THE LOCAL UNIVERSE

I. D. Karachentsev[1], V. E. Karachentseva[2], W. K. Huchtmeier[3], E. K. Grebel[4], D. Geisler[5], P. Guhathakurta[6], P. W. Hodge[7], A. Sarajedini[8], P. Seitzer[9], A. E. Dolphin[10]

[1] *Special Astrophysical Observatory, Russia*
e-mail: `ikar@luna.sao.ru`

[2] *Astronomical Observatory, Taras Shevchenko National University*
3 Observatorna St., 04053 Kyiv-53, Ukraine

[3] *Max-Planck-Institut für Radioastronomie*
Auf dem Hügel 69, D-53121 Bonn, Germany

[4] *Max-Planck-Institut für Astronomie*
Königstul 17, D-69117, Heidelberg, Germany

[5] *Departmento de Fisica, Grupo de Astronomia, Universidad de Concepcion*
Casilia 160-C, Concepcion, Chile

[6] *UCO/Lick Observatory, University of California at Santa Cruz, Santa Cruz, CA, 95064, USA*

[7] *Department of Astronomy, University of Washington, P.O. Box 351580, Seattle, WA, 98195, USA*

[8] *Astronomy Department, Wesleyan University, Middletown, CT, 06459, USA*

[9] *Department of Astronomy, University of Michigan, 830 Dennison Building, Ann Arbor, MI, 48109, USA*

[10] *Kitt Peak National Observatory, National Optical Astronomy Observatories*
P.O. Box 26732, Tucson, AZ, 85726, USA

We describe first results of international (Germany, Russia, Spain, Ukraine, USA) project to study a population, structure and kinematics of the Local Universe. The prime goal of the project is a creation of representative standard sample of the nearest galaxies with distances $D < 7$ Mpc to get reliable data on their luminosity function, HI-mass function, Dark Matter distribution on scales of [0.1–3] Mpc, star formation function, 3–D map of the Local Volume, and peculiar velocity field. We discuss results of the entire-sky search for new nearby dwarf galaxy candidates and a problem of completeness of the Local Volume sample.

INTRODUCTION

The Local Volume (LV) describes our extragalactic neighborhood out to 7 Mpc and includes galaxies with corrected velocities $V_0 < 500$ km/s. Apart from the Local Group, this volume contains several nearby galaxy groups as well isolated field galaxies. The galaxy census becomes increasingly incomplete for smaller galaxies with low surface brightness (LSB), particularly for dwarf galaxies. Furthermore, while most dwarf galaxies in the Local Group have been studied in great detail, very little is known still about the properties of dwarf galaxies beyond LG boundaries. The original Kraan-Korteweg & Tammann [28] list of 179 galaxies with $V_0 < 500$ km/s was updated by Huchtmeier & Richter [7], Schmidt & Boller [29], and Karachentsev [13] till to $N = 216$. The basic sources of the LV-sample complement are following: Z-surveys of known galaxy catalogues; HI and IR surveys in Zone of Avoidance made by Huchtmeier, Kraan-Korteweg, Henning and others; special searches for dwarf members of the known nearby groups: M81, IC 342 (Borngen & Karachentseva [3]), Centaurus and Sculptor groups (Côté *et al.* [5], Jerjen *et al.* [12]), CVn cloud and M101 group (Binggeli *et al.* [2], Bremnes *et al.* [4]); searches for LSB galaxies in wide sky regions (Shombert *et al.* [30], Impey *et al.* [11]), automated DSS survey around Andromeda (Armandroff *et al.* [1]), *etc.* The increase in the number of the known galaxies with $V_0 < 500$ km/s grows slowly (with a rate of several galaxies per year), and a discovery of very nearby galaxies happens in fact by chance. For example, among 369 LSB galaxies found by Shombert *et al.* [30] there are only 4 galaxies within 500 km/s. For these reasons we began a comprehensive study of dwarf galaxies in the Local Volume. The goal of the project is the creation of representative ($N > 300$ galaxies) standard sample of the nearest ($D < 7$ Mpc) galaxies to get reliable data on their luminosity function, mass function, Dark

Invited paper.

