Small galaxy groups: defining a selection criteria

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Resumen / El presente trabajo presenta un criterio de selección homogéneo de grupos menores de galaxias definidos como sistemas con al menos dos y hasta seis miembros, compactos y aislados, que favorecen las fusiones entre galaxias. La definición de un criterio de selección homogéneo es el punto de partida para un estudio comparativo de este tipo de sistemas, que se encuentre libre de posibles sesgos derivados de las diferencias en la función de selección.

Abstract / The present work presents a homogeneous selection criteria of small galaxy groups defined as systems with at least two and up to six members, compact and isolated, favoring mergers between galaxies. The definition of a homogeneous selection criteria is the starting point for a comparative study of this type of systems, exempt of possible biases derived from differences in the selection function.

Keywords / Galaxies: groups: general — Galaxies: interactions — Galaxies: statistics

1. Introduction

The standard paradigm of structure formation states that large structures form by accretion of less massive galaxy systems. According to these scenario, galaxies are preferably grouped into configurations ranging from pairs of galaxies to clusters with dozens and even hundreds of galaxies.

Within this hierarchical panorama of structure formation, the study of small galaxy systems is crucial to understand the formation and evolution of the large structures we observe today in the Universe.

Currently, there is no standardized definition of small galaxy group. The properties of different systems with a low number of members such as pairs of galaxies, triple systems and groups with four or more members have been analyzed individually. Several works states that the proximity in projected separation and radial velocity difference favors galaxy-galaxy interactions and mergers. For the identification of compact groups and triplets, different authors find that a linking length of 200 kpc represents an adequate scale (McConnachie et al., 2009; Elyiv et al., 2009; O'Mill et al., 2012; Duplancic et al., 2015). For galaxy pairs, the values range from 30 kpc to even 1 Mpc (e.g., Patton et al., 2000; Lambas et al., 2003; Ellison et al., 2008; Scudder et al., 2012). Regarding the velocity difference of group members, to consider physically associated galaxies in compact groups McConnachie et al. (2009) adopted a maximum radial velocity difference of 1000 $\mathrm{kms^{-1}}$. On the other hand, in the identification of pairs of galaxies Alonso et al. (2006) and Lambas et al. (2012) consider a radial velocity difference lower than 350 $\mathrm{kms^{-1}}$ and for galaxy triplets O'Mill et al. (2012) use a limit of 700 $\mathrm{kms^{-1}}$ while Argudo-Fernández et al. (2015) adopted a radial velocity cut of 160 $\mathrm{kms^{-1}}$.

From different group catalogs it is possible to build samples matched in redshift and luminosity that can be used to compare the properties of these systems and their member galaxies, correctly quantifying their similarities and differences. Nevertheless it is important to note that there could be biases in these type of studies due to the differences in the selection function of the groups in the catalogs under study. For this reason the present work proposes to establish a homogeneous selection criteria for the identification of small galaxy groups.

This paper is organized as follows: in section 2. we describe the galaxy catalogs used in this work. In section 3. we present the selection criteria for the construction of the small galaxy groups sample. Finally in section 4. we present the main results of this work.

Throughout this paper we adopt a cosmological model characterised by the parameters $\Omega_\mathrm{m} = 0.3$, $\Omega_\Lambda = 0.7$ and $\mathrm{H_0} = 70$ h $\mathrm{kms^{-1}\ Mpc^{-1}}$.

2. Data

The samples of galaxies used in this work were obtained from the tenth data release of the Sloan Digital Sky Survey (SDSS-DR10, Ahn et al., 2014). Galaxies with spectroscopy were selected from the Legacy survey and from the Baryon Oscillation Spectroscopic Survey (BOSS, Dawson et al., 2013). All catalogs used in this work were obtained through queries at CasJobs *.

