Dwarf Galaxies: From the Deep Universe to the Present
Proceedings IAU Symposium No. 344, 2019
K. B. W. McQuinn & S. Stierwalt, eds.

doi:10.1017/S1743921318006257

Very gas-rich extremely metal-poor blue void dwarfs

Simon A. Pustilnik[1], **Yulia A. Perepelitsyna**[1], **Alexei Y. Kniazev**[2,3], **Evgeniya S. Egorova**[3] **and Jayaram N. Chengalur**[4]

[1]Special Astrophysical Observatory of RAS,
369167, Nizhnij Arkhyz, Karachai-Circessia, Russia
emails: sap@sao.ru, jlyamina@yandex.ru

[2]South African Astronomical Observatory,
1 Observatory road, Observatory, 7935 Cape Town, South Africa
email: akniazev@saao.ac.sa

[3]Sternberg Astronomical Institute of Moscow State University,
Universitetsky Pr. 13, Moscow, Russia
email: eshaldenkova@gmail.com

[4]National Centre for Radio Astronomy (TIFR),
Postbag 3, Ganeshkind, Pune 411007, India
email: chengalur@ncra.tifr.res.in

Abstract. Half-dozen of extreme representatives of void dwarf galaxy population were found in our study of evolutionary status of a hundred galaxies in the nearby Lynx-Cancer void. They are very gas-rich, extremely low-metallicity $[7.0 < 12 + \log(O/H) <\sim 7.3]$ objects, with blue colours of outer parts. The colours indicate the ages of the oldest visible stellar population of one to a few Gyr. They all are intrinsically faint, mostly Low Surface Brightness dwarfs, with $M_{\rm B}$ range of -9.5^m to -14^m. Thus, their finding is a subject of the severe observational selection. The recent advancement in search for such objects in other nearby voids resulted in doubled their total number. We summarize all available data on this group of unusual void dwarf galaxies and discuss them in the general context of very low metallicity galaxies and their possible formation and evolutionary scenarios.

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

---

1. Introduction

The low-metallicity galaxies with gas metallicity $Z < Z_{\odot}/10$ (known number more than 350) remain very rare objects. Even more so are XMP galaxies with $Z < Z_{\odot}/20$ (or $12 + \log(\mathrm{O/H}) \lesssim 7.38$, about 50 known galaxies, Guseva *et al.* (2017)). XMP galaxies are important as the best local proxies for forming galaxies in the early Universe. Most of known low-metallicity galaxies are found via optical spectroscopy of star-forming galaxies. There is a problem of dearth of low-metallicity dwarfs (Sanchez Almeida *et al.* (2017). One of the exits is the existence of many quiscent, LSB dwarfs with low or subtle SFR, missed by optical redshift surveys. The alternative means, such as A) blind wide-angle HI surveys (ALFALFA, Haynes *et al.* (2018)), B) colour-morphological selection of blue dIr (e.g., James *et al.* (2017), Hsyu *et al.* (2018)) and C) the unbiased study of all galaxies in the nearby voids, open additional channels to identify 'quiscent' XMP dwarfs. We describe and discuss the most unusual XMP dwarfs found in the nearby voids.

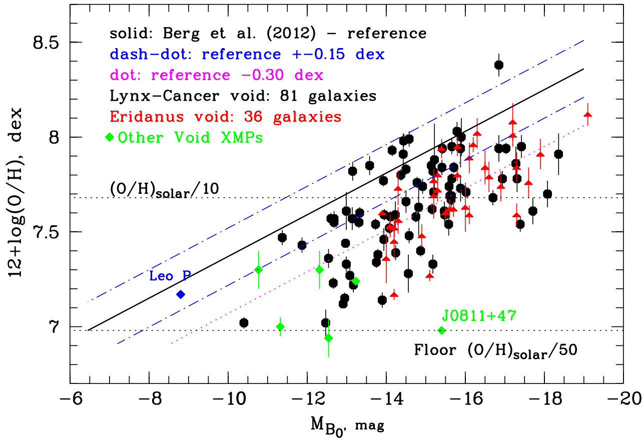

Figure 1. Nearby Void dwarfs on plot '$12+\log(\mathrm{O/H})$ versus M_{B}' in comparison with the linear regression (solid) for the reference sample of late-type galaxies in the Local Volume from Berg *et al.* (2012). Two dashed-dot lines show a one sigma scatter of the reference sample. Most of void galaxy data are from Pustilnik, Perepelitsyna, & Kniazev (2016) and Kniazev, Egorova & Pustilnik (2018). Several new void XMP galaxies are shown with green rombs. A dozen void dwarfs have $12+\log(\mathrm{O/H}) <\sim 7.20$, that is $Z_{\mathrm{gas}} <\sim Z_{\odot}/30$. Of them, 4–5 dwarfs have O/H at or near the so-called 'floor' level ($Z = Z_{\odot}/50$).

