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Evolution and demography of galaxies in groups and clusters

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Abstract. We study a sample of low-redshift galaxies distributed around groups and clusters to probe galaxy evolution according to the mass of their host clusters. We find that low-mass galaxies are the most affected, mainly in groups, especially in morphology. While high mass galaxies are mostly ellipticals, the low mass objects have higher fractions of lenticulars, mostly the group ones.

Resumo. Estudamos uma amostra de galáxias distribuídas em grupos e aglomerados de baixo *redshift* para explorar a evolução de galáxias de acordo com a massa de seus respectivos aglomerados. Encontramos que galáxias de baixa massa são as mais afetadas, principalmente nos grupos, especialmente quanto à morfologia. Enquanto galáxias de alta massa são majoritariamente elípticas, os objetos de baixa massa possuem frações mais altas de lenticulares, sobretudo aquelas em grupos.

Keywords. Galaxies: clusters: general – Galaxies: evolution – Galaxies: elliptical and lenticular, cD

1. Introduction

Galaxy evolution in groups and clusters is a central topic in Extragalactic Astrophysics. An important issue is understanding whether galaxies in clusters are affected by environmental effects, which may be dependent on the mass of the host clusters, or by effects internal to the galaxies, related to their own mass. From the recent literature, some authors point out that environment is fundamental for galaxy evolution, one recent paper which cites it is Paspaliaris et al. (2022), while others conclude that there are also mass effects inherent to the galaxies, as pointed out in Baxter et al. (2022). However, a less studied subject is if there are effects due to the systems' mass, a subject which we study here.

2. Methods

We study a sample of 3333 galaxies distributed around 435 systems. The redshift range is $0.03 < z < 0.1$, and the magnitude limit is $M_r \lesssim$ -20,5. The data came from the Sloan Digital Sky Survey (SDSS) database, being groups and clusters selected from 3 catalogs: Berlind et al. (2006), Tempel et al. (2017) and Yang et al. (2007). The member galaxies were defined using the shifting gapper method, as described in Lopes & Ribeiro (2009).

We classified the galaxies as star forming (active), with log_{10}(SSFR) > -11, and non stat forming (quenched), with log_{10}(SSFR) < -11, following the analysis of Wetzel et al. (2012). We also classified galaxy systems by their mass, as groups, with $log_{10}(M_{200}/M_{\odot}) < 14$, and as clusters, with $log_{10}(M_{200}/M_{\odot}) > 14$. Also, galaxies are defined as low-mass, with $log_{10}(M_*/M_{\odot}) <$ -11, and as high-mass, with $\log10(M_*/M_{\odot}) >$ -11. We then created four main subsamples of galaxies: low-mass in groups (LMG), low-mass in clusters (LMC), high-mass in groups (HMG), and high-mass in clusters (HMC).

Thus, we tried to check if galaxies from these sub samples have characteristic star formation or morphological types (TType), according to their environment and stellar mass. We did this by obtaining radial or mass profiles of their star formation rate (SFR) and TType, by use of the *varprof* code developed by Dailer Morell, and generously given to us to use. Galaxies with TType > 0 are classified as late-type; with −2 < TType < 0 as lenticulars; and with TType < −2 as ellipticals.

Furthermore, we did a projected density analysis of the projected phase space (PPS) diagrams, dividing the PPS in four regions, according to galaxies time since infall: Ancient, intermediate, recent, and infalling, based on the papers of Song et al. (2018) and Song et al. (2018). We did this analysis for every of our four classes of galaxies.

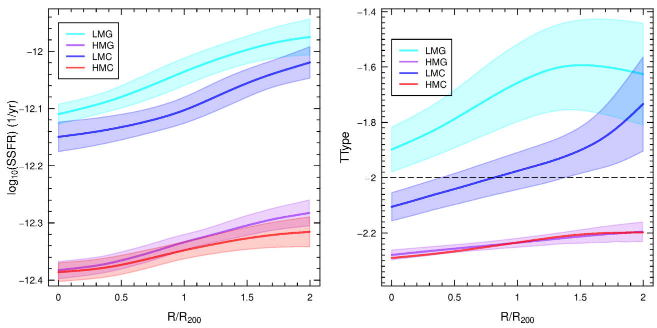

Figure 1. Left: Relationship between SSFR and the normalized projected distance. Right: Relationship between TType and projected distance. The dashed line in TType = -2 indicate the threshold where galaxies become ellipticals.

3. Results

From the SSFR radial profile (figure 1, left), we see that galaxies are quenched at all projected distances, with low-mass galaxies having higher SSFR than the high-mass ones. However, for the TType radial profile, (figure 1, right), while massive galaxies have TType < -2 (being probably ellipticals), low-mass galaxies have a higher fraction of lenticulars, indicating that the star formation evolution is faster than the morphological evolution. In other words, late-type galaxies become quenched before they become ellipticals.

