal indices \( \Theta_1 > 3.0 \) around the giant galaxies with absolute magnitudes \( M_B \approx -20^m0 \). The galaxies here are ranked according to their \( \Theta_1 \). The parameter designations in the columns are the same as in Table 4.

As one can see, the majority of dwarf galaxies on this list are detected in the H\textsc{i} line. This may be because other yet undetected dwarf systems have significant amounts of neutral hydrogen, but
they are too close to the massive galaxies and are not resolved as individual H\textsc{i} sources.

The average absolute magnitude of the dwarfs in Tables 4 and 5 is almost identical: $-12.9^6$ and $-12.8^8$, respectively. This agreement is to be expected if the late-type dwarf galaxies are experiencing their first passage near the massive galaxy, and after that, being deprived of their gas, move to the category of spheroidal dwarfs.

Attention is drawn to an inhomogeneous distribution of the number of irregular dwarfs, which are tightly located around the MDs. Four dwarf galaxies are close to M81 and all of them are young stellar systems formed in the tidal H\textsc{i} filaments connecting M81 with M82 and NGC 3077 (Yun 1999; Makarova et al. 2002; Karachentsev et al. 2011). Two giant spiral galaxies, NGC 6744 and NGC 6946, have four and three irregular dwarfs in their close vicinities, respectively. The Milky Way and six other MDs have only one such companion each. (We have not included the Small Magellanic Cloud (SMC) galaxy in Table 5 because its MD is not the Milky Way, but the LMC galaxy.) At the same time, such massive galaxies as M31, Centaurus A, and Sombrero (NGC 4594) have no nearby gas-rich dwarf companions at all.

It should be noted, however, that among the dwarf galaxies from Table 5, only one galaxy, the LMC, has its distance measured with high accuracy. For the other objects of this list, the distance error is about 25%.

As can be seen from Table 5, the Milky Way stands out among the other MDs by the presence of a nearby massive companion, the LMC. This peculiarity of the Milky Way was noted by Rodriguez-Puebla et al. (2013), Jiang et al. (2012), and others. This fact remains valid if we consider not only the $T = 9$, 10 dwarf companions, but also all other types of companions. Around the 20 most significant MDs of the Local Volume (Table 2) there are 27 physical companions with $\Theta_1 > 0$ and absolute magnitudes brighter than $-17^7.0$. The distribution of these galaxies by $(\Theta_1, M_B)$ is shown in Figure 6. We have also included the SMC galaxy, which lies in the potential well of the Milky Way, although its MD is the LMC (see Table 1). As one can see, some giant galaxies have physical companions of high luminosity, such as M33 in M31, NGC 3351 in NGC 3368, and NGC 2835 in NGC 2784. However, they are not located as close to their MDs as the LMC to our Galaxy. Note that among the 27 massive nearby companions in Figure 6, all but NGC 3412 are late-type galaxies with large amounts of neutral gas and active star formation. This circumstance may indicate that many gas-rich companions are still in the initial stage of falling toward their MDs.

As follows from Figure 6, the Milky Way and the suite of its companions does not quite look like a typical group. This observational fact should be taken into account when comparing the results of N-body simulations (Knebe et al. 2011; Libeskind et al. 2010) with the properties of the galaxies in the Local Group.

According to the $(\Theta_1, M_B)$ diagram, the suite around M81 is most similar to our Galaxy with its neighbors. However, the M81 group has its essential features: the presence of H\textsc{i} filaments (Yun 1999), young “tidal” Holm IX-type dwarfs (Makarova et al. 2002), and also BCD galaxies (Chiboucas et al. 2009), which all are absent in the Local Group.

