Observations of dwarfs in nearby voids: implications for galaxy formation and evolution

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Outline

- Brief overview: galaxies in large voids and model predictions
- Motivation for complementary approach. Nearby voids and galaxy samples
- Study of the Lynx-Cancer void sample (statistics, space distribution and clustering, measering O/H, HI mass, photometry & colours, HI maps).
- Results
- Prospects
- Summary

Overview

Properties of galaxies residing in voids – subject of continuous studies (e.g., Szomoru et al. 1996; Grogin & Geller 2000; Rojas et al. 2004, Patiri et al. 2006, Hoyle et al. 2013 among others).
Already mentioned in the review talk by Rien van de Weigaert.

Most of the last decade works dealt with large galaxy samples (thousands) in **large distant** voids and probed **the top of void luminosity function** ($M_B < -16$ to -17). Used photometric data and spectra from databases. Differences with walls are not large. There are **indirect indications on less evolved state** of void galaxies.

A different approach: **Void Galaxy Survey** (detailed study of 60 galaxies near the distant void centres: HI-maps, morphology & SF). (Kreckel et al. 2011, 2012, Beygu et al. 2013). **VGS** r*esults were just have been presented.* I notice discovery of 3 very gas-rich galaxies among the sample lowest mass objects and evidences of gas accretion.

General points:

1. the smaller galaxies, the more fragile and sensitive to effect of environment they are.
2. the bias in collapse of low-mass DM halos in the under-dense regions can lead to the retarded formation of a fraction of dwarfs.

N-body simulations: Gottloeber et al. 2003, Hoeft & Gottloeber 2010; Kreckel, Young, Cen, 2012: trend for lower-mass void galaxies to be evolutionary younger, but limited by mass resolution.

To check/prove these expectations observationally, one needs in low(est)-mass samples of void galaxies. Hence, the **nearby voids is a natural exit.**

Nearby voids

1. The **Local Void** is very large (R>20 Mpc), begins within the Local Volume (Tully et al. 2008). MW extinction is large in major part of this void. To date it is very empty: 16 galaxies identified inside this by Nasonova, Karachentsev (2012). (in particular, the unusual dwarf KK 246, see Kreckel et al. 2011).

2. Other nearby smaller voids after Fairall (1998) in [**Monoceros, Cetus**, **Volans, Cepheus**] have various limitations, including the SDSS footprint.

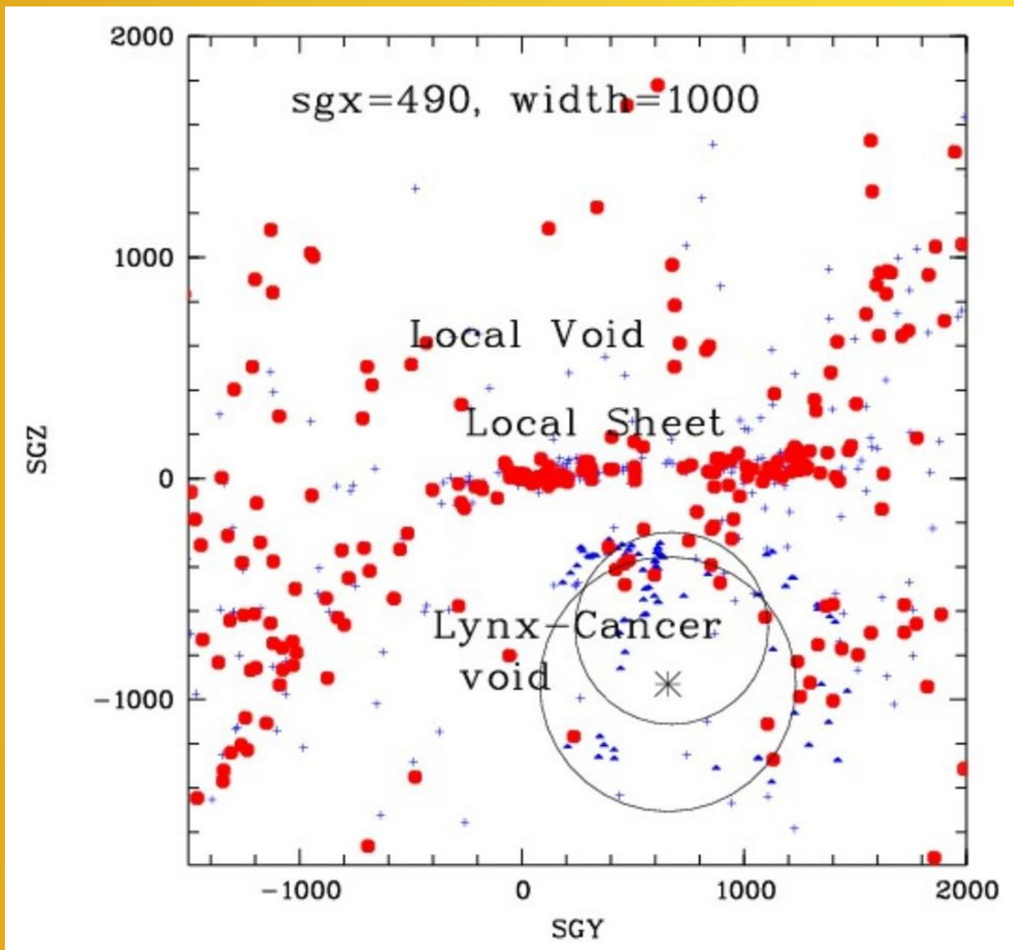
3. Newly discovered nearby void in Lynx-Cancer (Pustilnik et al. 2003; Pustilnik+ 2011a,b,c; Pustilnik et al. in prep.) is the most suitable (covered by SDSS, ALFALFA, access from SAO, Nancay RT). Known void objects provide reasonable statistics to compare with galaxies in denser environments. This and other nearby voids are part of the **ongoing project**: "**Study of galaxies in the nearby voids**"