Matter distribution, star formation function, 3–D mapping of the LV, and peculiar velocity field.

THE ENTIRE-SKY SEARCH FOR NEW NEARBY DWARF GALAXY CANDIDATES (KK-SURVEY)

KK- survey has been realized as a comprehensive visual inspection of photographic plates (POSS-II, ESO/SERC, and SERC EJ) to search for new dwarf galaxy candidates in the Local Volume. This project was based on previous experience of searching for LSB galaxies on the POSS-I prints (Karachentseva [21]–[23]), yielded the Catalogue of 1500 low surface brightness galaxies (Karachentseva & Sharina [24]). The project steps and main results were following:

A) Searching for new dwarf galaxies with angular diameters $a > 0\farcm5$ around 216 LV galaxies within $R = 0.5$ Mpc of each. Totally the 260 objects were found (Karachentseva & Karachentsev [25]), many of them look like Irr galaxies from DDO Catalog (van den Bergh [32]).

B) Searching for dwarf galaxies situated in Hercules-Aquila area {R. A. = 14.0^h, 23.5^h, D. = $-3°$, $+60°$}, so-called the Local Void (Tully [31]). 78 dwarf galaxies were found (Karachentseva *et al.* [26]). It was confirmed that Tully Void remains to be perfectly empty till to the galaxy absolute magnitude of $\mathrm{M} = -14^m$.

C) Inspection of the equatorial SERC EJ zone with D. = $[-18°, +2°]$. As a result, 50 nearby dwarf galaxies were found (Karachentsev *et al.* [19]).

D) Inspection of a wide region around M31. Two new dwarf spheroidal companions to M31, Cassiopeia and Pegasus, were discovered (Karachentsev & Karachentseva [15]).

E) Survey of the remaining northern (POSS-II) and southern (ESO/SERC) films. At total 182 dwarf galaxy candidates were found (Karachentseva & Karachentsev [27]; Karachentsev *et al.* [20]). Altogether, 1671 fields ($6° \times 6°$) covering 97% of the whole sky were inspected, mostly in B and R bands. At total 570 objects were found, of which 327 objects (57%) were not previously catalogued.

HI STUDIES OF THE LV GALAXIES

The mass HI line observations of KK-objects were carried out by W. Huchtmeier with three different radio telescopes for different declination ranges. The 100-m radio telescope in Effelsberg was used for declinations above $-31°$, the Nancay radio telescope was used for galaxies in the declination range $[-38°, -31°]$, and the multibeam radio telescope in Australia was used for galaxies south of $-38°$. The main results are following (Huchtmeier *et al.* [8]; Huchtmeier *et al.* [9]; Huchtmeier *et al.* [10]). About 550 KK-objects have been observed with the detecting rate of 50%. Their median radial velocity is 1200 km/s, the median line width is 60 km/s, and the median linear diameter is 3.5 kpc. About 50 new LV galaxies were revealed. The analysis of HI properties of the LV galaxies (Karachentsev *et al.* [16]) allows to establish the following relations:

- the mean HI mass-to-luminosity ratio increases from giant galaxies towards dwarfs, reaching the maximum value $\sim 5M_\odot/L_\odot$;
- the mean value of HI mass-to-total mass increases from HSB galaxies towards LSB ones;
- for the LV galaxies their HI mass and angular momentum follow a linear relation expected for rotating gaseous disks being near the threshold of gravitational instability, which is favourable for active star formation.