2. XMP dwarfs in the Lynx-Cancer, Eridanus and other nearby voids

Here we briefly summarize our recently published results on the unbiased study of Nearby Void galaxies (Pustilnik, *et al.* (2010), Pustilnik & Tepliakova (2011), Chengalur & Pustilnik (2013), Perepelitsyna, Pustilnik & Kniazev (2014), Pustilnik & Martin (2016), Pustilnik, Perepelitsyna, & Kniazev (2016), Chengalur, Pustilnik & Egorova (2017), Kniazev, Egorova & Pustilnik (2018)) or results from the papers in preparation.

1. Late-type void galaxies have in general reduced gas metallicity and elevated gas content, both in average by ∼40% with respect of reference samples of similar galaxies in the denser environment of the Local Volume.

2. In voids all dwarfs with $M_{\mathrm{B}} > -13$ and with measured O/H, appear to be in the low metallicity regime (O/H $<$ (O/H)$_{\odot}$/10).

3. A dozen void dwarfs have $12+\log(\mathrm{O/H}) <\sim 7.20$, that is $Z_{\mathrm{gas}} <\sim Z_{\odot}/30$. Of them, 4–5 dwarfs have O/H at or near the so-called 'floor' level ($Z = Z_{\odot}/50$) (see Fig. 1).

4. The most gas-rich void dwarfs have $\mathrm{M(HI)}/L_{\mathrm{B}} = 6-26$, or $M_{*}/M_{\mathrm{gas}} \lesssim 0.01-0.02$.

5. Blue colours in the outer parts outside the Star-Forming (SF) regions indicate relatively young stellar populations. Its time since the onset of SF $t_{\mathrm{SF}} <\sim 1-3$ Gyr for several most extreme XMP dwarfs. Their baryon masses (consisting practically of gas) fall in the range of $\sim 10^{7}$ M$_{\odot}$ to 3×10^{8} M$_{\odot}$.

3. Diversity of XMP dwarfs and prospects of deeper insights

There exist several scenarios explaining the existence of the most metal-poor dwarfs. They include:

A) probably the most common scenario of the substantial metal loss via the enriched gas outflow (wind) caused by SNe explosions during the episodes of elevated SF. One of the best examples is the nearest XMP dIr Leo P with $12+\log(\mathrm{O/H}) = 7.17$. Its carefully studied SF history based on the deep HST photometry, along with all other available data, indicates the loss of ∼95% metals produced during its cosmological evolution (McQuinn *et al.* (2015));

https://doi.org/10.1017/S1743921318006257 Published online by Cambridge University Press

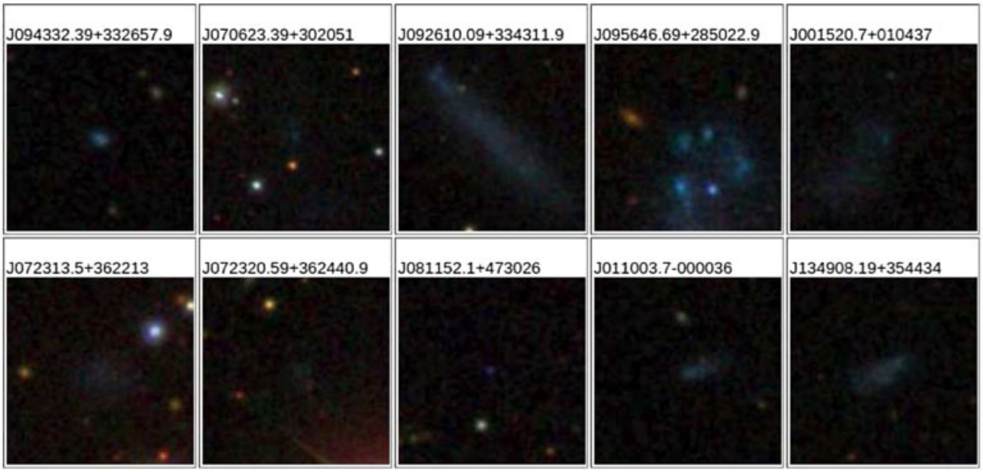

Figure 2. Eight Nearby Void dwarfs (including SF dwarf J0811+4730 at z=0.01444 from Izotov *et al.* 2018) with the confident or tentative $12+\log(\mathrm{O/H})$ in the range ∼7.0 – 7.2, that is $Z_{\rm gas} \sim Z_{\odot}/50$ – $Z_{\odot}/30$. Two similar extremely gas-rich faint void dwarfs without O/H, J0723+3622 and J0723+3624 are also included. Each finding chart is ∼50″ on side.

