

Nearby void dwarf galaxies: recent results, the ongoing project and prospects

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Abstract. Properties of dwarf galaxies formed and evolved in the lowest density environment remain largely unexplored and poorly understood. Especially this concerns the low-mass end ($M_{\text{bar}} < 10^9 M_{\odot}$). We overview the results of systematic study of a hundred void dwarfs from the nearby Lynx-Cancer void. We describe the ongoing project aiming to form Nearby Void galaxy sample ($R < 25$ Mpc) over the whole sky. 1354 objects with distances less than 25 Mpc fall within 25 voids delineated by 460 luminous galaxies/groups. The void major sizes range from 13 to 37 Mpc. 1088 of 1354 void galaxies reside deeply in voids, having distances to the nearest luminous neighbour of 2–11 Mpc. 195 nearest void galaxies reside in the Local Volume. We summarize the main statistical properties of the new sample and outline the prospects of study of both, the void dwarf properties and the fine structure of voids.

Keywords. galaxies: dwarf, galaxies: formation, galaxies: evolution, galaxies: general, large-scale structure of universe, catalogs

1. Introduction

Study of voids and their galaxies became especially popular in XXI century thanks to the massive redshift data from several very large surveys, such as SDSS, 2dFGRS, 6dF, ALFALFA, and the large progress in models and simulations.

However, almost all void galaxy studies are biased to distant (80–200 Mpc) voids, and hence, to the upper part of the void galaxy Luminosity Function ($M_B, M_r < -16$). Some models hint on possible delay in the epoch of formation and on the slow evolution of small void galaxies (e.g., [Einasto *et al.* \(2011\)](#), [Aragon-Calvo & Szalay \(2013\)](#)). However, observationally void galaxies with $M_B > -14^m$, and $M_{\text{bar}} \lesssim 10^9 M_{\odot}$ remain almost unexplored.

The main goal of our ongoing project is to fill the almost empty niche of ‘Galaxies in the Nearby Voids’, with the emphasis on studies of the smallest void galaxies. The first step in this direction is the formation of sample of nearby void galaxies. See the paper submitted to MNRAS (Pustilnik, Tepliakova, Makarov “Void galaxies in the nearby Universe. I. Sample description”).

2. Overview of results on galaxies in the nearby Lynx-Cancer void

The Lynx-Cancer void was first described in detail by [Pustilnik & Tepliakova \(2011\)](#). Its center is situated at the distance of 18 Mpc. The void’s volume is ~ 2000 cub. Mpc, it contains 108 galaxies with M_B of -9.6^m to -18.4^m and with $M(\text{HI})$ of 10^6 to $5 \times 10^9 M_{\odot}$. The galaxy sample is complete to $M_B \sim -14.0^m$, almost all void galaxies are late-type, and about a half of them are low surface brightness dwarfs (LSBDs).

The main conclusions from the study of relation "O/H versus M_B " (Pustilnik, Perepelitsyna & Kniazev (2016), see also Kniazev, Egorova & Pustilnik (2018)) and the ratio of $M(\text{HI})/L_B$ (Pustilnik & Martin (2016)), and the comparison with the control samples in the Local Volume are as follows.

For void galaxies we see that:

- a) The gas O/H in average is lower by $\sim 40\%$ (on 81 galaxies),
- b) $M(\text{HI})$ in average is larger by $\sim 40\%$ for a fixed M_B (on 103 galaxies),
- c) Several fainter/faintest void galaxies appear the extreme outliers in O/H (by 2–5 times lower than for the control sample) and/or the gas mass-fraction (up to 98–99 per cent) (e.g., Pustilnik, *et al.* (2010), Chengalur & Pustilnik (2013), Chengalur, Pustilnik & Egorova (2017)),
- d) Colours of the galaxies' outer parts versus the PEGASE evolutionary tracks are used as the age indicators. The great majority of galaxies have visible population with $T_{\text{stars}} \sim 10 - 14$ Gyr, and hence, have been evolving during the cosmological time. However, for $\sim 15\%$, the colours correspond to $T_{\text{stars}} \sim 1 - 5$ Gyr (Perepelitsyna, Pustilnik & Kniazev (2014)).

These findings: 1) imply the slower evolution of void galaxies as a whole, and 2) hint on the presence of void galaxies with much delayed formation epoch, and in particular, on the presence of half-dozen void VYGs (Very Young Galaxies, as defined by Tweed *et al.* (2018), following the discovery of the record-low metallicity star-forming dwarf J0811+4730 by Izotov *et al.* (2018)).

3. Main parameters of the Nearby Voids and their galaxies

The main goal of the ongoing project is to form a large, deep and representative sample of dwarf galaxies residing in voids of the nearby Universe. The sample is the basement for the mass study of the galaxy content, their evolutionary status, clustering and dynamics with respect to their counterparts residing in more typical, denser regions and for study of void small-scale substructures.

We identify 25 voids over the entire sky within the distance of $R = 25$ Mpc from the Local Group. The voids are defined as groups of lumped empty spheres bounded by ~ 450 'luminous' galaxies (or groups with 'luminous' galaxies) with the absolute K -band magnitudes $M_K < -22.0$. 1354 fainter galaxies residing in these nearby voids have absolute blue magnitudes of M_B in the range of -7.5^m to -19.5^m , with the median of -15.1^m . Of them, 1088 belong to the 'inner' subsample, with the distances to the nearest luminous neighbour of $D_{\text{NN}} \geq 2.0$ Mpc. Of them, 195 galaxies fall within the Local Volume ($R < 11$ Mpc). The distributions of the Nearby Void galaxies on M_B , distances from the Local Group and D_{NN} are shown Fig. 1, where the hatched part of the histograms separates the 'inner' subsample.