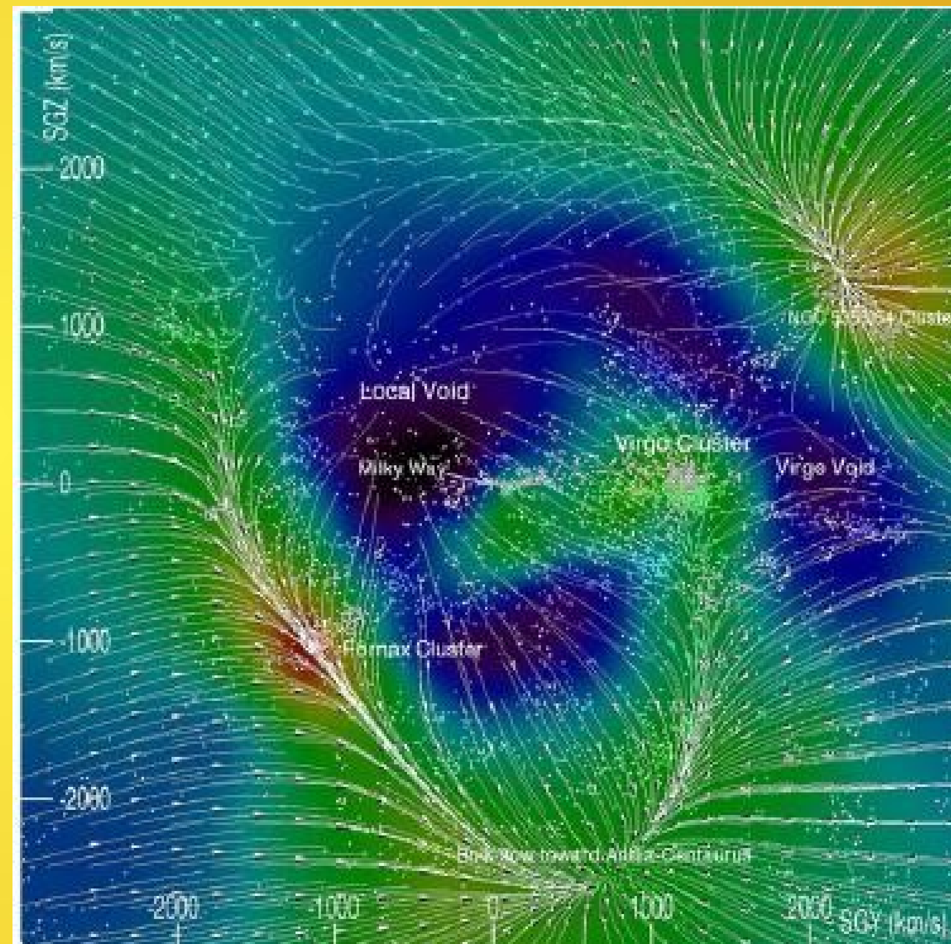
Lynx-Cancer void summary

1. The void is described at 1-st approximation as the maximal sphere, limited by delineating luminous galaxies, M_B < -19. Its center is at RA=7.9h, Dec=+27, V_LG=1030 km/s (**r=18 Mpc**), diameter **D~16 Mpc**. It looks adjacent the Monoceros void (on the South) through a `massive' filament.

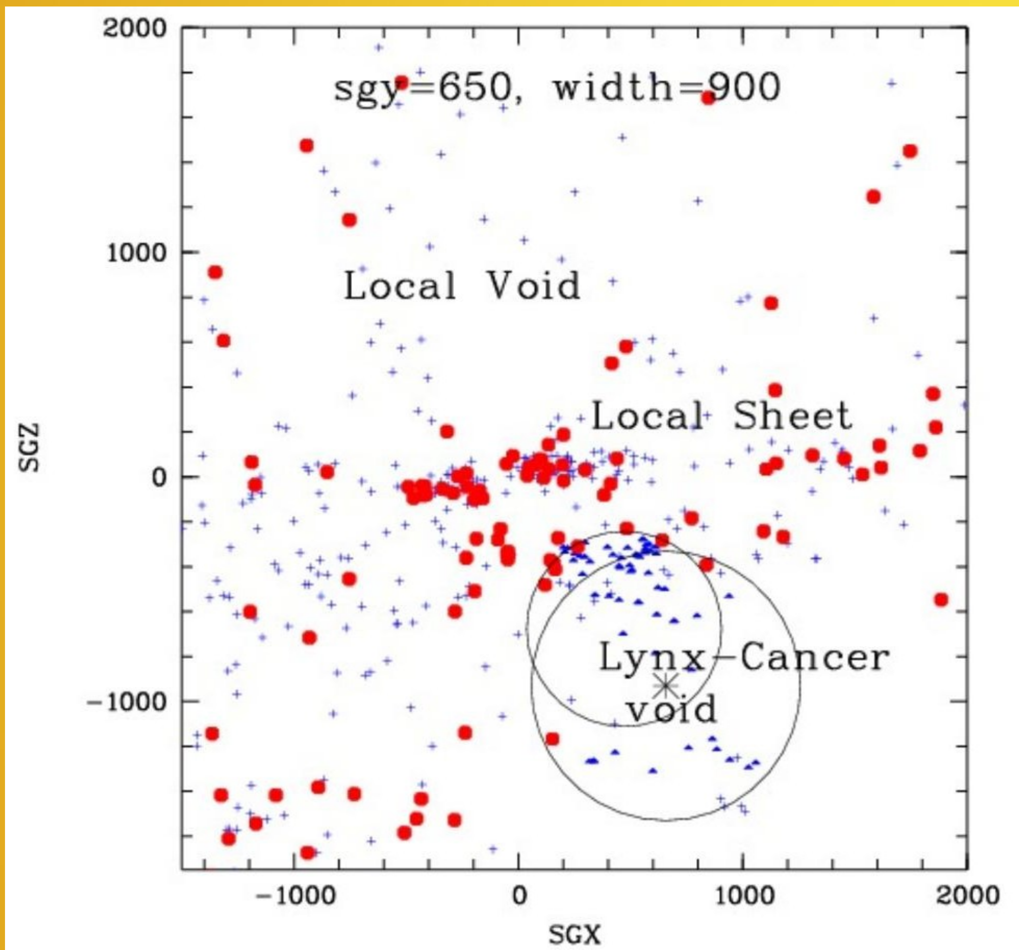
2. The current Lynx-Cancer void sample: 103 galaxies, distant from delineating luminous galaxies (D_NN > 2 Mpc). Full range of M_B: [-9.7, -18.4], median M_B = -14.5. Almost all are of late types; half of the sample -- in LSB regime (mu_B,c,0 > 23 mag/sq.arsc).

