Shakhbazian Groups in the SDSS sample

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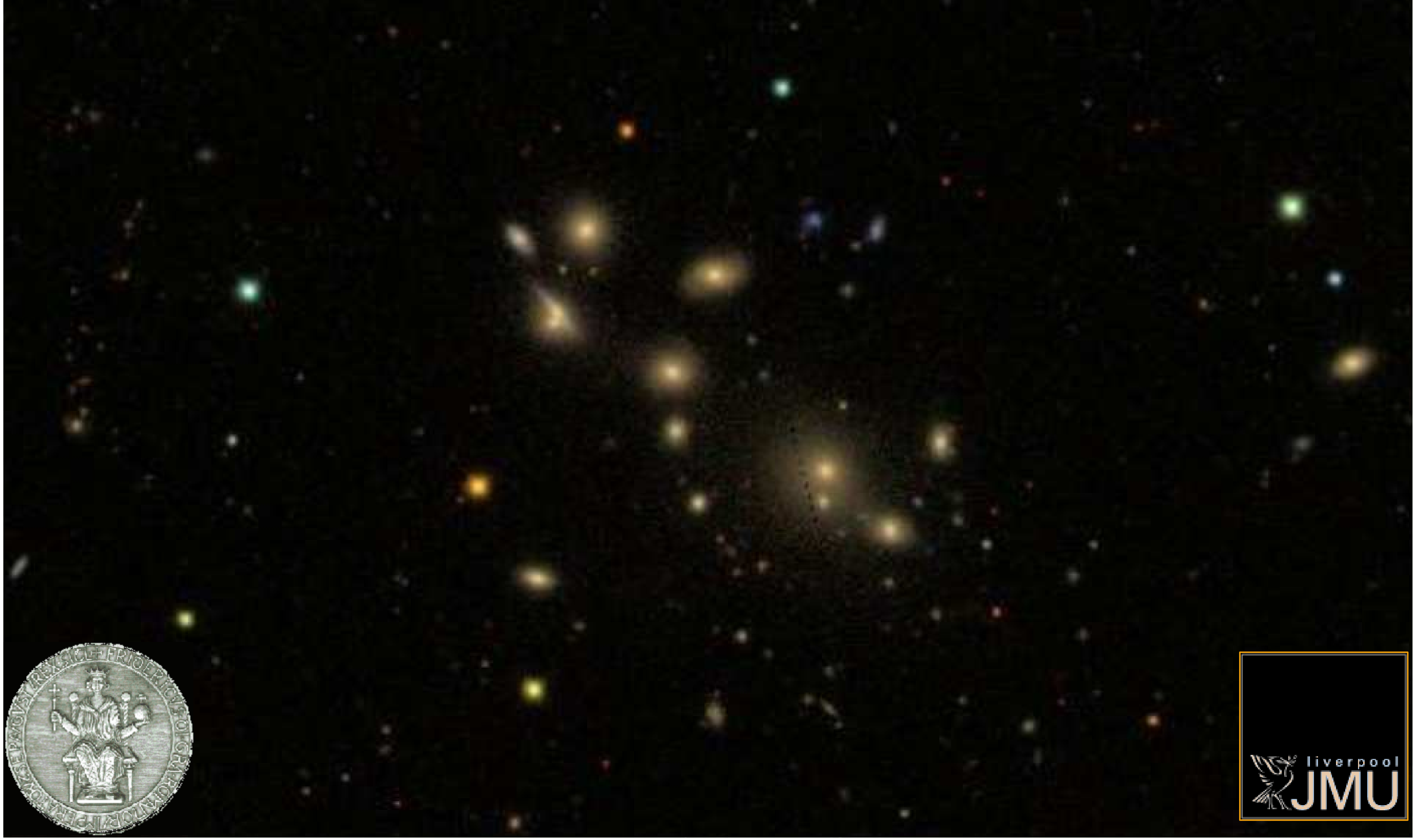

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Clusters and Groups of Galaxies

