COLORS AND MORPHOLOGY OF GALAXY PAIRS IN THE ENVIRONMENT OF RX J0152.7-1357 CLUSTER

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Abstract. A complete sample of 86 spectroscopically confirmed members of the massive X-ray cluster RX J0152.7-1357 ($z = 0.837$) is used for the analysis of the photometric and morphological properties of galaxies in pairs and groups. Combining optical-NIR photometric data, morphological data, and archival images from Hubble Space Telescope (ACS/ WFC) we obtained a kinematic galaxy pairs sample with 38 galaxies (Popescu, 2014). In the present paper, an extended study of the colors and morphology of the galaxy pairs in this sample is presented. As characteristics of interactions/mergers that trigger star formation activity, we determine features of interactions, with signs of morphological disturbance and bluer colors, at many galaxies in the studied sample of galaxy pairs.

Key words: galaxy groups and clusters – galaxy-galaxy interactions – galaxy pairs.

1. INTRODUCTION

Using the catalogs of Blakeslee *et al.* (2006) and Demarco *et al.* (2010), the environment of the massive X-ray cluster RX J0152.7-1357, at $z = 0.837$, was analyzed by us in previous papers (see Popescu, 2013; Popescu, 2014). A complete sample of 86 confirmed members with optical-NIR photometric data, morphological data and spectroscopic redshifts was obtained by us (Popescu, 2013), combining the catalog of Blakeslee *et al.* (2006) (with ($F625W$, $F775W$, $F850LP$) HST/ACS/WFC optical photometric data, spectroscopic and morphological data for 107 galaxies, in a 42 arcmin^2 field) and the catalog of Demarco *et al.* (2010) (with ($F625W$, Ks) optical and near-infrared photometric data, for 134 galaxies in a 46.24 arcmin^2 field).

In both catalogs the magnitudes are on the AB system (Oke, 1974), being corrected for Galactic extinction according to Schlegel *et al.* (1998) as follows: 0.038 mag in $F625W$ (denoted r_{625}); 0.029 mag in $F775W$ (denoted i_{775}); 0.021 mag in $F850LP$ (denoted z_{850}); 0.009 mag in Ks.

At the cluster redshift of $z \sim 0.84$, in the cosmological model $H_0 = 70$ km s^{-1} Mpc^{-1}, $\Omega_m = 0.3$, and $\Omega_\Lambda = 0.7$, $1''$ on the sky corresponds to 7.6 kpc in a physical distance. Thus, a linear size of 0.455 Mpc corresponds to $1'$ on the sky. The data from this catalog cover a field of 46.24 arcmin^2 (6.8 arcmin $\times$ 6.8 arcmin), which is

equivalent to an area of 3.1 Mpc $\times$ 3.1 Mpc at the cluster redshift.

A detailed study of the photometric and morphological characteristics of the confirmed members of the cluster RX J0152.7-1357 was done (Popescu, 2013). Especially the properties of the early type galaxies and the structural properties of the population of Extremely Red Galaxies (ERGs) were analyzed (Popescu, 2013). Also, we determined a galaxy-pairs sample of 38 galaxies in the field of the cluster RX J0152.7-1357, according to a strong pair isolation criterion in terms of the apparent angular separation and rest-frame line-of-sight velocity difference (Popescu, 2014). The photometric, morphological and spectroscopic characteristics of the 38 galaxies in the galaxy-pairs sample are presented in Tabel 1 (Popescu, 2014). In the present paper, an extended study of the colors and morphology of this sample of galaxy pairs is obtained, underlying the role of galaxy-galaxy interactions in triggering star formation and strong modification of galaxy morphology and colors.

2. COLORS AND MORPHOLOGY OF GALAXY PAIRS

The interactions and mergers between different types of galaxies can have essentially different final products. In the case of *dry mergers* (*i.e.* mergers between two gas-poor galaxies), the star formation rate may not be importantly changed. According to van Dokkum (2005), Bell *et al.* (2006), dry mergers could influence the stellar mass growth of massive red galaxies at the current epoch.