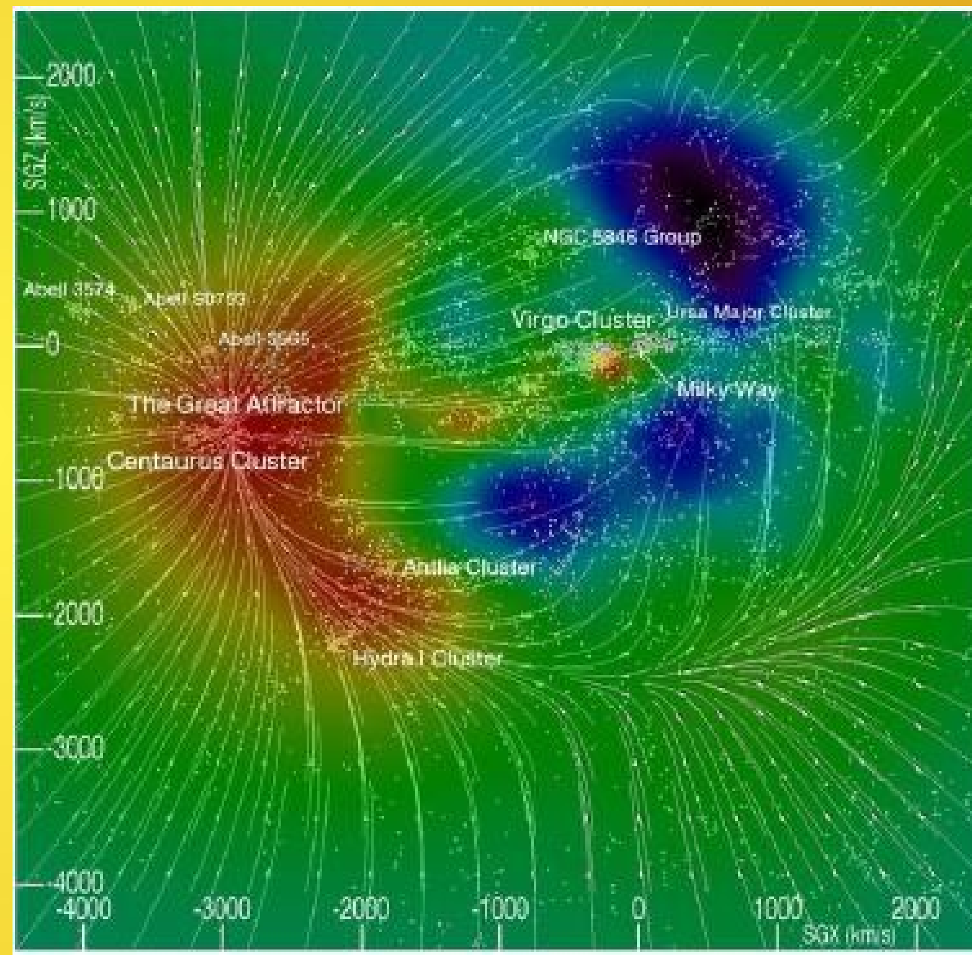
Environment of the Lynx-Cancer void (SGY-SGZ projection) and the related density field from Courtois et al. (2013) (SGX slice -1500 to +1500 km/s). The adjacent Monoceros void is also seen.





Environment of the Lynx-Cancer void (SGX-SGZ projection) and the related density field from Courtois et al. (2013) (SGY slice 0-2000, density at SGY=+800)





Goals of the ongoing project:

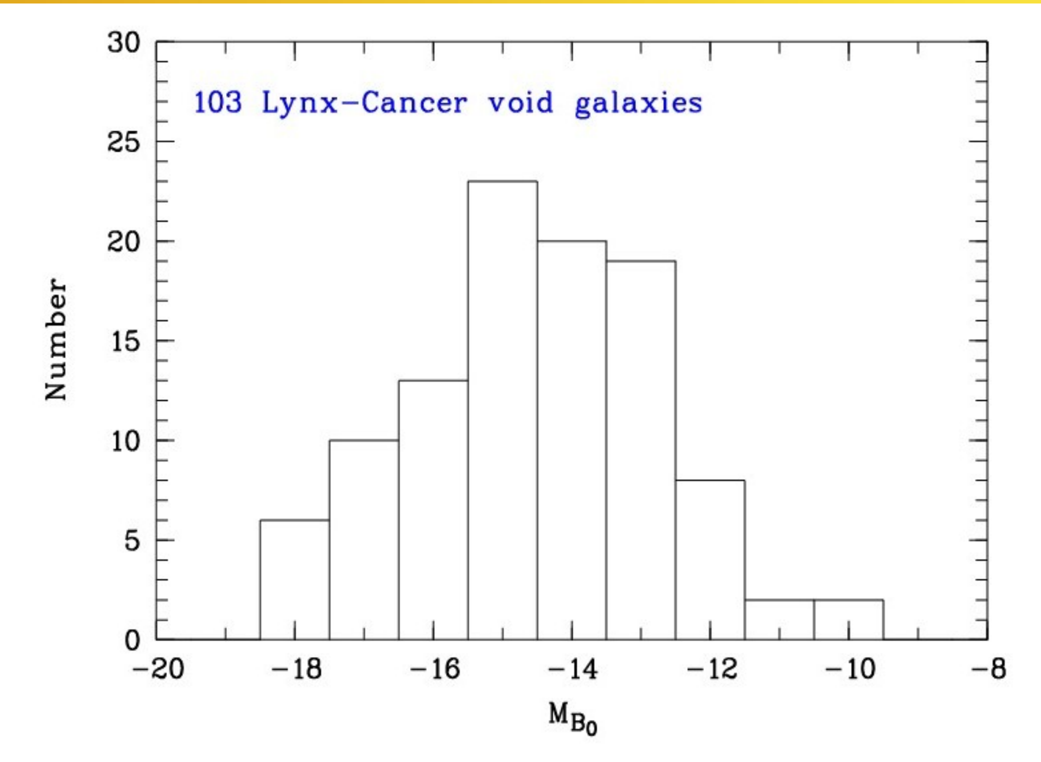
1. **Census of void galaxies** till M_B ~-12 and deeper (when possible): update the Local Volume observational **database for near-field cosmology** to include population of several voids.

