Search for and study of extremely metal-deficient galaxies

S.A. Pustilnik* (sap@sao.ru)
Special Astrophysical Observatory of RAS, Nizhnij Arkhyz, 369167, Russia

A.Y. Kniazev (kniazev@mpia.de)
Max Planck Institut für Astronomie, Königstuhl 17, D-69117, Heidelberg, Germany

A.G. Pramskij (pramsky@sao.ru) and A.V. Ugryumov (and@sao.ru)
Special Astrophysical Observatory of RAS, Nizhnij Arkhyz, 369167, Russia

Abstract. We summarize the progress in identifying and observational study of extremely metal-deficient (XMD) gas-rich galaxies (BCGs, dIr and LSBDs). Due to volume limitation only following issues are addressed: sample creation, some statistical data, Colour-Magnitude Diagrams (CMD) and ages, the case of SBS 0335–052 system, and probable evolution paths of various XMD objects.

Keywords: galaxy evolution

1. Introduction

XMD gas-rich galaxies (conditionally with \(12+\log(O/H) < 7.65\)), are very rare objects in Local Universe, which best approximate the properties of young galaxies formed \(\sim 13\) Gyr ago. Since real young galaxies at that epoch are too faint to study them in detail, their local cousins provide a valuable information on the complex process of galaxy formation and early evolution. Moreover, some of known XMD gas-rich galaxies can be truly young local galaxies, just recently past the phase of protogalaxy. The specifics of XMD galaxy properties can be understood from comparison with the properties of more typical galaxy samples. Therefore the parallel study of main properties of general BCG, LSB and dI samples is very important.

2. XMD galaxy sample creation

In the beginning of 90-ties we realized that to understand the nature of XMD galaxies as a group we need to study the properties of sufficiently large number of such galaxies with reliable estimates of \(O/H\). Besides of well known Second Byurakan Survey, the search for new XMD BCGs was in particular the goal of Hamburg-SAO survey (HSS) for ELGs (Ugryumov et al. 2001 and references therein), and HSS-LM (Ugryumov et al. 2002). Kunth & Östlin (2000) gave a compilation of XMD galaxies known in 1999, including 18 BCGs, 6 LSBDs and 7 dIs. dIs

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are from the Local Group (LG) and its environments. Since that time 4 BCGs of their list were revisited and rejected. 16 more BCGs are added (many of which are still in press or preparation), thus increasing the number of XMD BCGs till 30. 9 of them are from the HSS for ELGs and HSS-LM. 4 new XMD BCGs are from KISS (Melbourne & Salzer 2002). Only one LSBD (UGCA 292) was added (van Zee, 2000).

### 3. Some Statistical Data

Surface density of XMD BCGs, as revealed by systematical ELG surveys (combined SBS+HSS data) is \( \sim 4 \) per 1000 sq.deg. (for \( B \leq 18.5^{m}, 12+\log(O/H) \leq 7.63 \)). Over the whole unobscured sky (\( \left| b^{II} \right| \leq 20^{\circ} \)) \( \sim 120 \) XMD BCGs is expected till \( B \sim 18.5^{m} \). Six new XMD BCGs are found in Voids and similar environments. Is this a hint on special conditions for very slow or retarded formation/evolution?

Distribution of O/H can be a useful indicator of the nature of XMD BCGs. If all observed galaxies are from the same ensemble started star formation \( \sim 13 \) Gyr ago with different SF rates and metal loss efficiencies, one should expect smooth unimodal O/H distribution with a tail on small O/H. If small, but significant fraction of truly young XMD galaxies exists, this should result in a second peak at very low O/H, and hence in bimodality of O/H distribution. While the existing statistics is quite limited, there are hints on such bimodality (see, e.g., left panel of Fig. 1). Similar hint is present in plot of O/H vs \( M_0^B \), drawn on 236 galaxies (right panel of Fig. 1, BCGs are mainly from SBS, HSS-ELG and HSS-LM). While the well known trend is still noticeable, the scattering at very low O/H reaches 6 magnitudes, suggesting non-typical evolution histories for the most luminous XMD galaxies.

### 4. Resolved stars and old XMD galaxies

SF histories of the LG XMD dIr were studied with CMDs of resolved stars. All of them have detectable old populations. Due to lack of space we cite only review by Mateo (1998). LG XMD galaxies are, thus, certainly old. New HST data evidence for old stars in a bit more distant XMD LSBDs: DDO 53 (L.Makarova, priv. communication) and UGCA 292 (van Zee, priv. communication). Izotov & Thuan (2002) for UGC 4483 found stars with \( T \sim 2 \) Gyr. The most metal-deficient BCG I Zw 18 (\( Z \sim 1/51 Z_{\odot} \)) was claimed to have old stars (Östlin 2000 and references therein) on HST images. However this issue did not settled yet due to the problems with the proper account of clumpy dust extinction.
Figure 1. Left panel: Histogram of O/H distribution for 49 BCGs and dIs with $M_B$ near −17$^m$. Solid line shows a Gaussian fit. The outlier is SBS 0335–052 E. Right panel: O/H vs $M_B$ for 236 galaxies with $\sigma$(O/H) ≤ 0.10 dex.

Figure 2. Left panel: $(R-I)$ colours vs age for PEGASE.2 evolution tracks (Fioc & Rocca-Volmerange 1997) with superimosed $(R-I)$ colours of underlying emission of E and W components of SBS 0335–052, after the gas emission subtraction. Arrows indicate the range ±1σ for derived $(R-I)$. Right panel: VLA 21-cm map of giant disturbed $H\text{I}$ cloud, in which both Eastern and Western galaxies are immersed.

5. The case of XMD pair SBS 0335–052 E and W

To estimate the ages of unresolved stars in the outermost regions of XMD BCGs the subtraction of ionized gas emission is often crucial. The SAO 6 m telescope deep $UBVRI$,Hα surface photometry of SBS 0335–052 E,W (Pustilnik et al. 2002, in prep.) results in no traces of stellar populations with ages T>200 Myr. Comparison of derived gas-emission subtracted colours with the PEGASE.2 evolution models tracks is shown in the left panel of Fig. 2. The similar analysis of I Zw 18 by Papaderos et al. (2002) results in the similar conclusions.

The W component of the system SBS 0335–052 (at ~22 kpc from E component) is a dwarf galaxy with O/H close to that of I Zw 18
(Lipovetsky et al. 1999). Its pairing with the E galaxy favors a hypothesis of their common recent formation in one huge H\textsc{i} cloud disturbed by an external galaxy (see VLA H\textsc{i} map from Pustilnik et al. 2001 in Fig. 2, and discussion therein). A chance collision of two such unusual dwarfs looks highly improbable due to their very low space density.

6. Evolution paths of XMD galaxies

While the amount of observational data on XMD galaxies is far from sufficient for firm conclusions on their evolution status/scenario, some preliminary options emerge from the data accumulated to-date:

- Extremely gas-rich LSB galaxies outside the Local Group – DDO 154 (Kennicutt & Skillman 2001) and UGCA 292 (van Zee 2000), evolve very slowly well along the closed-box model track.

- Local Group XMD dIr galaxies have either the deficit of metals for their gas content (due to galactic winds), or stripped gas for their low metallicity (Kennicutt & Skillman 2001). They all are old objects.

- There are a few XMD BCGs with very blue LSB hosts. Probably some of them are young (e.g., SBS 0335–052 E and W, I Zw 18).

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