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Isolated groups of extremely blue dwarf galaxies

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Abstract. Interactions and mergers between dwarf galaxies are mostly gas-rich and should be marked by an intense star formation activity. But these processes, which are expected to be common at earlier times, are very difficult to observe at low redshifts. Furthermore, they might have an important role in building up the stellar mass and the hierarchical assembly of galaxies at low to an intermediate stellar mass regime. To investigate that, we look in the *Sloan Digital Sky Survey* for compact groups ($R_{\rm group} < 80\,{\rm kpc}$) that contain only galaxies with $g - i$ colours far below the red sequence ($> 4\sigma$) and at least one luminous compact galaxy (LCG) with very high sSFR ($-9.5 < \log({\rm sSFR/yr}) < -7.6$) and two other blue galaxies. We found 24 groups that satisfy these criteria, and until now we have confirmed that 8 are systems with at least 3 member galaxies. Here we want to investigate how interactions between galaxies affect their sSFR and the concentration of the LCGs. To estimate the intensity of the interactions, we calculated the tidal strength estimator Q for each LCG. Statistical tests do not reveal any relationship between Q and the LCG sSFR, but we found a correlation between Q and their concentration. Our results indicate that tidal interactions might be driving gas to the LCG inner regions, making them very compact.

Resumo. As interações e fusões entre galáxias anãs são majoritariamente ricas em gás e caracterizadas por intensas atividades de formação de estrelas (SF). Mas esses processos, que se espera que sejam comuns em épocas mais antigas, são muito difíceis de serem observados em baixos redshifts. Além disso, eles podem ter um papel importante na construção da massa estelar e na montagem hierárquica de galáxias em regime de massa estelar de baixo a médio porte. Para investigar isso, procuramos no *Sloan Digital Sky Survey* por grupos compactos ($R_{group} < 80$ kpc) que contêm apenas galáxias com cores g - i muito abaixo da sequência vermelha ($> 4\sigma$) e pelo menos uma galáxia compacta luminosa (LCG) com taxas de formação estelar específicas (sSFR) muito altas ($-9.5 < \log({\rm sSFR/ano}) < -7.6$) e duas outras galáxias azuis. Encontramos 24 grupos que atendem a esses critérios e, até agora, confirmamos que 8 são sistemas com pelo menos 3 galáxias membro. Aqui desejamos investigar como as interações entre galáxias afetam suas sSFR e a concentração das LCGs. Para estimar a intensidade das interações, calculamos o estimador de força de maré Q para cada LCG. Testes estatísticos não revelaram qualquer relação entre Q e as sSFRs das LCGs, no entanto, encontramos uma correlação entre Q e sua concentração. Nossos resultados indicam que interações de maré podem estar deslocando gás para regiões mais internas das LCGs, tornando-as muito compactas.

Keywords. Galaxies: dwarf – Galaxies: evolution – Galaxies: groups: general

1. Introduction

It is well known through simulations (e.g. L'Huillier et al. 2012) and semi-analytical (e.g. Cattaneo et al. 2011) models of galaxy formation that interactions and mergers between galaxies play a key role in the formation and evolution of massive systems. These events have been well studied at the high mass regime, especially in low redshifts (e.g. Krabbe et al. 2014, Rosa 11 et al. 2014), and are characterized by being major and gas-poor. However, dwarf galaxies are formed mainly through gas accretion (Cattaneo et al. 2011), what makes the interaction and mergers between these systems very rare. Moreover, the few cases studied are minor and gas-rich, i.e., drastically different from mergers between massive galaxies.

To address the hierarchical, gas-dominated assembly and the buildup of stellar mass in low-mass galaxies, some authors have been studying interaction and merger events of isolated pairs and groups of dwarf galaxies. Since the evolution of dwarf galaxies is highly susceptible to the environment, satellite groups of more massive galaxies are not suitable for investigating the ΛCDM mass assembly in the low-mass regime. Privon et al. (2017) studied an isolated pair of dwarf galaxies, and their results indicate important hydrodynamical differences from more massive galaxy interactions, including more widespread star formation and a lack of large-scale shocks. However, this study suffers from poor statistics, as they observe a single pair of dwarf galaxies. Furthermore, Stierwalt et al. (2017) analysed a larger sample of seven isolated dwarf galaxy groups, and they suggest that, given time, merging will turn some of these groups into isolated intermediate-mass galaxies.

