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Minor environmental effects on galaxy sizes

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Abstract

The different evolutionary paths followed by the galaxies along their lives are expected to leave an imprint in their sizes. Nevertheless, observationally the role that the environment plays on shaping the galaxies is still unclear. Taking advantage of the great statistics provided by SDSS data, we address this question using a mass-complete sample of 232000 objects. We study the stellar mass-size relation of galaxies in the field and in clusters in the nearby Universe. Our results show that galaxies are slightly smaller in high-density regions at a fixed stellar mass. This difference is of ~ 7.5 per cent for late-type galaxies and ~ 3.5 per cent for early-type galaxies. Moreover, the scatter of the relation is also smaller in clusters than in the field, with differences of ~ 0.8 per cent for late-type galaxies and ~ 3.5 per cent for early-type galaxies. These results point towards an earlier formation of the galaxies in high-density environments as well as to an evolution from a more homogeneous family of progenitors than those inhabiting less dense environments.

1 Introduction

The relation between the stellar mass and the size of galaxies provides valuable information on the processes suffered by a galaxy during its evolution. This evolution is expected to be dependent on the environment where galaxies live after their formation. Actually, several works point towards a fast and early evolution of halos inhabiting high density regions, whereas for halos in low-density environments the evolution would be more quiet [28, 9, 10, 15]. It has been also shown by different works that galaxies have suffered a strong size evolution since $z \sim 2$ [24, 22, 29, 30, 32], when galaxies were more much compact than at the present. This evolution is stronger on early-type galaxies than on late-type galaxies [31, 3].

How the environment affects this size evolution is still observationally an open issue. At intermediate to high redshifts ($0.5 < z < 2$), observational works show a variety of results: from elliptical galaxies being larger in clusters than in the field [6, 19, 7] to the opposite result of ETG's being smaller in clusters than in the field [21], through the absence of environmental effects shown by [23, 11].

Studies in the nearby Universe are not clear either. Regarding ETG's, some groups claim no differences in the size of the galaxies inhabiting high and low-density environments [14, 12], while others [20] find elliptical galaxies being more compact when residing in clusters. For late-type galaxies, [14] report low to intermediate mass spirals ($10^9\,\mathrm{M}_\odot < M_* < 10^{10}\,\mathrm{M}_\odot$) being larger in the field than in groups, but no difference was found in higher stellar masses. On the other hand, [8] found late-type galaxies in isolation have larger sizes than those in more dense environments, but only for masses $> 10^{10}\,\mathrm{M}_\odot$.

Not only the stellar mass-size relation can provide interesting clues about the processes involved in the evolution and growth of galaxies, but also its scatter can provide valuable information. The measured scatter of the Fundamental Plane and other scaling relationships has been recurrently found to be lower than predicted in simulations [16, 5, 17, 18, 26, 27] and only models with very fine tuning on the parameters of the progenitors can reproduce the observed values. In this work we will try to shed some light into the issue by taking advantage of the great statistics provided by the NYU-VAGC Catalogue [2] at low redshifts.

2 Data and environment characterization

Our data is extracted from the publicly available NYU-VAGC Catalogue [2] based on the SDSS-DR7 [1]. This catalogue provides photometric and spectroscopic information, including redshifts, structural parameters and stellar masses. Although the catalogue extends through a wider range of redshifts, we limit our sample to the redshift range $0.005 < z < 0.12$ to minimize the effect of the size evolution with redshift. Morphology and size were determined using a Sérsic [25] fit to the radial intensity profile. With this fit, we are able to segregate early from late-type galaxies using the Sérsic index: galaxies with $n < 2.5$ are considered as late-type, while galaxies with $n > 2.5$ are considered as early-type.

To study the environment of the galaxies in our sample, we use two different methods. The first of them is to compute the stellar mass density surrounding each galaxy in a fixed radius, obtaining a distribution of densities in our sample. From this distribution, we take the 10% of the galaxies with the lowest values of our density estimator and the 10% with the highest values. These two samples are representative from galaxies inhabiting low-density and high-density environments respectively.

The second method consists on compiling a large sample of galaxy clusters in the volume explored in our work and segregate galaxies residing inside the clusters and outside them. For both cases we select a search radius of 2 Mpc around the studied galaxy in the first case and the centre of the cluster in the second case.