In Table 1 we present the list of the Nearby Voids along with their main parameters. It includes the void number in the catalog, the approximate equatorial coordinates and the distance (in Mpc) of void center, the maximal extent of void in three projections in supergalactic coordinates, the total number of galaxies assigned to this void and the respective number of galaxies from the 'inner' void sample, that is galaxies with $D_{\text{NN}} \geq 2.0$ Mpc.

4. Summary and prospects

The absolute majority of the Nearby Void dwarfs are irregular galaxies and late-type spirals. About 30 blue gas-rich dwarfs are candidates to VYGs. About 7% of the void sample are of early types: dE/E-S0 galaxies with the wide range of M_B . Most of them

Table 1. Main parameters of nearby voids

#	Void name (1)	RA _c hours (2)	Dec _c degr (3)	Dist _c Mpc (4)	Max.ext. $\Delta X, \Delta Y, \Delta Z$ Mpc (5)	Tot. void gals (6)	Inner void gals (7)
1	Cas-And	00.7	+53	19.0	19,19,23	19	15
2	Tuc	00.9	-64	11.2	14,14,14	56	44
3	Cet-Scu-Psc	01.3	-02	15.2	33,17,29	108	85
4	Pho	01.4	-54	18.0	17,19,18	80	66
5	Tau	03.8	+17	18.8	24,27,21	53	46
6	Per	04.0	+52	19.7	14,14,13	4	3
7	Eri-Ori	05.1	-07	18.5	20,18,17	41	30
8	Ori-Tau	05.4	+15.2	07.5	18,14,14	46	36
9	Aur	05.8	+38	13.5	23,22,21	36	34
10	Lep	05.85	-17	06.3	13,13,13	43	32
11	Mon	06.4	-07	20.2	19,15,16	7	2
12	Cnr-CMi-Hyd	08.5	+10	17.5	29,25,23	129	106
13	Vel	09.5	-50	19.0	20,27,21	76	59
14	Hyd	09.8	-15.2	19.2	18,14,17	22	15
15	Cen-Cir	14.4	-65	21.0	15,14,15	20	14
16	UMa	14.8	+59	21.0	15,16,13	82	73
17	Vir-Boo	14.8	+07	10.2	14,14,15	20	12
18	Boo	15.3	+27	19.4	20,24,26	49	33
19	Lib	15.4	-26.5	18.3	19,21,24	40	31
20	Her	16.6	+20	13.5	21,22,25	118	97
21	Oph-Sgr-Cap	18.5	-18	13.0	37,30,35	121	89
22	Dra-Cep	20.4	+71.1	13.9	21,21,17	50	44
23	Cyg	20.6	+36.3	19.3	22,23,28	20	18
24	Pav-Oct	20.7	-73.1	15.7	23,20,18	36	30
25	Aqu	22.7	-02.5	15.5	20,22,24	80	72

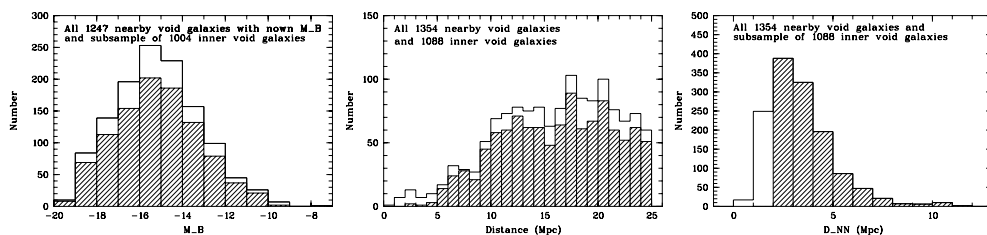


Figure 1. Distributions of all void galaxies and ‘inner’ (hatched) void sample. **Left panel.** M_B distribution of all 1247 void galaxies with known M_B , with median of -15.1^m . **Middle panel.** Distance distribution of all 1354 void galaxies. **Right panel.** Distribution of distances of void galaxies to the nearest luminous galaxy/group D_{NN} .

are well isolated, and thus can represent an unusual sub-type of field/void early-type galaxies.

The new large sample of 1354 galaxies residing in the Nearby Voids opens the prospects of systematical studies of galaxy formation and evolution as well as of the properties of voids themselves. These include the following directions:

- 1) search for and study of the lowest mass void dwarfs, including candidates to the so-called Very Young Galaxies;
- 2) study the origin and evolution of early-type galaxies in voids;
- 3) search for appearance of cold accretion as a driving mechanism of galaxy evolution;
- 4) study of void small-scale structure, in particular as a probe of the predicted effect of voids as ‘time machine and cosmic microscope’ (Aragon-Calvo & Szalay (2013)) and of the possible role of Warm Dark Matter in its formation;

5) study the void galaxy motions from their void centers as a mean to determine void global properties. The work is supported by grant of Russian Science Fund No. 14-12-00965.

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