Small Galaxy Groups
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Observed isolated galaxy triplets in the Las Campanas redshift survey

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Abstract. Some problems and statistical approaches in studies of galaxy groups are discussed.

1. Introduction

Small galaxy groups and especially large clusters have attracted people's minds for a long time but only in the last two decades has a detailed mapping of the three-dimensional space started to take place thanks to various redshift surveys. Most small galaxy group studies have been focussed on compact systems with local densities comparable to those in clusters of galaxies. We will pay our attention only to isolated galaxy triplets extracted from the Las Campanas Redshift Survey catalog (hereafter LCRS; Shectman et al. 1996; Lin 1996) containing 12,202 galaxies located in three $\sim 1.5^\circ \times 80^\circ$ slices and 13,125 galaxies in three $\sim 1.5^\circ \times 110^\circ$ slices in the Northern and Southern Galactic Caps, respectively, spanning in velocity space cz from 1045 $\mathrm{km\,s^{-1}}$ to 96 041 $\mathrm{km\,s^{-1}}$. Apparent R-band magnitude limits vary in a range of $15.0 \leq R \leq 17.7$. Detailed studies of LCRS galaxy groups were done by Tucker et al. 1997. They also describe technical details of the survey that are especially important investigating close galaxy groups and we refer the reader to their paper.

Galaxy triplets are the smallest dynamically stable systems without an exact analytical solution. Apparently, there is a very big step going from binaries to triplets. However, note that it follows from a pure mathematical fact that any compound system can be characterized by a dispersion of some quantity, and the last is defined only for 3 or more members. This indicates incompleteness of our mathematical knowledge. That means that a number of 3 galaxies per group is not a well argumented choice and we will not be very strict about it in the sense that in reality some of "our triplets" may be higher order systems and on the other hand also some smaller systems (including "empty spaces") may become triplets because of the observational selection effects.

Since the best way to study such systems is in the absence of external fields, we have extracted only isolated galaxy triplets from the publicly available Las Campanas Redshift Survey catalog (Lin 1996).

In the next section we discuss some problems which arise in defining groups of galaxies. We then discuss a statistical aproach for studiues of small galaxy groups, and in the last section draw our conclusions.

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2. Problems with definitions of small groups of galaxies

Boundness. The greatest problem defining any small group of galaxies is its boundness. How can one be sure that it is a gravitationally bound system? Currently, solutions are to use N-body simulations and observationally, active radio and especially X-ray features may indicate the true boundness state of a system.

Interlopers or members. A very serious problem in optical studies of galaxy groups and clusters is member identification. This rises largely because of the real space distortions in the redshift space. Also this problem is closely related to the boundness problem. In a cluster of galaxies, this problem may be solved by statistical means, however, this is not the case for a small galaxy group, especially for triplets because of the low number statistics. At this point we assume that we have obtained the two sky coordinates and a redshift of each galaxy which makes up only 50% of the total phase-space information we are interested in.

Observational selection effects. Because of the observational selection effects not all galaxies have been detected. That does not allow us to use the number of galaxies as a strict definition of a group. Since all galaxies from a real triplet (the one that can not be approximated by binary!) have approximately similar probabilities to be picked up by a redshift survey then we avoid to use any correction modeling for each individual case.

3. Model independent approach

Unfortunately there are no any strict methods how to identify small galaxy group members. Because of our poor knowledge about these systems, we have avoided to do any modelling corrections of the data set rather than applying various selection criteria. We have exploited the friends-of-friends (FOF) algorithm introduced by Huchra & Geller 1982. We assume that galaxy is associated with another if it lays within a distance Δv_{gap} from it. We use a fixed gap interval $\Delta v_{gap} = 1000$ km s^{-1} in both radial velocity and the sky projection directions. The choice of this value was made to make probability large enough that all selected galaxy groups are isolated also in the real space. Secondly, such selection choise should include loose galaxy groups. A scaling parameter k may be introduced between the real and redshift space coordinates, however at this study avoiding any modeling we simply set it equal to 1. This procedure would lead us to an overestimated number of observed isolated galaxy triplets because some non-bound objects could be associated together. On the other hand some groups within Δv_{gap} from others will not be picked up.

Applying the FOF to the 25,327 galaxies of the LCRS dataset we extract a catalog of 88 isolated galaxy triplet candidates making 1% of the total galaxy number. An increase of number of triplet candidates with redshift is observed simply due to the enlargement of a space volume in a slice type geometry of the survey. We limit our study to galaxies with velocities $\leq 60,000$ km s^{-1} leading to 44 and 26 galaxy triplet candidates in the North and South catalogs, correspondingly. This number density discrepancy can not be regarded as significant because of the different luminosity functions in the both catalogs.