On the other hand, the mergers between two gas-rich galaxies (*i.e.* , *wet mergers*) can trigger additional star formation (Lambas *et al.*, 2003; Lin *et al.*, 2007; Barton *et al.*, 2007), causing quasar activity and the transformation of the disk galaxies into ellipticals (Toomre and Toomre, 1972).

Additionally, the relation between mixed pairs (*i.e.* , an elliptical/lenticular galaxy + a spiral or irregular galaxy) and the separation of galaxies might offer indication on the efficiency of the elliptic galaxies to interrupt the star formation even of other neighboring galaxies.

Generally, there are two main approaches to define the samples of mergers:

1) The morphological selection criterion - this procedure is focused on structural disturbances and/or tidal features (Bridge *et al.*, 2010; Chou *et al.*, 2011). Galaxy mergers tend to present strong morphological disturbances at the first encounter and the last merging stage. Then, the morphological selection criteria are biased toward selecting mergers at the final merging stages.

2) The kinematic selection criterion - this procedure identifies mergers by limiting the projected physical separation and the velocity differences between two close pair members (Patton *et al.*, 2000; Lin *et al.*, 2008; Patton and Atfield, 2008; Patton *et al.*, 2011).

In our study, in the detection of the galaxy mergers sample for the galaxies in the field of RX J0152.7-1357 we consider the kinematic selection criterion (see Popescu, 2014).

A strong evidence of galaxy interactions is represented by the galaxy color. According to Ellison *et al.* (2010) and Patton *et al.* (2011), the presence of a nearby companion in galaxy pairs can often be related with triggered central star formation, that has as result bluer colors.

In our sample, one observes that the galaxies in pairs present obvious features of interactions, with bluer $(i_{775} - z_{850})$ and $(r_{625} - Ks)$ colors, as characteristics of interactions/mergers that trigger star formation activity (see Table 1 in Popescu, 2014). Also, in this paper we define the Extremely Red Galaxies (ERGs) as objects whose colors satisfy the conditions $(r_{625} - Ks)_{AB} \geq 3.594$ (Hall and Green, 1998; Hall *et al.*, 2001), that is the equivalent of the usual definition relation $(R - K)_{Vega} \geq 5$. The morphologies of galaxies in the considered ACS field (down to an AB magnitude limit of $i_{775} < 23.5$) have been classified according to Postman *et al.* (2005).

In the case of a morphological analysis of the galaxy pairs sample, evidences of the interactions can be observed looking at the Fig.1 - Fig.6, where some of the galaxy pairs are presented (the archival images from Hubble Space Telescope (ACS/WFC), from CADC database). In the following we will describe these galaxy pairs.

Fig.1 presents the pairs formed by the galaxies (B1808, B1859, B2420), and by (B2412, B2747, B2623, B2569) - see also Table 1 (Popescu, 2014) for the morphology, colors and other characteristics. Among these pairs we mention the close pair of extremely red elliptical galaxies (B1808, B1859), with $(r_{625} - Ks)_{AB} = 3.716$ and $(r_{625} - Ks)_{AB} = 3.604$, respectively. In the same figure, the (B2623, B2569) galaxy pair has $r_{proj} = 27.862$ kpc, being a close pair formed by an elliptical and an S0.

In Fig.2, (B5495, B5417) represents a dry merger with a small projected physical separation $r_{proj} = 13.847$ kpc, and the photometric characteristics K_{AB}=19.119 (B5495), and K_{AB}=19.147 (B5417). These galaxies are among the brightest elliptical galaxies in the field of RX J0152.7-1357 cluster.

Fig.3 shows the triplet (B0499, B0748, B0899), that contains an extremely red galaxy (B0499) with $(r_{625} - Ks)_{AB} = 3.633$ (see also Popescu (2014) - Table 1 for the morphology, colors and other characteristics).