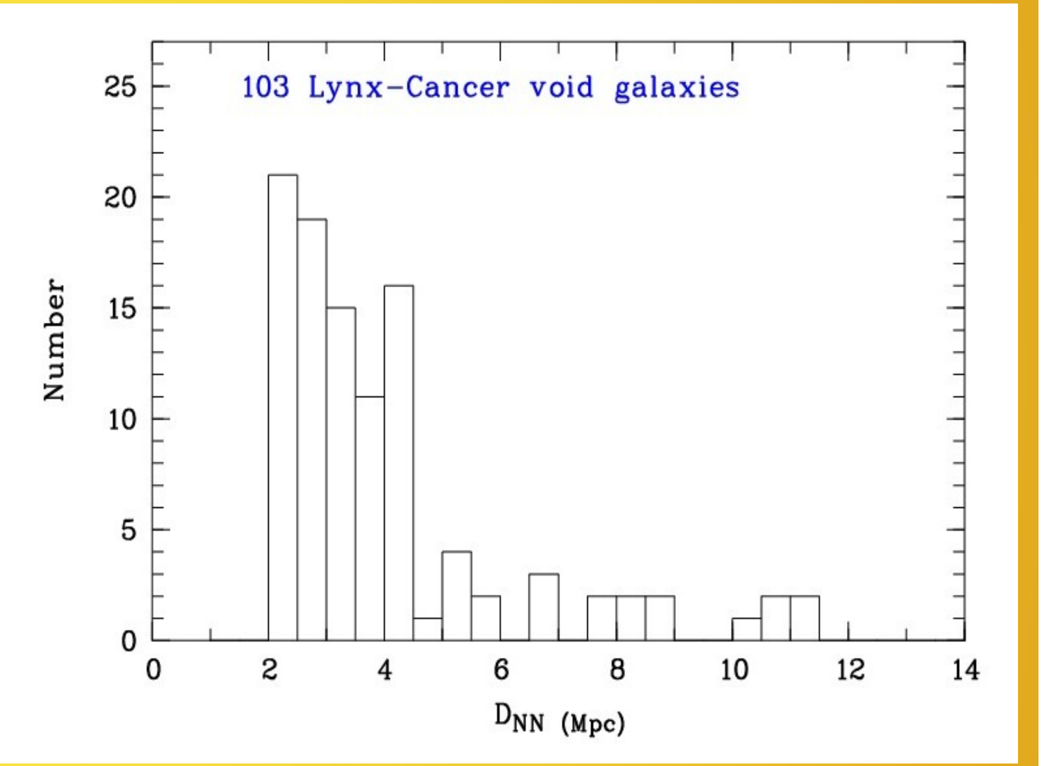
2. **Evolutionary status** via gas metallicity (O/H in HIII regions), gas mass-fraction (integrated HI fluxes and optical photometry), ages of the oldest stellar population (optical colours of outer parts).

3. Study of **morphology and dynamical state via HI** mapping (GMRT), including the role of interactions and cold accretion.

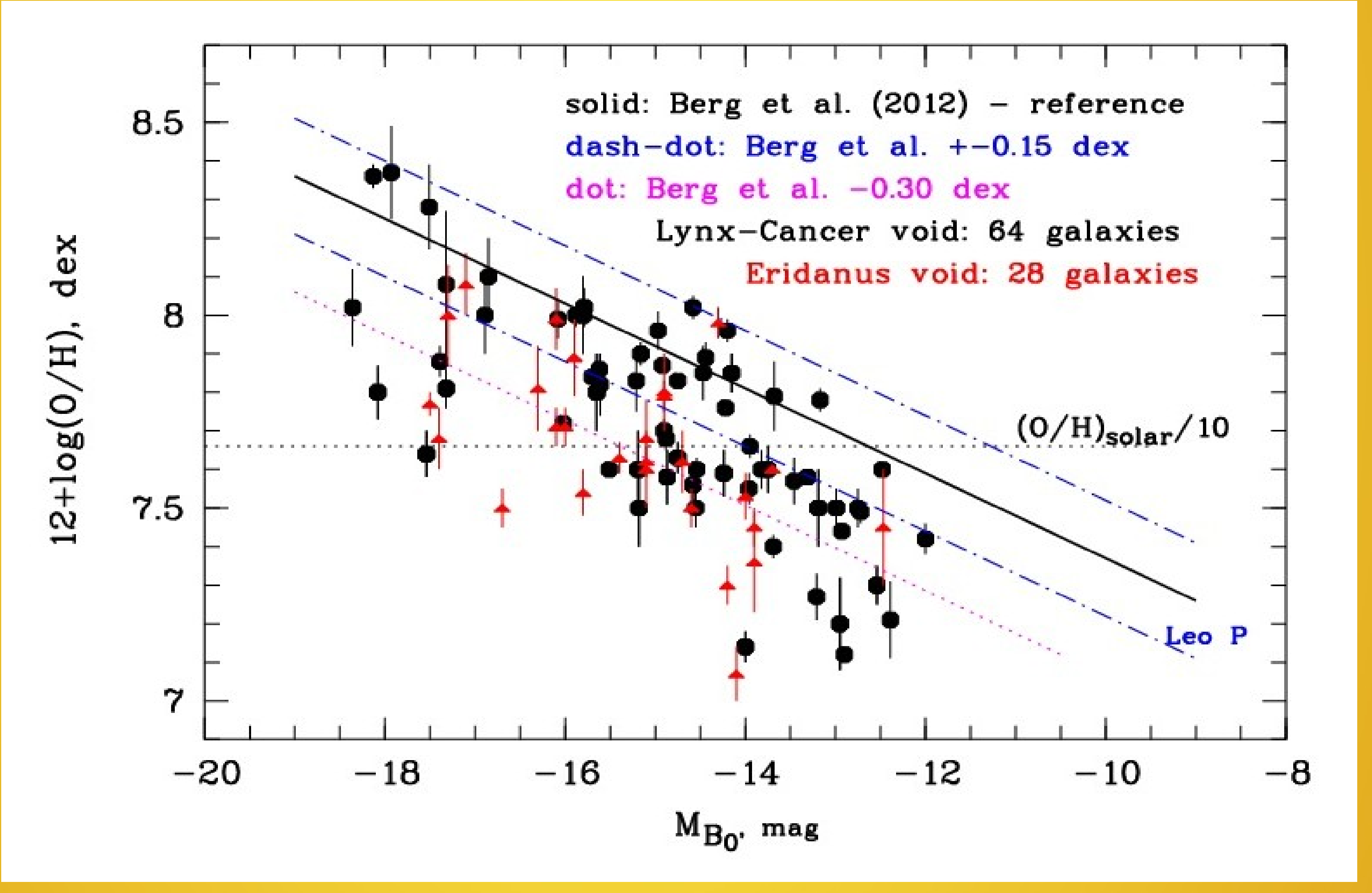
4. **Clustering of void galaxies**: paring, dwarf groups and unbound correlated structures (filaments).