The existence of these dwarf groups at such a low redshifts raises many interesting questions: what is the metallicity of these systems? What is the global specific star formation rate (sSFR) in these groups? Can tidal interactions lead to extremely high sSFRs? How do the properties of these isolated groups compare to those of groups associated with a massive host?

To answer these questions, we built a sample of 24 compact groups of galaxies containing one luminous compact galaxy (LCG) with very high sSFR and at least two other dwarf galaxies, all of them with $g - i$ colours far below the red sequence. The compactness, blue colours, and the presence of the LCGs suggest that these are interacting systems with strong ongoing star formation.

In this paper, we will explore how tidal interactions affect the star formation activity and morphology of the LCGs residing in compact groups of dwarf galaxies. The results presented here are part of a detailed study of the properties of these groups as well as the galaxies within them, specially the LCGs. The paper is organized as follows: in Section 2, we describe how we selected our sample of groups. The relation between the LCG properties and the tidal forces acting on it is presented in Section 3. Finally, we discuss our results and the perspectives of our study in Section 4.

2. Sample selection

To built our sample of groups of dwarf blue galaxies, we used the *Sloan Digital Sky Survey* (SDSS) database to look for groups that meet the following criteria:

1. The group must contain at least 3 blue galaxies ($g-i$ colours $> 4\sigma$ below the red sequence), including the LCG, that are brighter than $r \leq r_{\rm LCG}+1 \leq 19$, where $r_{\rm LCG}$ is the extinction-corrected apparent magnitude in the r band of the LCG.
2. The radius of the group (which corresponds to the radius of the smallest circle that contains all member galaxies) is $R_{\rm group} \leq 100$ kpc. The group centre and radius were determined iteratively, starting with the center at the position of the LCG and $R_{\rm group} = 100$ kpc. Then $R_{\rm group}$ and center are redefined until the list of member candidates remains unchanged.
3. There are no galaxies in the red sequence within $R < R_{\rm group} + 50$ kpc.

These criteria lead to a sample of 24 groups of galaxies. In Table 1, we present the properties of 13 groups (out of 24) that have SDSS spectroscopic data for at least 2 member galaxies; only 2 of them are spectroscopically complete. Group candidates that are not complete were or will be observed with GMOS@Gemini: 6 groups were observed during 2018A and 2019B (the data are currently being reduced), and 5 will be observed during 2020A (time already granted).

3. How the interactions affect the LCG sSFR and morphology?

To investigate how tidal interactions affect the properties of the LCGs, we computed the tidal strength estimator, Q, for the LCGs residing in each of the 13 groups listed in Table 1:

$$Q_i = \frac{F_{tidal}}{F_{binding}} \propto \frac{M_i}{M_{LCG}} \left(\frac{D_{LCG}}{R_{i,LCG}}\right)^3 \quad (1)$$

where M_i is the stellar mass of the neighbour galaxy, $M_{\rm LCG}$ is the stellar mass of the LCG, $D_{\rm LCG}$ is the LCG diameter (which we assumed the diameter of the region containing 90% of the Petrosian flux in the r-band), and $R_{i,\rm LCG}$ is the projected distance between the neighbour galaxy and the LCG. The galaxy stellar masses and radii were retrieved from the SDSS database.

Since the spectroscopic SDSS observations are incomplete for most of our sample groups, we cannot estimate the tidal effects due to all interactions between galaxies in these groups. Instead, we compute the average Q value including only those members for which we have redshift and stellar masses derived from the spectra.