Fig.4 depicts the (B6434, B6417) mixed pair with strong signs of interactions (see also Table 1 in Popescu, 2014).

Fig.5 presents the (B3941, B3940) galaxies, that form the pair with the smallest projected physical separation $r_{proj} = 12.555$ kpc, and the photometric characteristics K_{AB}=19.197 (B3941), K_{AB}=19.244 (B3940). These galaxies are among the brightest galaxies in the field of RX J0152.7-1357 cluster, forming a mixed pair that present obvious signs of the close interaction between an extremely red elliptical galaxy and

an Sa type galaxy. Another pair in this figure is (B10164, B10259), that represents a wet merger with $r_{proj} = 28.257$ kpc, with evident signs of interactions (see also Table 1, Popescu, 2014).

In Fig.6, (B4680, B4219) represents the dry merger with the brightest galaxies from the entire sample, with K_{AB}=18.817 (B4680), K_{AB}=18.613 (B4219), positioned at a large projected physical separation $r_{proj} = 104.72$ kpc. Other pairs are formed by (B4126, D1356) galaxies, and the (B4003, B10673, B3956) triplet of galaxies that generate a mixed pair and a dry merger (see Table 1 in Popescu, 2014).

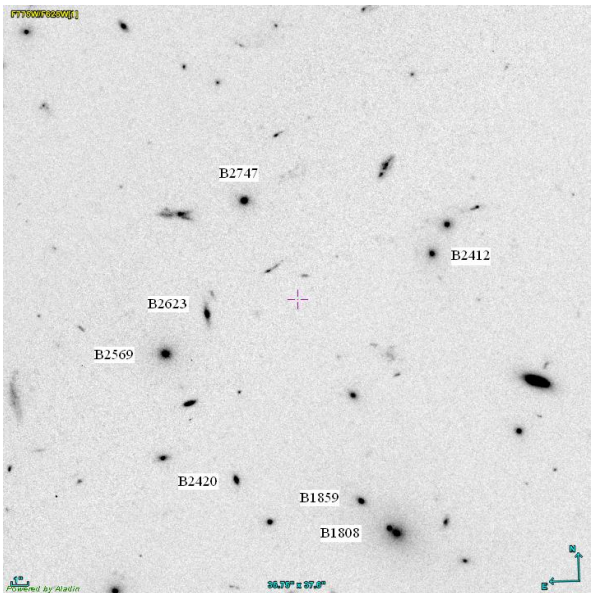

Fig. 1 – The image of the (B1808, B1859, B2420) elliptical/S0 galaxies, and the (B2412, B2747, B2623, B2569) group that contains dry mergers.

In the case of the galaxy pair sample for RX J0152.7-1357 environment, one observes that the blue-blue pairs (the candidate for wet mergers) are found in field-like environments, while the red-red pairs (the candidate for dry mergers) and blue-red pairs (the candidate for mixed pair) tend to lie in denser environments (group and/or cluster-like environments).

An important remark concerns the presence of the emission line galaxies (see Table 1 in Popescu, 2014) in the case of three mixed pairs (B5606, B5037), (B6434, B6417), (B1355, B1571), and a wet merger (B1809, B1898).

Among the 38 galaxies in the sample, we have identified eleven galaxy-pairs, three triplets of galaxies, and a small group of 4 galaxies. Only the pairs formed by galaxies with identification numbers B5495 - B5417 (with $r_{proj} = 13.847$ kpc),