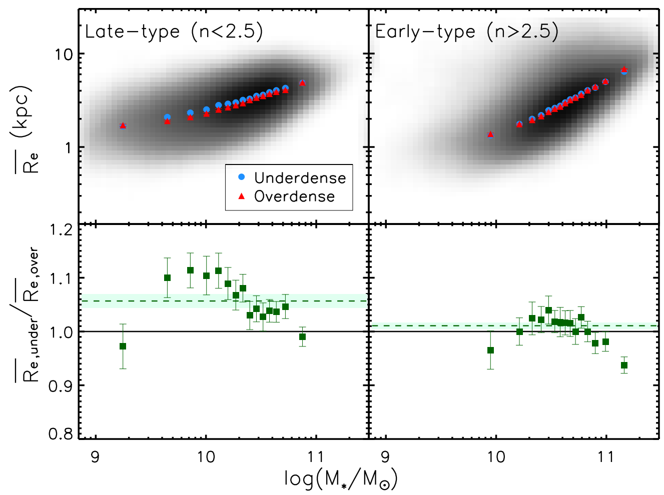

Figure 1: The stellar mass-size relation for low and high density environments selected depending on their stellar mass density value. Gray shaded area in the upper panels represent the overall distribution of galaxies for late an early-type galaxies, respectively. Overplotted on them are the mean size at a fixed mass for galaxies for low (blue dots) and high-density environments (red triangles). The bottom panels show the ratio between mean sizes. The green dashed line represents the robust mean of those ratios, with its 1σ errors shown as a green shaded area. Figure taken from [4].

3 Results

Figure 1 shows the mean sizes for late and early-type galaxies at a fixed stellar mass, considering the surrounding stellar mass density as indicator for the environment. Lower panels show the difference in mean size among the environments. There is a systematic offset for galaxies in the lowest-density regions towards larger sizes independently on the morphology, although the effect is more pronounced for late-type galaxies. Nevertheless, the differences in size are very small: on average late-type galaxies are $6 \pm 1\%$ larger when inhabiting low-density environments. Early-type galaxies are only $1.1 \pm 0.6\%$ larger in less dense regions.

Results for the dispersion of the size distribution in different environments can be seen in Fig. 2. We find that the scatter in the relation is larger for galaxies in over-dense regions when we consider early-type galaxies ($4 \pm 1\%$). There is not a significant difference for late-type galaxies in the mean ratios between low and high-density environments. Nevertheless, low mass galaxies ($M_* < 10^{10}\,\mathrm{M}_\odot$) do show larger scatter in low-density environments.

We conduct now the same analysis but using galaxies in clusters and comparing their mean sizes and dispersion with the galaxies in the field. Figures 3 and 4 show our results for these samples. These results are in the same line that those previously found for the stellar mass density, but the effect appears to be enhanced when considering cluster galaxies: late-type galaxies are $7.8 \pm 0.6\%$ larger in the field than in clusters, while early-type galaxies

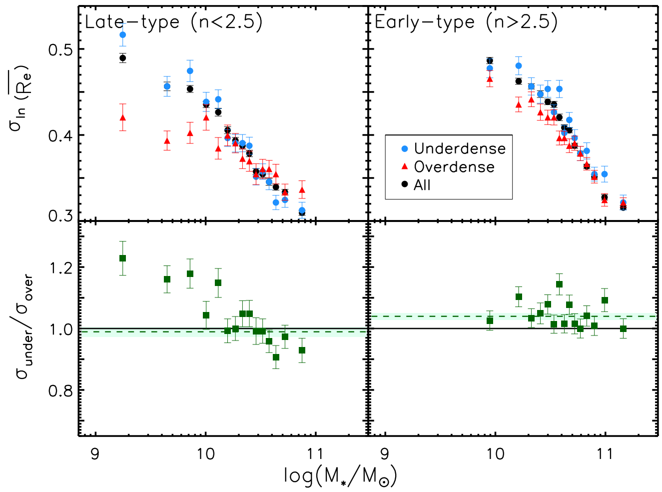

Figure 2: *Top* panels show the computed scatter in the stellar mass-size relation for galaxies in low (blue dots) and high-density environments (red triangles). *Bottom* panels represent the ratio between the dispersions of low-density and high-density regions (green squares), as well as the mean difference (green line). Figure taken from [4].

in the field are $4.0 \pm 0.8\%$ larger (Fig. 3).