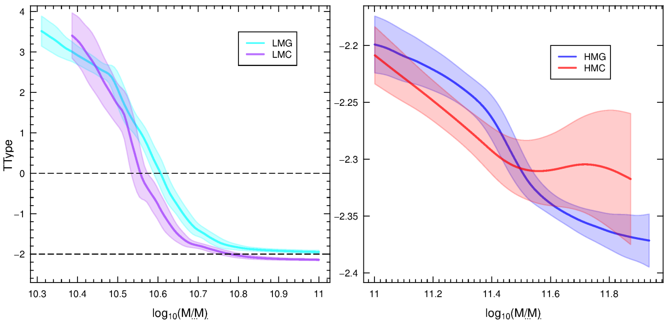

Figure 2. Relationship between TType and stellar mass, M_*. The dashed line in TType = 0 indicate the threshold where galaxies become early-type.

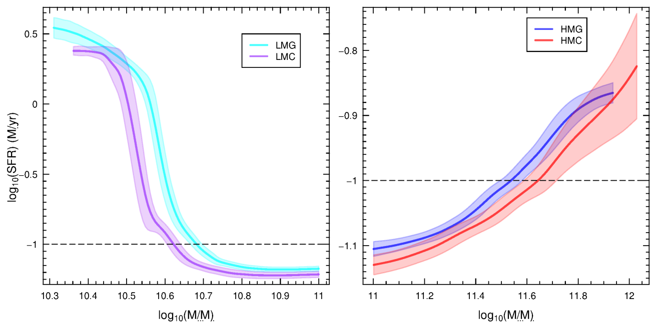

Figure 3. Relationship between SFR and stellar mass, M_*. Left: Galaxies in groups; Right: Galaxies in clusters. In blue: Low mass galaxies; In red: High mass galaxies.

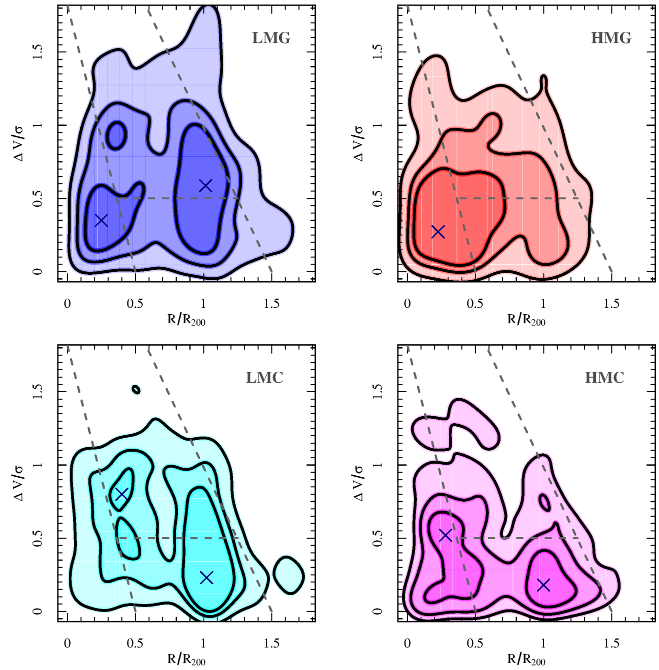

Figure 4. Galaxy density in the projected phase space diagrams of our sample. The X's indicate the density peaks, and the color intensity indicates the regions of 1, 2 and 3 σ.

At the same time, we see that high-mass galaxies have decreasing TType with stellar mass, (figure 2), and that they are mostly ellipticals, while for the low-mass objects, around $10.5 < log_{10}(M_*/M_\odot) < 10.8$, there is a dominance of lenticulars, and a dominance of late-types around $log_{10}(M_*/M_\odot) \sim 10.5$.

From the SFR vs stellar mass plot (figure 3), we see that low-mass galaxies in both groups and clusters show decreasing SFR with stellar mass, but that this behavior is more intense for objects in clusters. With a similar behavior for the TType profile. We also note a small but significant recovery of the SFR for high-mass galaxies, suggesting a renewal of them.

Finally, we find that the four sub-samples present significantly different demographics in the PPS, (figure 4), according to the kernel density global comparison test.

The LMGs and LMCs have a density peak in the region of recent infall, moreover, HMGs exhibit a density peak in the region of ancients. However, the HMCs have 2 density peaks, one in the regions of ancients, and another in the region of intermediate infallers. We interpret these results as evidence of pre-processing, indicating that those galaxies belong to smaller groups entering the clusters, which is reinforced by the presence of this density peak in the LMCs.

4. Conclusions

From our results, we see that, from the radial point of view, low-mass galaxies have higher SSFRs, despite being quenched, and have higher fractions of lenticulars, specially the ones in groups. From the stellar mass profiles, low-mass galaxies have similar decreasing behaviors for the TType and SFR, with objects with $log_{10}(M_*/M_\odot) < 10.8$ having higher fractions of lenticulars and late-type objects. While from our PPS analysis, we see evidence of pre processing, with density peaks of galaxies in the regions of intermediate and recent infall.

To summarise, ur results indicate the importance of both stellar mass and environment for the evolution of galaxies, but we find that morphology is affected more slowly, and that groups of galaxies are still sites for significant galaxy evolution at low redshifts.

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