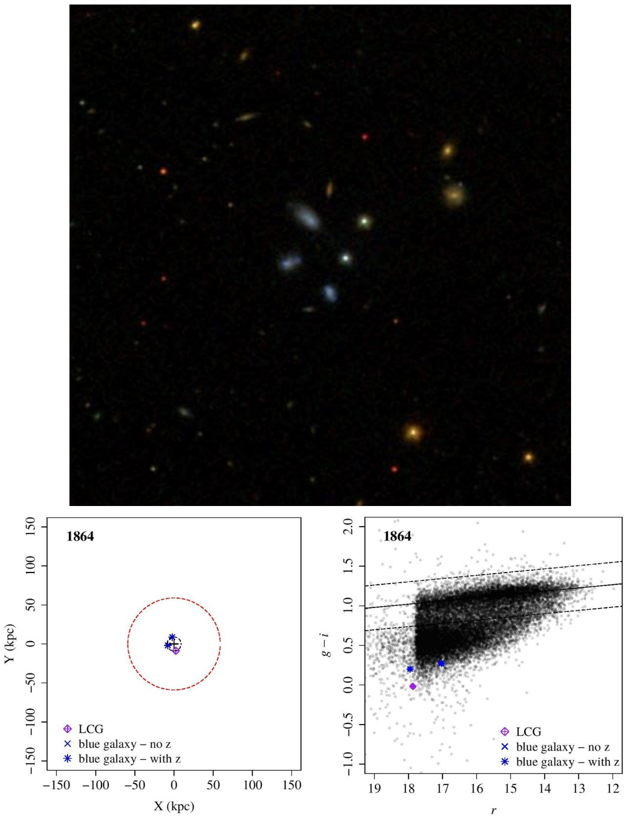

Figure 1. SDSS image of our most compact group containing the LCG 1864 (*top*), positions (*bottom left*) and color-magnitude diagram (*bottom right*) of its member galaxies. **Top:** The size of the image is $(2R_{\rm group} + 100)$ kpc, where $R_{\rm group}$ is the radius of the group ($R_{\rm group} = 8.96$ kpc, in this case). **Bottom left:** The center of the group is indicated by the black cross and coincides with the center of the smallest circle that contains all the member galaxies (black dashed line). The red dashed line illustrates the isolation criteria: there are no red galaxies within the region delimited by the red circle. **Bottom right:** The black symbols show the colors and magnitudes of "normal" galaxies that are at $z = z_{\rm LCG} \pm \Delta z$, with $c\,\Delta z = 1000\,{\rm km\,s^{-1}}$. The solid and dashed lines show the best fit to the red sequence $\pm 4\sigma_{\rm rs}$, where $\sigma_{\rm rs}$ is the scatter of the red sequence. In both bottom panels, the LCG is indicated by the purple symbol and the blue symbols show the member galaxies brighter than $r \leq r_{\rm LCG} + 1$ mag.

In Fig. 2, we show how the LCG sSFR correlates with the tidal strengh estimator. The sSFRs are corrected for the age of the burst ($\rm sSFR_0$, Izotov et al. 2011). A Kendall and Spearman correlation tests indicate a weak correlation between these quantities, with coefficients $\tau = 0.21$ (p-value = 0.37) and $\rho = 0.29$ (p-value = 0.34).

On the other hand, the LCG concentration is strongly correlated to Q. This is shown in Fig. 3, where we plot the ratio $\log R_{90}/R_{50}$ (radius containing 90% and 50% of the Petrosian flux of the LCG) versus the parameter Q. The strong correlation is confirmed by a Kendall and Spearman correlation tests, with coefficients $\tau = 0.49$ (p-value = 0.02) and $\rho = 0.58$ (p-value = 0.04), respectively.

Table 1. Properties of the galaxy groups. (1) ID of the LCG contained by the group; (2) group radius; (3) redshift of the LCG that belongs to the group; (4) number of member galaxy candidates; (5) number of spectroscopically-confirmed member galaxies.