The void galaxy sample: distributions on M_B and D_NN, distance to the nearest `luminous' neighbour. Reasonably complete to M_B ~ -14. Apparent preference of the outer void regions: consistent with expected due to the increasing volume.

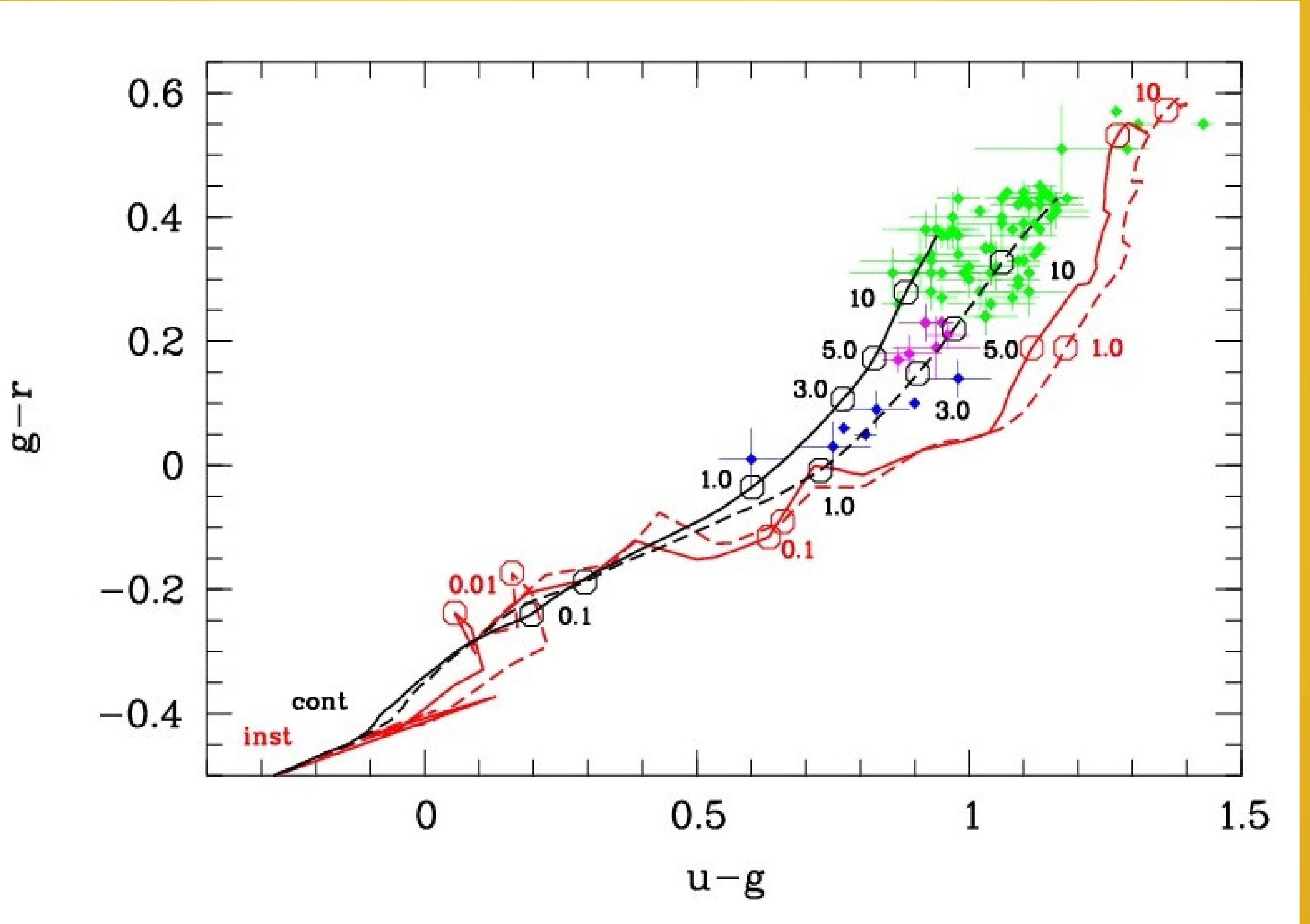




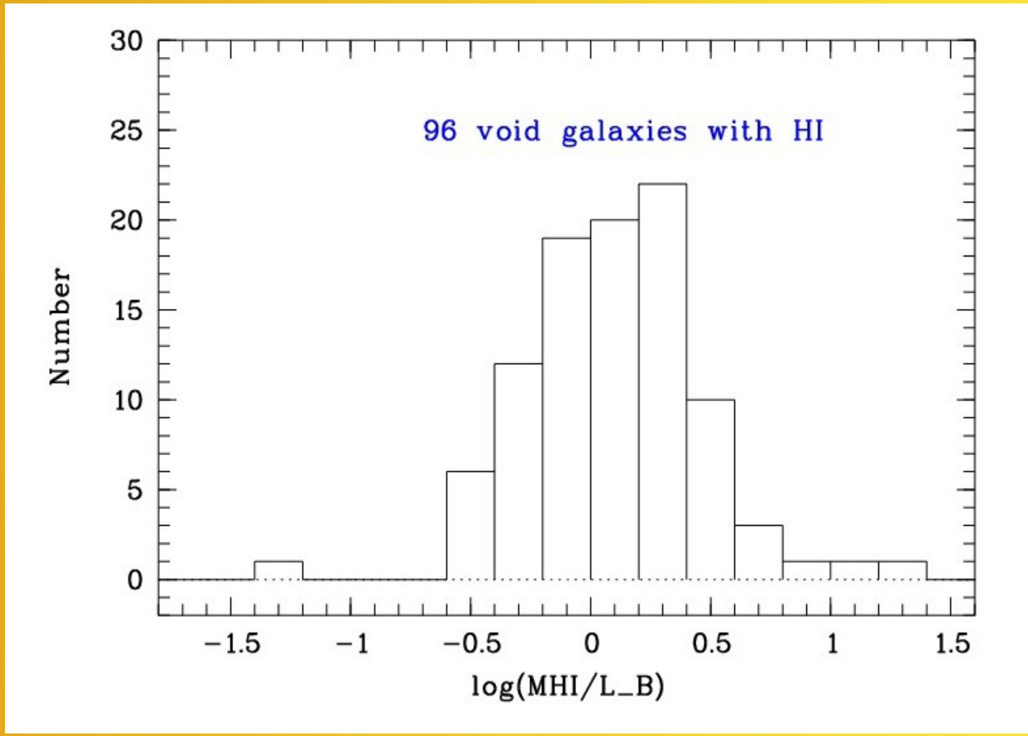
O/H vs M_B relation: 92 galaxies from Lynx-Cancer plus Eridanus void, compared to similar galaxies in denser environment (Berg et al. 2012, “reference”). Systematic overall O/H drop & sizable fraction (> 10%) of strong outliers (deficiency of O/H by factor of 3-5).(Pustilnik et al. 2011, and in prep.)