The magnitudes used in this work are the `model` magnitudes corrected by extinction. K corrections were calculates following the methodology described in O'Mill et al. (2011). We considered galaxies brighter than absolute magnitude $\mathrm{M_r}$ =-19, in the spectroscopic

*http://skyserver.sdss.org/CasJobs

redshift range 0.05< z_{spec} <0.18. We address the incompleteness in the SDSS data due to the fiber collision effect following O'Mill et al. (2012). To this end we selected galaxies without spectroscopy, with magnitude 13.5< r <17.77 and with photometric redshift obtained from the KF estimates in the SDSS Photoz table, in the range 0.01< z_{phot} <0.2.

Under these constraints the sample of galaxies used to identify small galaxy groups contains a total 675473 galaxies.

3. Selection criteria

Our aim is to obtain a catalog of small galaxy groups defined as systems with at least two member galaxies, which promote galaxy-galaxy interactions and mergers and with a suitable isolation criteria that guarantee that the system is located far away from larger structures that may affect its dynamical evolution.

Therefore, we consider galaxies with projected separation $r_p \leq 200$ kpc. We are using both spectroscopic and photometric redshifts, then for the radial velocity limit, if both galaxies have spectroscopy we consider a maximum value $\Delta V_{ss} = 500$ kms^{-1}. If one galaxy have spectroscopy but its neighbor have photometric redshift, then the limit is $\Delta V_{sp} = \sqrt{\Delta V_{ss}^2 + 1.5\ c\ \sigma_{zi}^2}$. Finally, if both galaxies have photometric redshift $\Delta V_{pp} = \sqrt{1.5\ c\ (\sigma_{zi}^2 + \sigma_{zj}^2)}$. Were σ_z is the error associated to the photometric redshift and c is the speed of light.

We define a local isolation criteria which prevent neighbors with $M_r \leq -19$ within a fixed aperture of 500 kpc centered in the geometric center of the group. In order to calculate the radial velocity difference we consider the average redshift of the group calculated using only its spectroscopic galaxies. If the neighbor have spectroscopic redshift we consider $\Delta V_{isos} \leq 1000$ kms^{-1} and if the redshift is photometric we assume $\Delta V_{isop} \leq \sqrt{\Delta V_{isos}^2 + 1.5\ c\ \sigma_{zi}^2}$.

Also in order to avoid satellite galaxies we impose the restriction that the difference between the magnitude of the brightest and the faintest galaxy in the system should be lower than 2 magnitudes. As our aim is to select compact systems we calculate the compactness of the group $S = \sum_{i=1}^{N} r_{90}^2/R^2$, were N is the number of members in the group, r_{90} is the radius enclosing 90% of the Petrosian flux of the galaxy in the r-band and R is the radius of the minimum circle containing the centers of the group members. We adopt a threshold S >0.03 which corresponds to the compactness of compact groups of galaxies (Duplancic et al., 2013). Additionally, we select systems that have at least half of its members with spectroscopy. This is a strong restriction but gives confidence to the identification of the system as a physical entity.

The final sample comprises 11286 small galaxy groups (SGGs) with two or more members. Within this sample 10396 are pairs of galaxies, 777 triplets and 113 groups with four or more members. It is important to remark that there are no groups with more than 6 members, this is a consequence of the selection criteria and no an imposed restriction. Furthermore it important to highlight that 67% of the groups do not have any members with photometric redshift.

Fig. 1 shows the distribution of group radius, velocity dispersion (calculated using only spectroscopic members), virial mass and maximum magnitude difference between galaxies in the system, calculated following the methodology of Duplancic et al. (2015).

From this figure it can be appreciated that the group radius increases from pairs, to triplets and groups. Galaxy pairs have separation between member galaxies lower that 200 kpc, this is a consequence of the selection criteria and no an imposed restriction. For the velocity dispersion it can be appreciated that in all cases it is lower than 350 kms^{-1} and for the sample of galaxy pairs presents the lowest values. This trend is also evident in the distribution of the maximum magnitude difference of galaxy members, suggesting that most of pair systems in our sample are major mergers. In the case of the virial mass, the values are in agreement with previous works (McConnachie et al., 2008; Duplancic et al., 2015). Table 1 present the mean value for these quantities and their respective errors calculated with bootstrap resampling techniques.