B) temporary strong local dilution of metals in the regions of current SF by blobs of the ambient intergalactic medium due to so called 'Cold Accretion' along cosmological filaments of low-Z gas ($Z \sim Z_{\odot}/50$) (many examples by Sanchez Almeida & co-authors). However, Filho *et al.* (2015), and Sanchez Almeida *et al.* (2016)) also find that the low-metallicity dwarfs favor voids.

C) Inflow of very metal-poor unprocessed ($Z \gtrsim Z_{\odot}/50$) gas from the distant periphery of gas-rich dwarfs to the central region of straburst due to the induced loss of gas stability by an external disturber (Ekta & Chengalur (2010)).

D) Additional effect of void environment: slower evolution due to the significantly reduced rate of galaxy interactions and probable delayed dwarf formation in shallow gravitational potential of negative density contrast. Such objects are expected to be true Very Young Galaxies (VYG, as defined by Tweed *et al.* 2018). The SF galaxy J0811+4730 at $D = 180$ Mpc with $Z_{\rm gas} = Z_{\odot}/50$ (Izotov *et al.* 2018) with only young stellar population is a probable VYG. The most interesting candidates to such nearby VYGs with lower SFR are presented here. See their SDSS images in Fig. 2. A couple dozen similar candidates in our Nearby Void Galaxy sample (Pustilnik *et al.* 2018, MNRAS, submitted) await for the additional checks.

The work is supported by grant of Russian Foundation for Basic Research No. 18-52-45008.

References

Berg, D. A., Skillman, E. D., Marble, A. R., *et al.*, 2012, *ApJ*, 754, 98
Chengalur, J. N., & Pustilnik, S. A., 2013, *MNRAS*, 428, 1579
Chengalur, J. N., Pustilnik, S. A., & Egorova, E. S., 2017, *MNRAS*, 465, 2342
Ekta, B., & Chengalur, J. N., 2010, *MNRAS*, 406, 1238
Filho, M., Sanchez Almeida, J., Muñoz-Tuñon, C., *et al.*, 2015, *ApJ*, 802, 82
Guseva, N. G., Izotov, Y. I., Fricke, K. J., & Henckel, C., 2017, *A&A*, 559, A65
Haynes, M. P., Giovanelli, R., Kent, B. R., *et al.*, 2018, *ApJ*, 861, 49
Hsyu, T., Cooke, R. J., Prochaska, J. X., & Bolte, M., 2018, *ApJ*, 863, 134
Izotov, Y. I., Thuan, T. X., Guseva, N. G., & Liss, S. E., 2018, *MNRAS*, 473, 1956

https://doi.org/10.1017/S1743921318006257 Published online by Cambridge University Press

James, B., Koposov, S., Stark, D., Belokurov, V., Pettini, M., Olszewsky, E., & McQuinn, K., 2017, *MNRAS*, 465, 3977

Kniazev, A. Y., Egorova, E. S., & Pustilnik, S. A., 2018, *MNRAS*, 479, 3842

McQuinn, K. B. W., Skillman E. D., Dolphin, A., *et al.* 2015, *ApJ*, 815, L17

Perepelitsuna, Y. A., Pustilnik, S. A., & Kniazev, A. Y., 2014, *Astrophys. Bull.*, 69, 247 (arXiv:1408.0613)

Pustilnik, S. A., & Tepliakova, A. L., 2011, *MNRAS*, 415, 1188

Pustilnik, S. A., & Martin, J.-M., 2016, *A&A*, 596, A86

Pustilnik, S. A., Tepliakova, A. L., Kniazev, A. Y., Martin, J.-M., & Burenkov, A. N., 2010, *MNRAS*, 401, 333

Pustilnik, S. A., Perepelitsyna, Y. A., & Kniazev, A. Y., 2016, *MNRAS*, 463, 670

Sanchez Almeida, J., Perz-Monter, E., Morales-Luis, A. B., Muñoz-Tuñon, C., Garcia-Benito, R., Nuza, S. E., & Kitaura, F. S., 2016, *ApJ*, 819, 110

Sanchez Almeida, J., Filho, M. E., Dalla Vecchia, C., & Skillman, E. D., 2017, *ApJ*, 835, 159

Tweed, D. P., Mamon, G. A., Thuan, T. X., Cattaneo, A., Dekel, A., Menci, N., Calura, F., & Silk, J., 2018, *MNRAS*, 477, 1427