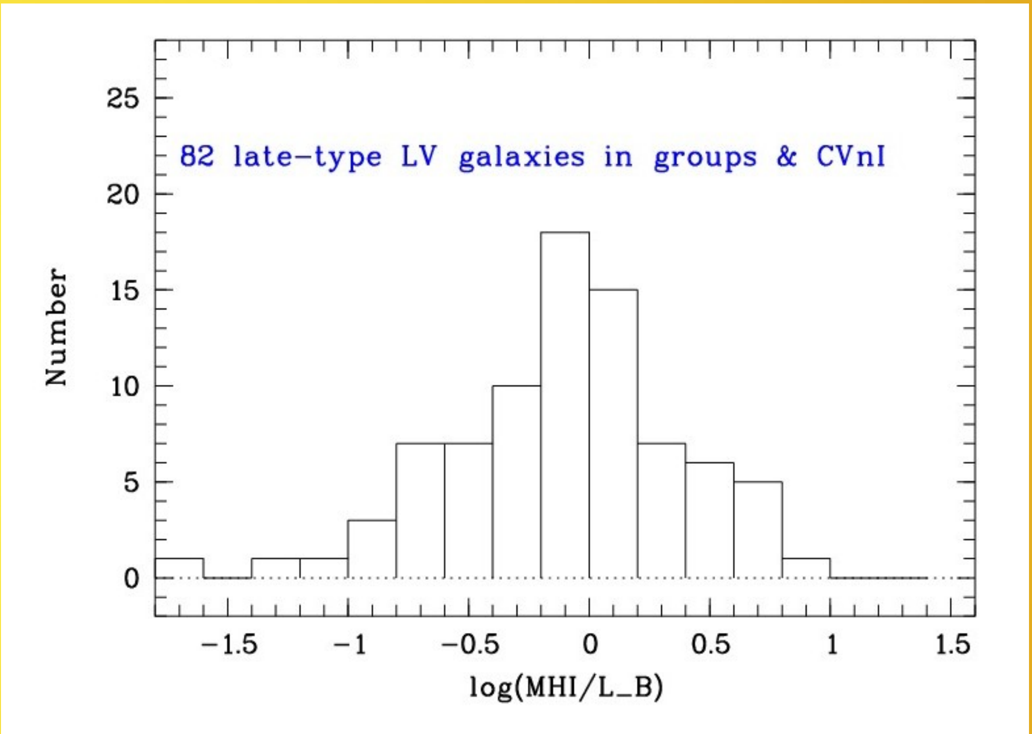


Age indicators: ugr colours of outer parts in 85 Lynx-Cancer void galaxies (on SDSS images) superimposed on PEGASE evolutionary tracks. Most are old. But ~15% show retarded main Star Formation, started only 1-6 Gyr ago (Perepelitsyna etal. 2014)

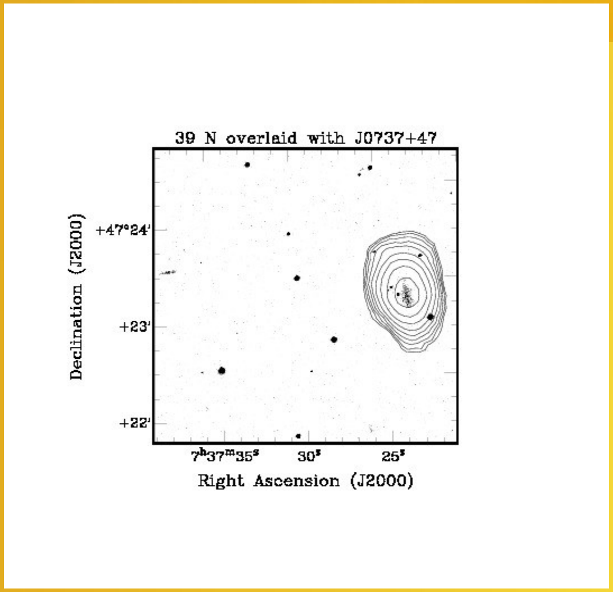


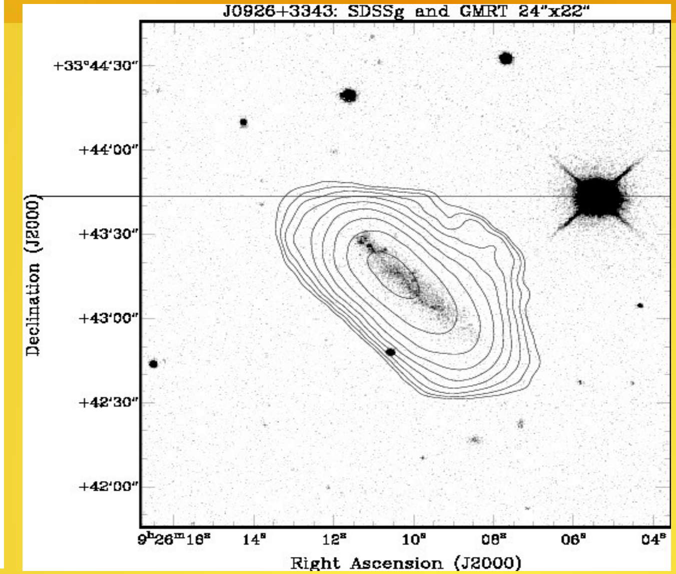
M(HI)/L_B ratio: Lynx-Cancer void galaxies vs similar galaxies in the Local Volume groups and CVn I cloud (after Karachentsev 2005). Confident elevation of gas mass, in average by ~40%. (Pustilnik, Martin 2014)

