SF2A 2014
J. Ballet, F. Bournaud, F. Martins, R. Monier and C. Reylé (eds)

GALAXY LUMINOSITY FUNCTION: EVOLUTION AT HIGH REDSHIFT

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Abstract. There are some disagreements about the abundance of faint galaxies in high redshift clusters. DAFT/FADA (Dark energy American French Team) is a medium redshift ($0.4 < z < 0.9$) survey of massive galaxy clusters ideal to tackle these problems. We present cluster galaxy luminosity functions (GLFs) based on photometric redshifts for 30 clusters in B, V, R and I restframe bands. We show that completeness is a key parameter to understand the different observed behaviors when fitting the GLFs. We also investigate the evolution of GLFs with redshift for red and blue galaxy populations separately. We find a drop of the faint end of red GLFs which is more important at higher redshift while the blue GLF faint end remains flat in our redshift range. These results can be interpreted in terms of galaxy quenching. Faint blue galaxies transform into red ones which enrich the red sequence from high to low redshifts in clusters while some blue galaxies are still accreted from the environment, compensating for this evolution so that the global GLF does not seem to evolve.

Keywords: galaxies: cluster: general - galaxies: evolution - galaxies: formation - galaxies: luminosity function, mass function

1 Introduction

The evolution of galaxy population in clusters is still an ongoing problem. In particular, the behaviour of the faint end of the galaxy luminosity function (GLF) of clusters gives us some clues about cluster formation and evolution. The disagrement found in the litterature arises from the use of small data sets, differences in observations and in techniques. Most authors find that the GLF faint end is decreasing at high redshift (e.g. Rudnick et al. 2009) but some authors still see a flat faint end at the same redshift (e.g. De Propris et al. 2013). The first observation would require a galaxy type evolution inside clusters while the second would result in fixed galaxy populations from redshift around $z = 0.9$ until now.

We want to address this problem with the largest galaxy cluster sample dedicated to this kind of studies to conclude on the different observed scenarii. We show here some preliminary results for a small number of clusters. A complete description of this work, taking into account about 30 clusters can be found in Martinet et al. (in revision).

DAFT/FADA is a survey of about 90 massive clusters at medium high redshift ($0.4 < z < 0.9$) based on HST data and on a ground based follow up on 4m class telescopes. The work presented here concerns a subsample of 6 clusters for which we have gathered ground based images in the u or B, V, R, I, Z optical bands and also in the J or Ks near infrared bands. The various telescopes used are CFHT, Subaru, VLT, WIYN, SOAR and CTIO.

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2 Measuring Galaxy Luminosity Functions (GLF)

Magnitudes are extracted using Sextractor (Bertin & Arnouts 1996) and are corrected from the extinction calculated from dust maps of Schlegel et al. (1998).

In order to properly estimate the cluster membership of galaxies, we compute photometric redshifts (photo-zs) for each galaxy with the LePhare software (Ilbert et al. 2006). The use of the combined optical and near infrared images plus a spectroscopic calibration allows us to achieve a precision of $\sigma_{photoz} = 0.06$ for every type of galaxy. Once photometric redshifts are calculated, we transpose our magnitudes measured on images from various telescopes into the VLT filters to homogenize our sample.

We also accurately measure the completeness of our data in each image. To do this we simulate stars of various magnitudes using the extracted PSF of the image and then insert and redetect these fake stars in the initial images. In average, our data are 90% complete until a magnitude of i=23.2. The k-correction is taken into account both for galaxies and when converting the completeness limit from apparent to absolute magnitudes.

GLFs are obtained by summing galaxies in bins of absolute magnitude in a 1 Mpc radius around the cluster optical center. Galaxies are said to belong to the cluster if their photo-zs lie in an interval of ± 0.2 around the cluster spectroscopic redshift. This large interval is chosen to be about 3σ of the standard deviation on our photo-zs. Background galaxies are then subtracted using field GLFs from Ilbert et al. (2005) calculated in the same redshift bins. Finally GLFs from different clusters are stacked together by averaging their galaxy numbers in the same absolute magnitude bins. Only clusters with the same 90% completeness limit can be stacked in this way, leading to stacks including different numbers of clusters.

We have also separated the early type and late type populations. This separation is done in a (V-I) versus I color magnitude diagram for galaxies already selected to belong to the cluster based on their photo-z. The red sequence is determined by a fixed slope (Durret et al. 2011) and a width of ± 0.3 in colour. The ordinate varies with redshift and is thus fitted on diagrams for each cluster. Galaxies within the red sequence correspond to early type galaxies, also refered to as red galaxies, and galaxies below the red sequence correspond to late type galaxies or blue galaxies. The other steps of the reduction are done in the same way as for all galaxy GLFs.