DETAILED OPTICAL STUDIES OF THE LV GALAXIES

The southern and northern telescopes were involved to provide ground-based observations: 6-m BTA, SAO, Russia (Karachentsev, Tikhonov, Kopylov, Sharina, Makarova, Drozdovsky); 1.5-m ESO telescope (Grebel, Geisler), 2.6-m Nordic, La Palma, Spain/Finland (Aparicio, Takalo, Valtonen), 2.4-m MDM and 3.5-m APO, New Mexico (Grebel, Karachentsev); 10-m Keck, Hawaii (Grebel, Guhathakurta). About 130 northern LV galaxies were imaged in 2 or 3 bands. Most of the objects were resolved into stars for the first time, that made it possible to derive photometric distances via brightest blue and red stars with the accuracy of 0.4 mag (much better that can be achieved by the Tully–Fisher relation for dwIrrs). Many new dwarf companions were found in the vicinity of the nearest bright spirals: NGC 628, NGC 672, IC 342, NGC 6949, M 101, *etc.* The nearest BCDG, NGC 6789, was discovered just outside the Local Group at D = 2.1 Mpc. Detailed optical follow-up of the LV dwarf galaxies is being pursued with WFPC2 aboard Hubble Space Telescope (programmes #8192 and 8601 with P. Seitzer as PI) that allows to measure accurate distances to the dwarf galaxies using the tip of the red giant branch, as well as to derive their metallicities via a slope of the red giant branch. The new HST data allow to augment the faint end of galaxy luminosity function, to improve the census of globular clusters in dwarf galaxies, and to check the universality of the relation between mean metallicity, central surface brightness, and luminosity for different types of dwarf galaxies. First results of our HST Snapshot survey are published in several articles, *e.g.*, Karachentsev *et al.* [17], Karachentsev *et al.* [18], Dolphin *et al.* [6].

THE LOCAL VOLUME STRUCTURE

The Local Volume sample contains currently ∼340 members in comparison with 179 in 1979; 189 galaxies of this sample have photometric distances (against 17 in 1979). We estimate a present LV sample completeness to be of about 70%. A new criterion for bound group of galaxies (Karachentsev [13]) was applied to the Local Volume galaxies to study its three-dimentional structure.

The LV structure looks to be fractal. About 80% of the volume is occupied by "minivoids" with typical diameter of 3 Mpc. There are no sings of galaxy segregation according to their masses. No morphological segregation for giant/normal galaxies is seen, but there is a clear segregation among dwarf galaxies: dSphs usually occur within 300 kpc respect to a giant galaxy.

About 24% of the LV galaxies are the "Main Disturbers" (*i.e.*, significant attractors) for the rest galaxies. Each "MD" has its "nest" with a population in a range of (1–34). About 50% of the LV galaxies are isolated objects, *i.e.*, their crossing time with respect to their "MD" exceeds the cosmic time 1/H.

THE LOCAL VELOCITY FIELD

A sample of 145 galaxies with radial velocities relative to the LG centroid $V_0 < 500$ km/s and photometric distances $D < 7$ Mpc was considered. Their peculiar velocity field is described with a tensor of the local Hubble parameter H_{ij}, having the principal axies 81:62:48 (km/s Mpc) with a standard error of ∼4 km/s Mpc each. The minor axis of the Hubble ellipsoid is aligned almost along the polar axis of the Local Supercluster, and the major axis is directed $(29 \pm 5)^\circ$ away from the Virgo cluster center. Such a configuration of the local velocity field disagrees with known models of spherical symmetric Virgocentric flow and may be caused by a possible differential rotation of the Local Supercluster. The observed radial velocity dispersion is 74 km/s within D = 7 Mpc (Karachentsev & Makarov [14]), but for the field galaxies situated between the LG and other nearby groups the radial velocity dispersion does not exceed 25 km/s.

Acknowledgements. This work was supported by DFG grant KS 9112, the Henri Chretien International Research Grant administered by the American Astronomical Society, and NASA grant GO-08192. I. D. Karachentsev thanks the SOC for financial support.

REFERENCES

[1] *Armandroff T. E., Davies J. E., Jakoby G. H.* // Astron. J.–1999.–**118**.–P. 1220.

[2] *Binggeli B., Tarengui M., Sandage A.* // Astron. and Astrophys.–1990.–**228**.–P. 42.

[3] *Borngen F., Karachentseva V. E.* // Astron. Nachr.–1985.–**306**.–P. 301.

[4] *Bremnes T., Binggeli B., Prugniel P.* // Astron. and Astrophys. Suppl. Ser.–1998.–**129**.–P. 313.

[5] *Côté S., Freeman K. C., Carignan C., Quinn P. J.* // Astron. J.–1997.–**114**.–P. 1313.