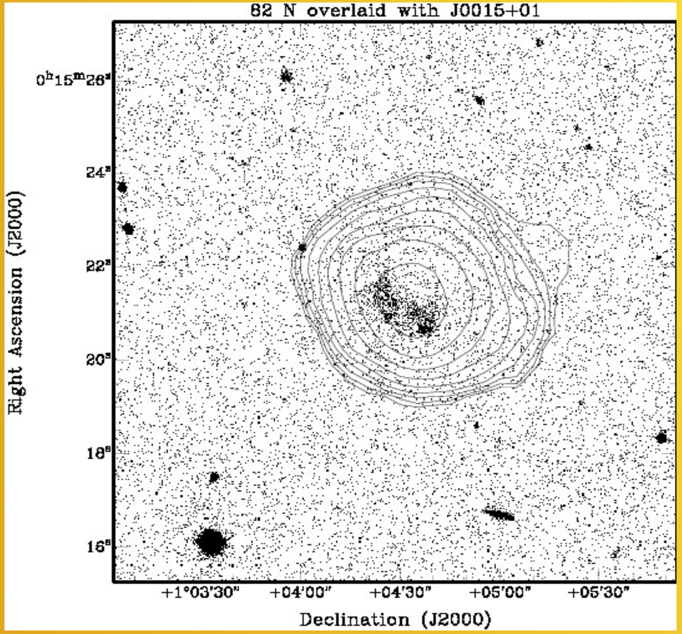




Disturbed HI morphology in isolated void LSBD galaxies on GMRT data: J0737+4724, J0926+3343, J0015+0104 *(Chengalur, Pustilnik, in prep.)*