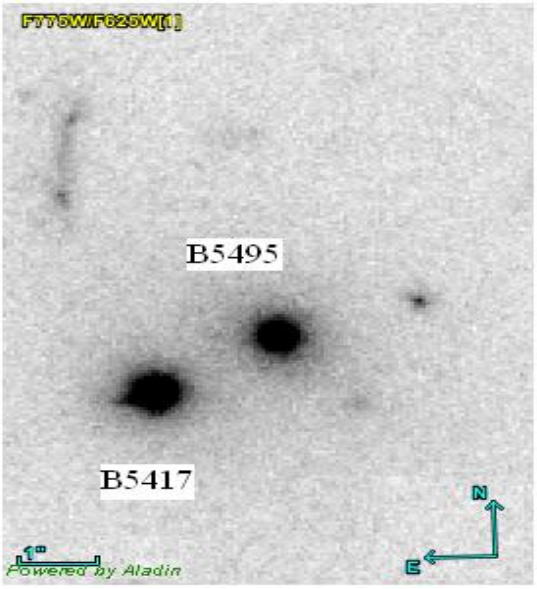

Fig. 2 – The image of the (B5495, B5417) dry merger, with a small projected physical separation of $r_{proj} = 13.847$ kpc.

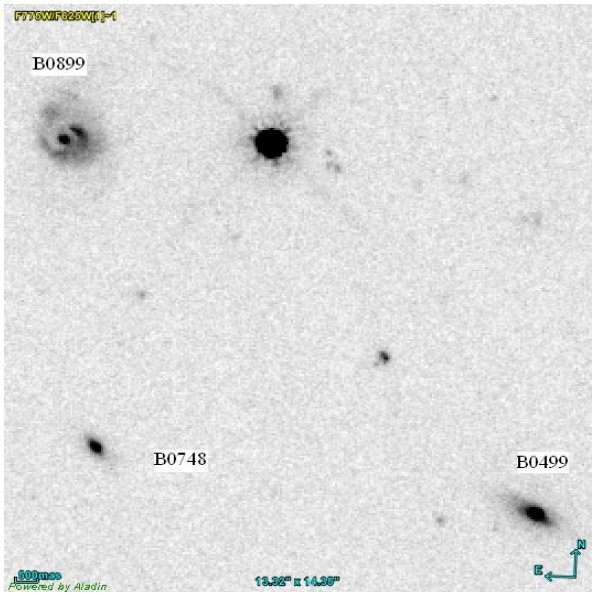

Fig. 3 – The image of the (B0499, B0748, B0899) triplet galaxies, that form mixed pairs between S0/Sa and later type spiral (Sp) galaxies.

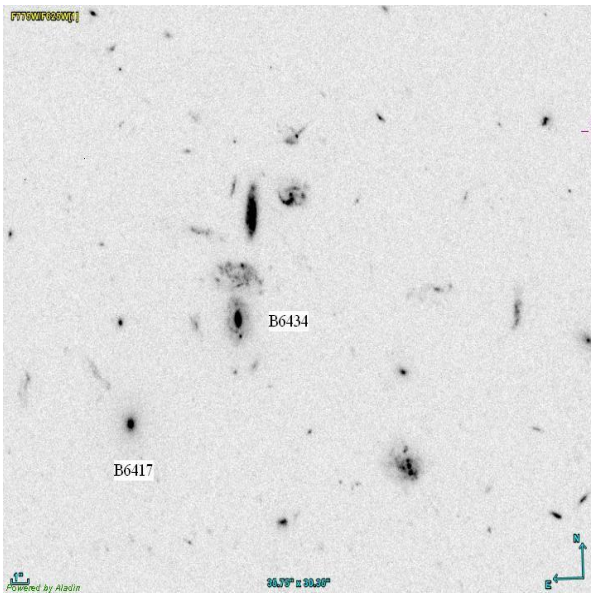

Fig. 4 – The image of the (B6434, B6417) mixed pair.