ID (1)	R (kpc) (2)	z (3)	N (4)	N_{spec} (5)
LCG1381	61.08	0.0397	4	2
LCG1864	8.96	0.0300	3	3
LCG2027	49.10	0.0237	3	2
LCG2507	43.63	0.0302	3	2
LCG2543	58.15	0.0364	4	2
LCG2547	28.20	0.0319	3	2
LCG2764	22.26	0.0154	3	3
LCG3174	24.00	0.0368	3	2
LCG3621	24.42	0.0348	3	2
LCG3866	45.95	0.0238	4	3
LCG4308	32.78	0.0498	4	2
LCG7854	56.30	0.1021	4	2
LCG8102	11.81	0.0959	3	2

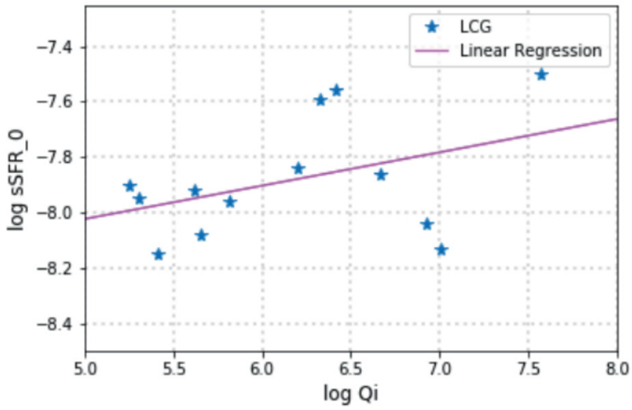

Figure 2. Specific star formation rate (corrected for the age of the burst) as a function of the tidal strength estimator, Q. The plot shows only the groups for which we have at least two galaxies with SDSS spectroscopic observations. The purple line corresponds to the best linear fit to the data. The Kendall and Spearman correlation coefficients are $\tau = 0.21$ (p-value = 0.37) and $\rho = 0.29$ (p-value = 0.34);

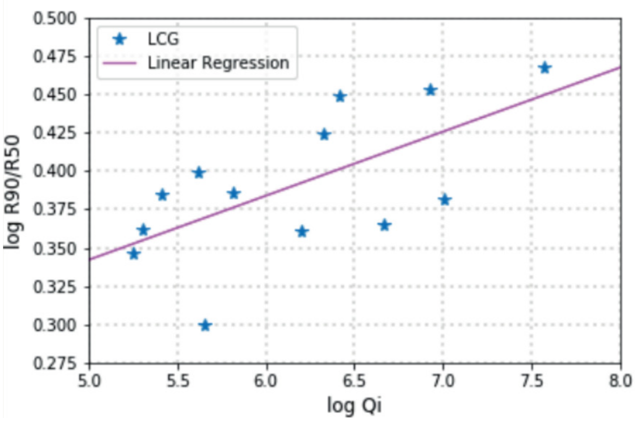

Figure 3. Concentration as a function of the tidal strength estimator. The notation is the same as in Fig. 2. The Kendall and Spearman correlation coefficients are $\tau = 0.49$ (p-value = 0.02) and $\rho = 0.58$ (p-value = 0.04), respectively.

4. Conclusions and perspectives

The correlation found between the Q parameter and LCG concentration (Fig. 3) indicates that the tidal interactions between the member galaxies might be driving gas to the LCG inner regions and making the LCG very compact. Interestingly, the star formation activity in the LCG does not seem to be strongly affected by the tidal effects, given the weak correlation that we found between Q and $sSFR_0$. This weak correlation could be related to the short duration of bursts of star formation (a few tens of million years), even when correcting the sSFRs for the age of the burst. The fact that we are not computing the total tidal forces acting on the LCG (i.e., we include only the spectroscopically confirmed group members) might be washing out the correlation. Therefore, the observations that are being carried out using GMOS@Gemini are important to correctly estimate the relation between sSFR and tidal interactions.

References

Cattaneo et al. 2011, A&A, 533, 5
Izotov et al. 2011, ApJ, 728, 161
L'Huillier, B. et al. 2012, A&A, 544, 68.
Krabbe et al. 2014, MNRAS, 437, 1155
Rosa et al. 2014, MNRAS, 444, 2005
Privon, G. C. et al. 2017, ApJ, 846, 74.
Stierwalt, S. et al. 2017, NatAs, 1, 25.