4. Results and future work

In this work we present a selection criteria to identify small galaxy groups as systems with a low number of members inhabiting an environment that promote galaxy-galaxy interactions and mergers. We consider galaxies close in the sky and with low radial velocity difference. As an isolation criteria we prevent the group to have significant neighbors within a fixed aperture of 500 kpc. We also consider systems populated by galaxies with similar luminosities and with more than half of its members with spectroscopic resdhift. Our results suggest that there is a scaled relation between the group properties and its number of galaxy members. Galaxy pairs present lower values of system radius, velocity dispersion, virial mass and maximum magnitude difference between member galaxies. On the other hand galaxy groups with four or more members are the most massive and have higher velocity dispersion and greater group radius than pairs and triplets. For galaxy triplets we found that the distribution of their properties present intermediate values between galaxy pairs and groups.

The results found in the present work promote the study of these small galaxy groups samples, considering for example the properties of its member galaxies and their relation with local and global environment. It is important to highlight that these forthcoming analysis will be driven over a catalog of small galaxy groups constructed from a homogeneous selection criteria, therefore the results will be free of biases that could arise from discrepancies in the selection function of different group samples.

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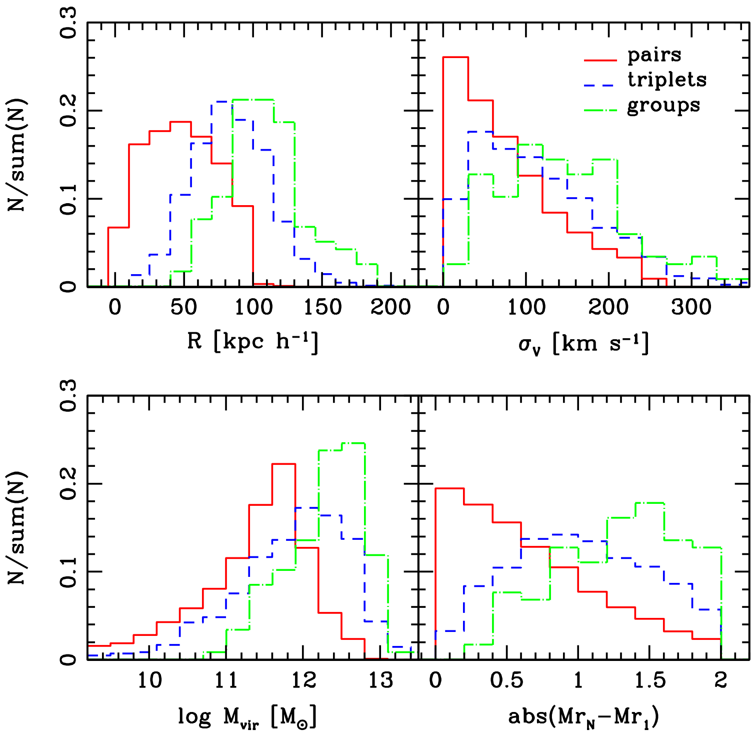

Figure 1: Radius of the system (Top Left), Velocity Dispersion (Top Right), Virial Mass (Bottom Left) and Maximum magnitude difference of member galaxies (Bottom Right) for pairs (solid), triplets (dashed) and groups with 4 or more members (dot-dashed) selected from the SGGs sample constructed in this work.

Table 1: Main Properties of the SGG. Sample name, number of galaxy members (Nm), total number of groups (Nt), Group Radius (R), velocity dispersion (σ_V), virial mass (M_{vir}) and maximun magnitude difference ($|M_{rN} - M_{r1}|$).

Name	Nm	Nt	R kpc h^{-1}	σ_V kms^{-1}	$\log(M_{vir})$ $M_\odot$	$\lvert M_{rN} - M_{r1}\rvert$ mag
Pairs	2	10396	50.84±0.27	19.75±0.90	11.23±0.01	0.69±0.005
Triplets	3	777	82.62±0.98	115.78±2.98	11.81±0.03	1.04±0.015
Groups	4-6	113	108.13±2.80	144.76±6.86	12.21±0.06	1.28±0.039

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