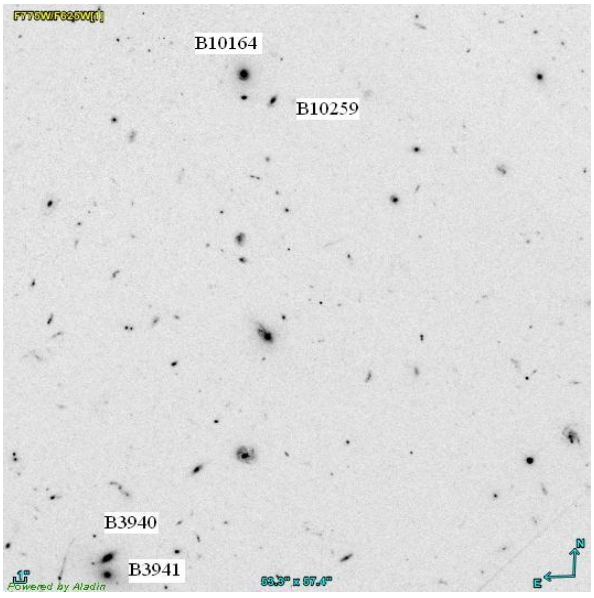

Fig. 5 – The image of the (B3941, B3940) mixed pair, and the (B10164, B10259) wet merger.

B3270 - B3297 (with $r_{proj} = 46.14$ kpc), B1808 - B1859 (with $r_{proj} = 22.656$ kpc), B2623 - B2569 (with $r_{proj} = 27.862$ kpc), B3941 - B3940 (with $r_{proj} = 12.555$

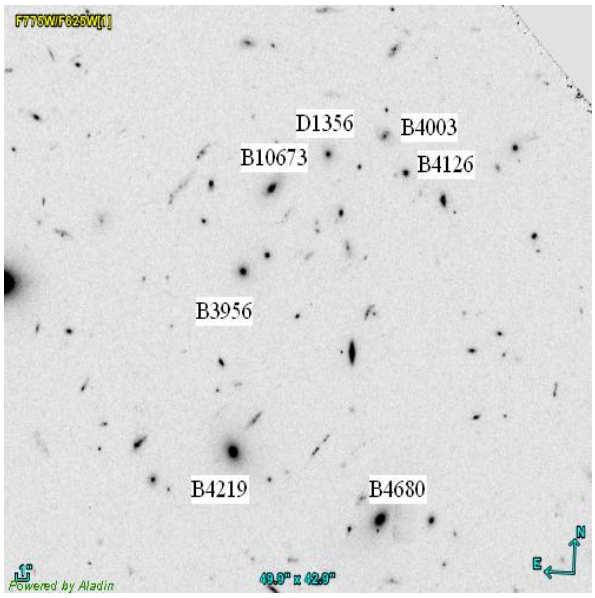

Fig. 6 – The image of the (B4680, B4219) mixed pair, and the (B4003, B10673, B3956) triplet of galaxies.

kpc), and B10164 - B10259 (with $r_{proj} = 28.257$ kpc) have the projected distances less than 50 h^{-1}kpc, and fulfill the criteria for close pairs of galaxies.

The other galaxies represent wide pairs of galaxies, with projected distances in the range 50 h^{-1}kpc $\leq r_{proj} \leq$ 143 h^{-1} kpc.

Features of interactions, with signs of morphological disturbance and bluer colors, as characteristics of interactions/mergers that trigger star formation activity were observed at many galaxies in the galaxy pairs sample.

3. CONCLUSIONS

In this paper we performed a detailed characterization of the photometric and morphological properties of 38 galaxies in pairs, triplets, and small groups, in the environment of the cluster RX J0152.7-1357 ($z = 0.837$), using optical-NIR photometric data, morphological data, redshifts and HST (ACS/WFC) archival images. We determined a large fraction of red galaxies in pairs, triplets and small groups, and we revealed the presence of the emission line galaxies in the case of three mixed pairs, and a wet merger. Additionally, wet mergers were discovered in field-like environments, and dry mergers and mixed pairs were determined in denser environments, confirming the well known relation between galaxy colour and local density.

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