3 Evolution with type and redshift

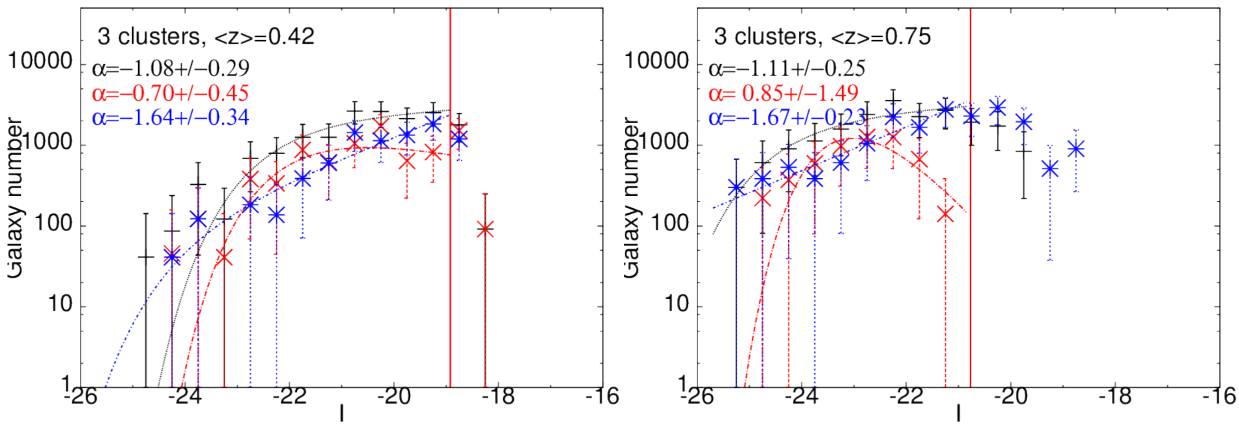

Fig. 1. Evolution of total, early type and late type I restframe band GLFs with redshift. **Left**: GLFs for three clusters at intermediate redshifts ($0.40 < z < 0.65$) stacked together. **Right**: GLFs for three clusters at higher redshift ($0.65 < z < 0.90$) stacked together. Total, early type and late type GLFs are respectively shown in black, red and blue. The α parameter is also displayed for each population. The vertical red line corresponds to the 90% completeness limit and only bins brighter than this limit are taken into account when performing the fit.

GLFs are usually fitted with Schechter functions (eq. 3.1, Schechter 1976).

$$N(M) = 0.4\log(10)\phi^*[10^{0.4(M^*-M)}]^{\alpha+1}\exp(-10^{0.4(M^*-M)}) \tag{3.1}$$

We investigated the variation of these Schechter parameters with various cluster observables (optical band, mass, redshift, completeness, environment, ...) and those results can be found in Martinet et al. (in revision). Here we only discuss the variation of the faint end slope with redshift in the I restframe band and for different galaxy populations. The faint end is characterized by the α parameter, with $\alpha = -1$ corresponding to a flat faint end, $\alpha < -1$ to a steep faint end and $\alpha > -1$ to a decreasing faint end.

Fig. 1 shows total, early type and late type I restframe band GLFs along with their best Schechter fits for stacks of three intermediate redshift clusters ($0.40 < z < 0.65$) and three higher redshift clusters ($0.65 < z < 0.90$).

When looking at all galaxy types together and at blue galaxies, we see no significant variation from one redshift range to another. All type GLFs remain flat with α very close to -1 and blue GLFs remain steep. However, when looking at red GLFs, we see a small drop of the faint end at intermediate redshift that becomes more important at high redshift. This drop means faint early type galaxies are not found in clusters at high redshift. This result goes in favor of an evolutionary scenario in which blue late type galaxies are quenched into red early types to populate the faint part of the red sequence from high redshift until today. In the mean time the abence of variation of the blue faint end means clusters are enriched in faint blue galaxies at any redshift since $z = 0.9$.

4 Conclusions

With this subsample of our data, we see a drop at the faint end of the red sequence GLF which is redshift dependent. On the other hand the blue and total GLFs remain respectively steep and flat with redshift at their faint end.

We conclude that galaxies in clusters still have to evolve from $z = 0.9$ to appear as they are at redshift zero. Blue galaxies transform into red ellipticals and progressively populate the red sequence until today while some blue faint galaxies keep being accreted.

We acknowledge long term financial support from CNES.

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