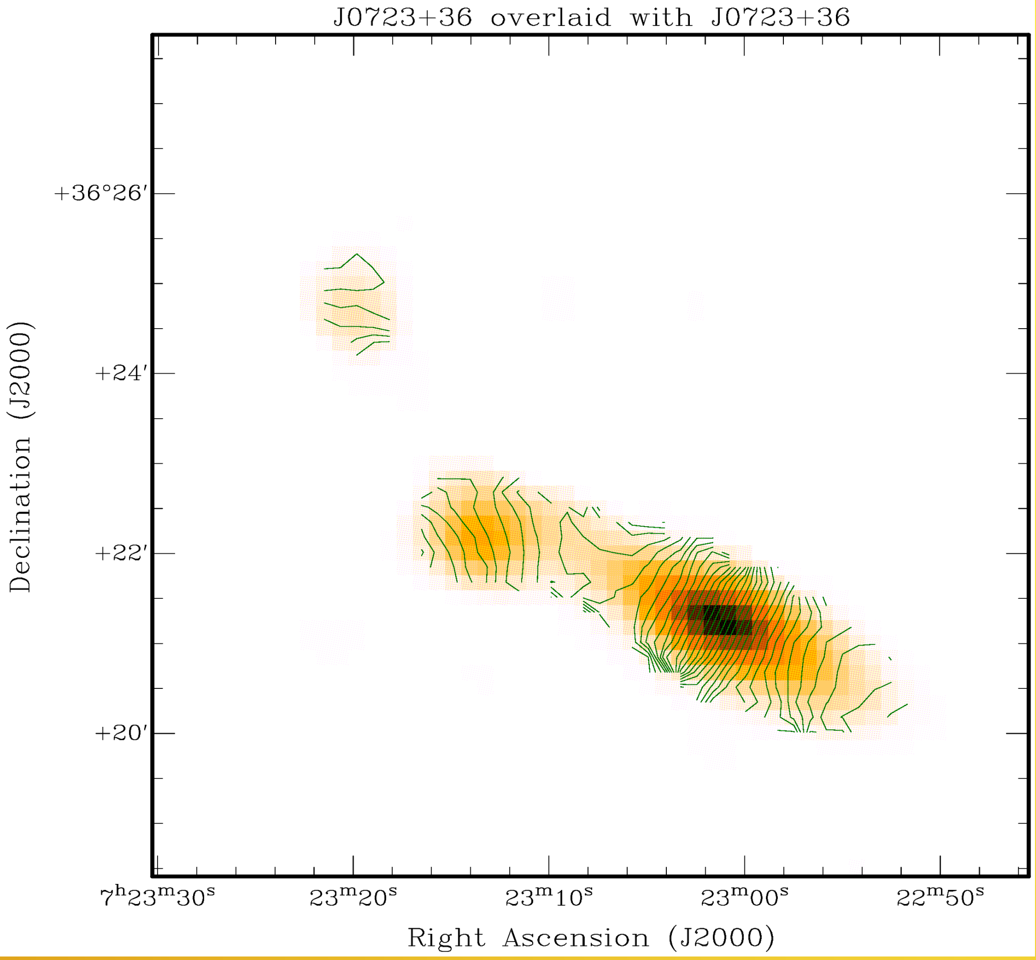


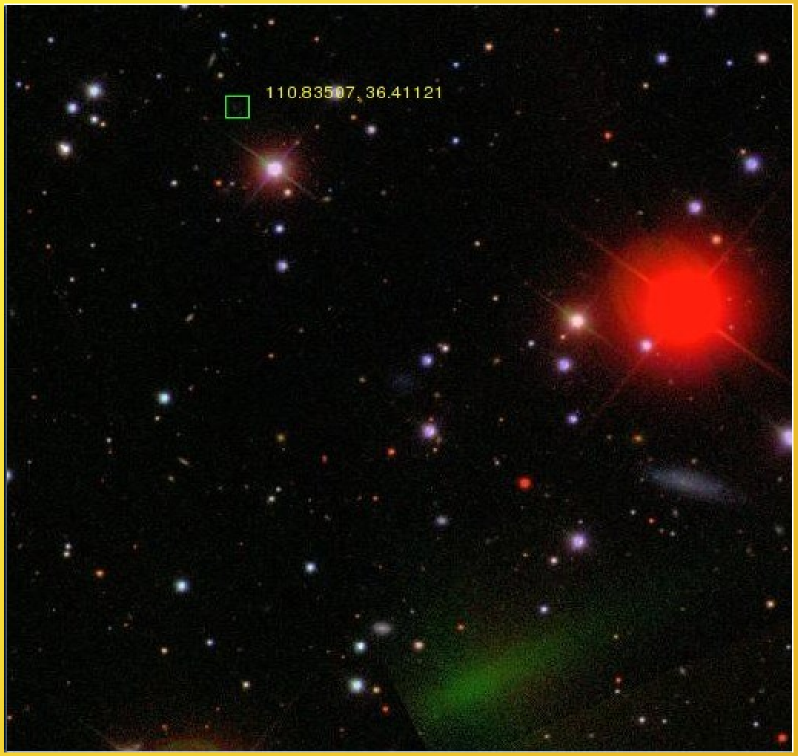


Two of them are the most metal-poor known LSBDs with 12+log(O/H)=7.07 and 7.12 (Guseva et al. 2009; Pustilnik et al. 2010)

Evidence for cold pristine accretion? Previous SF episode? Interaction with dark galaxies?

Discovery of extremely gas-rich dwarf triplet J0723+36 close to center of Lynx-Cancer void: M(HI)/L_B ~3, 10 and 25 (M_B of -14.2, -12, -9.7). Projected size ~25 kpc, dV~55 km/s (M_bary ~3*10^7--3*10^8 Mo). Hint to possible hidden void population of very gas-rich low mass galaxies for M_B > -11.5. (Chengalur, Pustilnik, 2013)

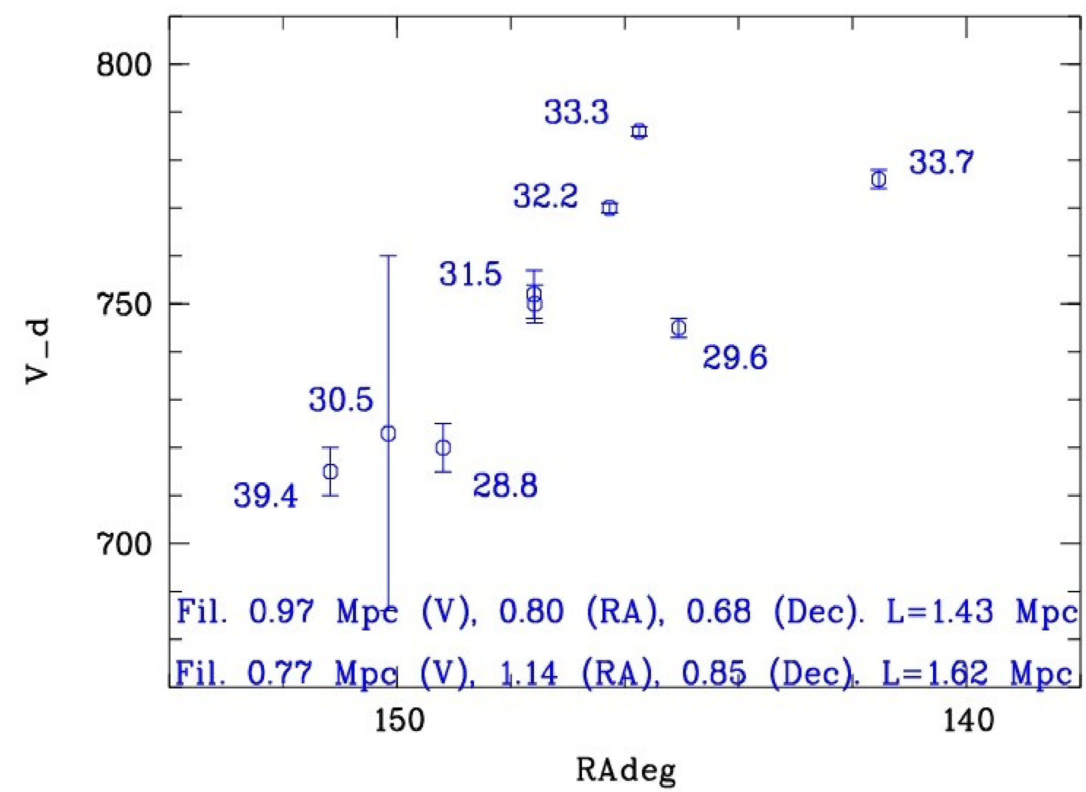




Void filaments: potential for comparison with simulations. (recently emphasized for voids in GAMA in Alpaslan et al. 2014)

Small filaments with lengths of ~1.5 Mpc, are identified in the Lynx-Cancer void. Currently they look too short in comparison to CDM simulations.

They may be a problem for WDM+(CDM) cosmology?



Plans and Prospects

1. **Increase** of nearby void galaxy samples and statistics by the **inclusion of all regions adjacent** the Local Volume: to understand better properties, diversities, evolutionary status, and thus to provide basement for comparison with cosmological simulations. **Takes large** optical and radio **telescopes**, needs **high resolution** N-body **simulations**.

2. **Search** for new **unevolved** low-mass **galaxies** and study of their properties: they can be crucial objects to test modern theories of galaxy formation.

3. Study of nearby voids' **filamentary structure** and its **relation to** the **cold accretion**. Properties of void filaments can be important to confront them with structure formation for scenarios with Cold+Warm Dark Matter.

Summary

* Study of evolutionary status of galaxies in nearby voids evidences for **slower chemical evolution and gas consumption** (in average by ~30-40%).

* ~1/3 of known the least luminous void objects (M_B > -13.2, M_bary <~10^8 Mo) show properties of **unevolved galaxies**, started their Star Formation on the later epoch, at T < (1-6) Gyr ago. Due to severe observational selection, such unusual void population with M_B > -11, -12 can be still mostly **hidden**.

* **Disturbed outer HI** morphologies with no `intruder' for lowest O/H void dwarfs suggest **cold pristine gas accretion** as an important factor of void galaxy evolution. Needs in further clarification.

* **Need** in good resolution **simulations of void galaxy** formation and evolution in the M_bary range of 10^7 to 10^9 Mo (DM mass of 3*10^8-10^10 Mo): a **challenge for the todays possibilities?**

Thank you for attention! Stay tuned.