### Table 5

| Name      | Type | $A_{26}$ | $M_B$ | $lg M_\star$ | $lg M_{26}$ | $lg M_{H_1}$ | $\Theta_1$ | MD     | $D$ | $\Delta v$ | $n_i$ |
|-----------|------|----------|-------|--------------|-------------|--------------|-----------|--------|-----|------------|-------|
| HolmIX    | Ir-N | 2.96     | -13.6 | 7.70         | 8.53        | 8.40         | 5.1       | M81    | 3.61 | 88         | 53    |
| [KK2000]71| Ir-N  | 4.41     | -14.7 | 8.13         |             |              | 4.7       | NGC 6744 | 8.30 | 12         |       |
| ClumpF    | Ir-N  | 0.20     | -8.3  | 5.57         |             |              | 4.2       | M81    | 3.60 | -129       | 53    |
| CKT0959-468|Ir-L  | 0.88     | -10.1 | 6.29         |             |              | 4.0       | M81    | 3.60 | -150       | 53    |
| [KK2000]72| Ir-L  | 1.36     | -11.9 | 7.00         |             |              | 4.0       | NGC 6744 | 8.30 | 12         |       |
| ClumpIII  | Ir-N  | 0.11     | -8.3  | 5.57         |             |              | 3.9       | M81    | 3.60 | -85        | 53    |
| KKSG18    | BCD-N | 4.45     | -16.6 | 9.27         |             |              | 3.9       | NGC 3115 | 9.70 | 17         | 12    |
| KKSG20    | Ir-N  | 1.68     | -12.8 | 7.37         | 6.69        | 6.18         | 3.9       | NGC 3521 | 10.70 | 38         | 4     |
| [KK2000]70| Ir-L  | 1.37     | -12.1 | 7.09         | <6.44       | 3.6          | 3.8       | NGC 6744 | 8.30 | 12         |       |
| LV1217+47 | Tr-L  | 0.69     | -11.0 | 6.66         |             |              | 0.06      | M.Way  | 0.05 | 93         | 38    |
| LMC       | Im-N  | 10.06    | -17.9 | 9.42         | 9.44        | 8.66         | 3.5       | M.Way  | 0.05 | 93         | 38    |
| ESO104-044|Ir-L  | 4.37     | -14.8 | 8.17         | 8.81        | 8.33         | 3.5       | NGC 6744 | 8.30 | -92        | 12    |
| KK251     | Ir-L  | 3.48     | -13.6 | 7.70         | 8.32        | 8.05         | 3.5       | NGC 6946 | 5.89 | 78         | 8     |
| N2903-HI-1|Ir-N  | 0.71     | -11.7 | 6.92         | 5.99        | 6.42         | 3.3       | NGC 2903 | 8.90 | 27         | 15    |
| KK 69     | Ir-L  | 3.15     | -12.2 | 7.12         | 6.65        | 7.51         | 3.3       | NGC 2683 | 7.70 | 53         | 13    |
| UGC 11583 | Ir-L  | 4.71     | -14.3 | 7.98         | 8.98        | 8.27         | 3.3       | NGC 6946 | 5.89 | 79         | 8     |
| LeG13     | Ir-N  | 1.25     | -12.8 | 7.35         | 5.97        | 6.75         | 3.1       | NGC 3368 | 10.40 | -22        | 31    |
| KK 252    | Ir-L  | 2.33     | -14.1 | 7.89         | 8.73        | 7.04         | 3.1       | NGC 6946 | 5.89 | 86         | 8     |

| Figure 6 | Distribution of physical companions around the 20 most massive galaxies of the Local Volume by their tidal index and absolute magnitude. |
5. ON THE KINEMATICS OF COMPANIONS IN MD SUITES

The penultimate column of Table 1 shows the line-of-sight velocities of galaxies of the suite relative to the velocity of the main galaxy. These data provide important information about the kinematics and dynamics of the nearest groups. The distribution of the line-of-sight velocity difference in the 20 most populated suites around their massive main galaxies is shown in the left panels of Figure 7. Physical members of the groups with $\Theta_1 > 0$ are depicted by filled circles, while the peripheral objects (or field galaxies) are marked by open circles. As we can see from the top panel, the variance of the line-of-sight velocity difference is almost independent of the value of $\Theta_1$ in the region of $\Theta_1 > 0$.

All of the group members except one lie in the strip of $\pm 300$ km s$^{-1}$. However, among the field galaxies with $\Theta_1 < 0$, there are some cases with a large line-of-sight velocity difference, for example, the dwarf galaxies VCC 114 and VCC 1675 in front of the Virgo cluster, for which the giant Sombrero galaxy (NGC 4594) turned out to be the MD. Increasing relative velocity scatter in the region of $\Theta_1 < 0$ is quite expected and indicates the absence of a physical relation of such galaxies with their MDs.