[6] *Dolphin A. E., Makarova L. N., Karachentsev I. D., et al.* // Mon. Notic. Roy. Astron. Soc.–2001.–submitted.

[7] *Huchtmeier W. K., Richter O.-G.* // Astron. and Astrophys.–1988.–**203**.–P. 237.

[8] *Huchtmeier W. K., Karachentsev I. D., Karachentseva V. E.* // Astron. and Astrophys.–1997.–**322**.–P. 375.

[9] *Huchtmeier W. K., Karachentsev I. D., Karachentseva V. E., Ehle M.* // Astron. and Astrophys. Suppl. Ser.–2000.–**141**.–P. 469.

[10] *Huchtmeier W. K., Karachentsev I. D., Karachentseva V. E.* // Astron. and Astrophys. Suppl. Ser.–2000.–**147**.–P. 187.

[11] *Impey C. D., Sprayberry D., Irwin M. J., Bothun G. D.* // Astrophys. J. Suppl. Ser.–1996.–**105**.–P. 209.

[12] *Jerjen H., Freeman K. C., Binggeli B.* // Astron. J.–1998.–**116**.–P. 2873.

[13] *Karachentsev I. D.* // Astron. and Astrophys. Transactions.–1994.–**6**.–P. 1.

[14] *Karachentsev I., Makarov D.* // Astron. J.–1996.–**111**.–P. 535.

[15] *Karachentsev I. D., Karachentseva V. E.* // Astron. and Astrophys.–1999.–**341**.–P. 355.

[16] *Karachentsev I. D., Makarov D. I., Huchtmeier W. K.* // Astron. and Astrophys. Suppl. Ser.–1999.–**139**.–P. 97.

[17] *Karachentsev I. D., Sharina M. E., Grebel E. K., et al.* // Astron. and Astrophys.–1999.–**352**.–P. 399.

[18] *Karachentsev I. D., Karachentseva V. E., Dolphin A. E., et al.* // Astron. and Astrophys.–2000.–**363**.–P. 117.

[19] *Karachentsev I. D., Karachentseva V. E., Suchkov A. A., Grebel E. K.* // Astron. and Astrophys. Suppl. Ser.–2000.–**145**.–P. 415.

[20] *Karachentsev I. D., Karachentseva V. E., Huchtmeier W. K.* // Astron. and Astrophys.–2001.–**366**.–P. 481.

[21] *Karachentseva V. E.* // Soobsch. Byurakan. Obs.–1968.–**39**.–P. 62. (in Russian).

[22] *Karachentseva V. E.* // Astron. Tsirk.–1972.–**723**.–P. 1. (in Russian).

[23] *Karachentseva V. E.* // Astrophys. Issled. (Izv. SAO).–1973.–**5**.–P. 10. (in Russian).

[24] *Karachentseva V. E., Sharina M. E.* // Comm. Spec. Astrophys. Obs.–1988.–**57**.–P. 3. (in Russian).

[25] *Karachentseva V. E., Karachentsev I. D.* // Astron. and Astrophys. Suppl. Ser.–1998.–**127**.–P. 409.

[26] *Karachentseva V. E., Karachentsev I. D., Richter G. M.* // Astron. and Astrophys. Suppl. Ser.–1999.–**135**.–P. 221.

[27] *Karachentseva V. E., Karachentsev I. D.* // Astron. and Astrophys. Suppl. Ser.–2000.–**146**.–P. 359.

[28] *Kraan-Korteweg R., Tammann G. A.* // Astron. Nachr.–1979.–**300**.–P. 181.

[29] *Scmidt K.-H., Boller T.* // Astron. Nachr.–1992.–**313**.–P. 189.

[30] *Schombert J. M., Bothun G. D., Schneider S. E., McGaugh S. S.* // Astron. J.–1992.–**103**.–P. 1107.

[31] *Tully R. B.* Nearby Galaxy Catalog.–Cambridge Univ. Press, 1988.

[32] *Van den Bergh S.* // Publ. DDO.–1959.–N 5.–P. 147.