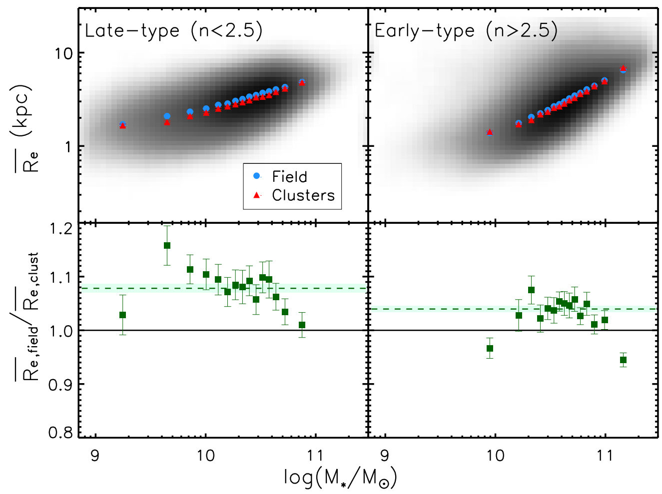

Figure 3: Same as Fig. 1 but using samples of galaxies in clusters and in the field. Figure taken from [4].

Also similar results are found when analysing the dispersion in the stellar mass-size relation in our sample (see Fig. 4). Low mass ($M_* < 10^{10}\,\mathrm{M}_\odot$) late-type galaxies are more scattered in the field than in clusters, although no trend is found for late-type galaxies with higher stellar masses. Regarding early-type galaxies, they show a larger scatter in the field than in clusters independently on the mass, although this difference is small (3.0 ± 0.9).

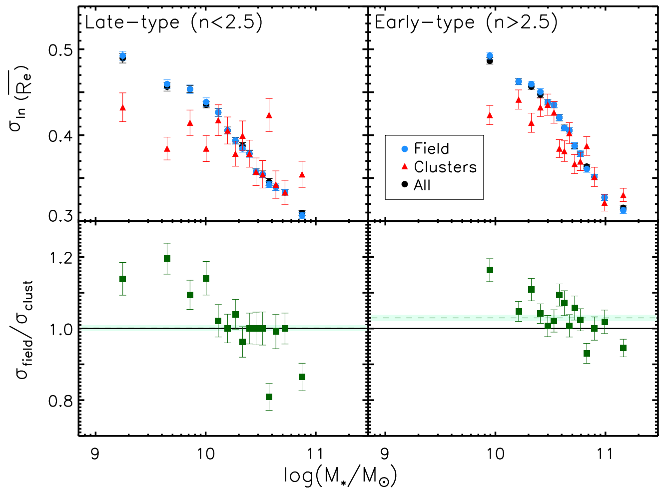

Figure 4: Same as Fig.2 but using galaxies in clusters and in the field. Figure taken from [4].

4 Discussion

Our results show that galaxies are on average larger when residing in low density regions, independently on the morphology or the estimator used to determine the density of the environment. Nevertheless, this difference is very small: on average, late-type galaxies are 7.5% larger and early-type galaxies only 3.5% larger. One would expect that, given the different environments in which these galaxies have evolved, different processes lead them to present different sizes, but our results show that this is not the case: all the galaxies follow a tight stellar mass-size relation in the nearby Universe.

This, together with the fact that the scatter in the relation is smaller for galaxies residing in high-density environments or clusters, leads us to think that galaxies in clusters evolved early and fast, and from a more homogeneous family of progenitors than galaxies in the field. However, galaxies in dense regions slowed down their growth, while galaxies in the field keep evolving until in the nearby Universe their sizes became very similar.

This picture is enforced with some studies such as that of [13], who found that, although early-type galaxies galaxies were larger in clusters at $z > 1$, this trend becomes weaker as we approach to the present-day Universe ($z < 1$). Our results are also supported by [15]. In their simulations, the present-day accretion rate is 4-5 times larger in low density regions than in high-density environments, while the trend is inverted for higher redshifts ($z > 1$).

Our work shows that, although observations and simulations at higher redshifts find that galaxies in different environments undergo very different evolutionary paths, in the present day Universe the stellar mass-size relation do not reflect those differences.

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