The bottom left panel of Figure 7 compares the velocity difference in the suite galaxies with the absolute magnitude of their main galaxy. In the physical group members (filled circles), the velocity dispersion tends to decrease toward the low luminosity of main galaxies.

The right-hand panels of Figure 7 represent the same data for the least populated suites, which are composed of only one galaxy. The luminosities and masses of MDs with one companion are much lower than those of the main galaxies of 20 populated suites. Obviously, for this reason, the variation in the line-of-sight velocity differences there lies in a narrower strip of only $\pm 200$ km s$^{-1}$, which is substantially lower than in the companions of massive galaxies.

It should be mentioned that a significant number of galaxies in the nearby suites have no line-of-sight velocity measurements to date. Filling this gap is an urgent observational task.

6. CONCLUDING REMARKS

The above data show that nearby groups of galaxies significantly differ from each other in the structure and morphological composition of their populations. This fact should be taken into account when comparing the results of N-body simulations of the Cosmic Web structure with the observational data.

Usually, the object of such a comparison is the Local Group (Libeskind et al. 2010; Zavala et al. 2009; Knebe et al. 2011), which consists of two dynamically isolated suites of dwarf galaxies around the Milky Way and Andromeda (M31), approaching each other with mutual velocities of center, $\sim 100$ km s$^{-1}$. However, based on a number of features, the
Local Group is not typical among the nearby groups. Therefore, a comparison of the results of numerical simulations should be conducted with the characteristics of the mean (synthetic) group of the Local Volume, relying in particular on the data of Table 2.

One of the important observational parameters of nearby groups is the number of their members. To characterize not a single group, but rather their ensemble in a certain volume, we usually chose the value of the mean group population, \( n_g \). Trentham & Tully (2002) added another dimensionless variable to this parameter, the ratio of the numbers of dwarf and normal galaxies \( n_d/n_n \), which, according to them, varies greatly from one group to another. It is easy to see that both of these parameters, \( n_g \) and \( n_d/n_n \), are not robust characteristics, as they are sensitive to the choice of threshold absolute magnitudes for dwarf galaxies and normal ones.

If one considers the belonging of a certain galaxy to its MD as an analogue of a bibliographic reference, then the ensemble of suites around the MDs in a fixed volume can be described by a single number—the \( h \)-index, suggested by Hirsch (2005). The value of \( h \) equal to, say, 10, means that the given volume contains 10 suites (or groups) with 10 or more companions to the MDs. According to the data of Table 1, we see that the suites in the Local Volume are characterize by an \( h \)-index of \( n_s = 13 \). Ignoring the suite members with \( \Theta_1 < 0 \) as the general field galaxies, for the physical groups of galaxies in the Local Volume we obtain \( h_g = 9 \). The \( h \)-index is quite robust. If we exclude the ultra-dwarf galaxies with \( M_B < -19.9 \)0 from the group members, then the \( h \)-index for the groups will remain unchanged.

We have to note that, in general, the suite can show a hierarchy structure: the main suite can contain sub-suites. Table 1 gives us these examples: the LMC belongs to the suite of the Milky Way, but at the same time it is the MD for its close neighbor, SMC; another example in the Local Group is the dwarf spheroidal galaxy And XXII near M33, which is itself a member of the suite of M31. In such cases, the populations of “secondary” sub-suites can be considered as members of the general suite around the most massive galaxy. Nevertheless, it follows from Table 1 data that the presence of hierarchical sub-groups does not change the value of the \( h \)-index \( h_g = 9 \) for the Local Volume.

The recent sky surveys in the optical range and in the H1 line have discovered new galaxies in the Local Volume and measured/refined their line-of-sight velocities. The \( HST \) has continued the programs measuring the distances to nearby galaxies. These targeted efforts promise to soon make the Local Volume the common sample for the analysis of various properties of galaxies and their systems.

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The Astronomical Journal, 147:13 (9pp), 2014 January

Karachentsev, Kaisina, & Makarov

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