To achieve a model independent approach, we have performed only statistical analysis of the data set. For this purpose we find very useful the following quantities describing the galaxy group candidates: σ_x - the dispersion of the quantity x; $|\Delta x|_{max}$ - the maximal deviation from the mean $\langle x \rangle$, where $\Delta x = x - \langle x \rangle$; $|\Delta x|_{max} - \sigma_x$ - this quantity describes statistical discrepancies of the set of all x of a group, members with equal corresponding property would generate a value of $|\Delta x|_{max} - \sigma_x = 0$; $|\Delta x|_{max} / \sigma_x$ - the meaning of this dimensionless quantity is similar to the previous one, a value of 1 indicates similarities in the x distribution; $\langle \Delta x \rangle$: the average deviation describes the size of the system; $\sigma_{\Delta x}$: the dispersion of deviation of x describes the size of a system but is more sensative to statistical discrepancies than $\langle \Delta x \rangle$. Note also that all these quantities do not depend on any parameters but contain the same useful information as for example a mass estimate of a system which depends on a value of the Hubble constant H_0. As the quantity x vs. velocity $v = cz$, we sugest to use: (1) velocity v; (2) the modulus of the 3-D redshift space distance from the mean center: $R = |(RA, DEC, kv) - \langle (RA, DEC, kv) \rangle|$ that describes a possible real size of a system; (3) R-band magnitude of galaxies. Some characteristic graphs are shown in Figs 1 and 2.

4. Conclusions

The problem persists to separate real galaxy groups from the artificial. Figs 1 and 2 show few "non-typical" groups that probably are unreal. From a statistical point of view they seem not to differ much from the bound ones. Generally, this study shows that statistical properties of galaxies are similar within a group. This can be explained in the following way: the Universe is evolving actively at the present and experiencing many merging events of galaxy groups and clusters. Thus most of the galaxy groups are probably not yet virialized.

Studying the large scale structure elements of the Universe, one should try to avoid any data modeling because of our poor knowledge of structure and dynamics of galaxy groups and clusters.

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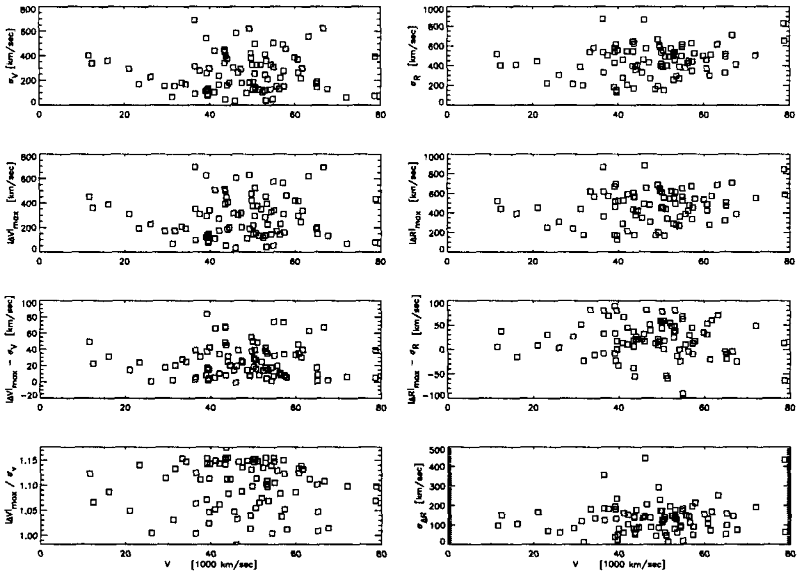

Figure 1. The kinematical/dynamical properties of galaxy triplet candidates of the LCRS data set. See explanations in the text.

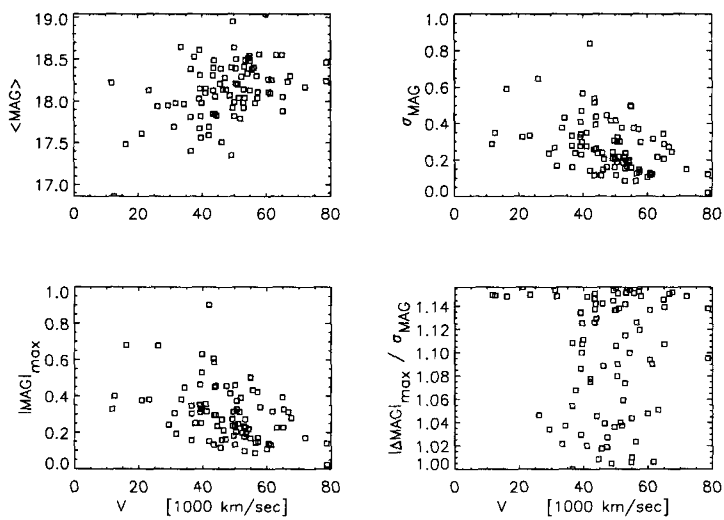

Figure 2. LCRS galaxy triplet candidate R-band magnitude properties. See explanations in the text.

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