Properties	**Clusters**	**Groups**
N (gal)	30-300	3-30
F_{St}	5%	55%
ρ (h^3 gal Mpc^{-3})	$10^{-5} \div 10^{-6}$	$10^{-3} \div 10^{-5}$
σ (km s^{-1})	~750	~250
R (h^{-1} Mpc)	1.5	0.1-1
t_{dyn} (yr)	10^{11}	10^{8}
M (r ≤ 1.5 h^{-1} Mpc)	$(10^{14}\text{-}2\text{x}10^{15})h^{-1}\ M_\odot$	$(10^{12.5}\text{-}10^{14})h^{-1}\ M_\odot$
L(B) (r ≤ 1.5 h^{-1} Mpc)	$6\text{x}(10^{11}\text{-}10^{12})h^{-2} L_\odot$	$(10^{10.5}\text{-}10^{12})h^{-2}\ L_\odot$
$\langle M/L_B \rangle$ ($M_\odot/L_\odot$)	~300 h	~200 h
L_X (h^{-2} erg s^{-1})	$(10^{42.5}\text{-}10^{45})$	$\lesssim 10^{43}$

Groups of Galaxies and Cosmology

- In the hierarchical clustering they're the foundamental bricks of Large Scale Structures
- Their properties study is needed to constrain observationally the fundamental cosmological parameters (Ω, q_0) and to test cosmological models
- They constitute the most common environment in which galaxies are found, determining their morphologies and affecting their evolution
- They are the ideal laboratory for studying gravitational interaction phenomena among galaxies such as *merging* and ram *pressure* stripping

Dynamic evolution simulation of a 6 galaxies group and formation of an elliptical galaxy as final byproduct

SHAKHBAZIAN GROUPS

- Catalogue edited by *R. K. Shakhbazian* between 1973-1979. The objects were selected on the Palomar Sky Survey plates at the Astrophysics Observatory of Byurakan.The catalogue contains 377 groups.

- These groups were observed again by *D. Stoll* between 1993-1997, who cleaned out the original catalogue of spurious objects.

SHAKHBAZIAN GROUPS

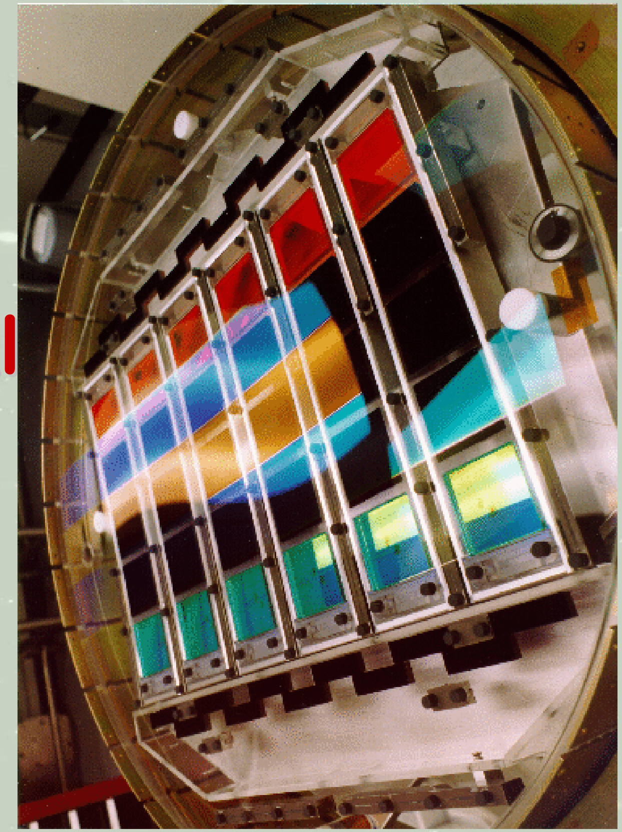
- Catalogue groups selection criteria:
  - They must contain 5-15 member galaxies.
  - Each galaxie's apparent magnitude must be between $14^m \div 19^m$.
  - They are compact. Relative distances of the member galaxies must be $3 \div 5$ times the characteristic diameter of a galaxy.
  - Almost all galaxies must be extremely red; there must be no more than 1-2 blue galaxies.
  - Galaxies are compact (high surface brightness and border not diffuse).
  - The group is isolated.

WHY STUDY SHAKHBAZIAN GROUPS ?

- **Because they don't satisfy Hickson's selection criteria. By applying them, a catalogue of 100 groups of galaxies was compiled.**
- **--- therefore, they cover a poorly studied spatial density range.**
- **Because are located at different distances ($0.02 < z < 0.3$, 83 Mpc $< D <$ 1.25 Gpc) so they could be going through different evolutionary states.**

SDSS 5

It's s public Survey which will cover 10,000 *deg*^{2} of the celestial sphere in 5 photometric bands (*u, g, r, i, z*). It's complete for galaxies with r < 22.2.

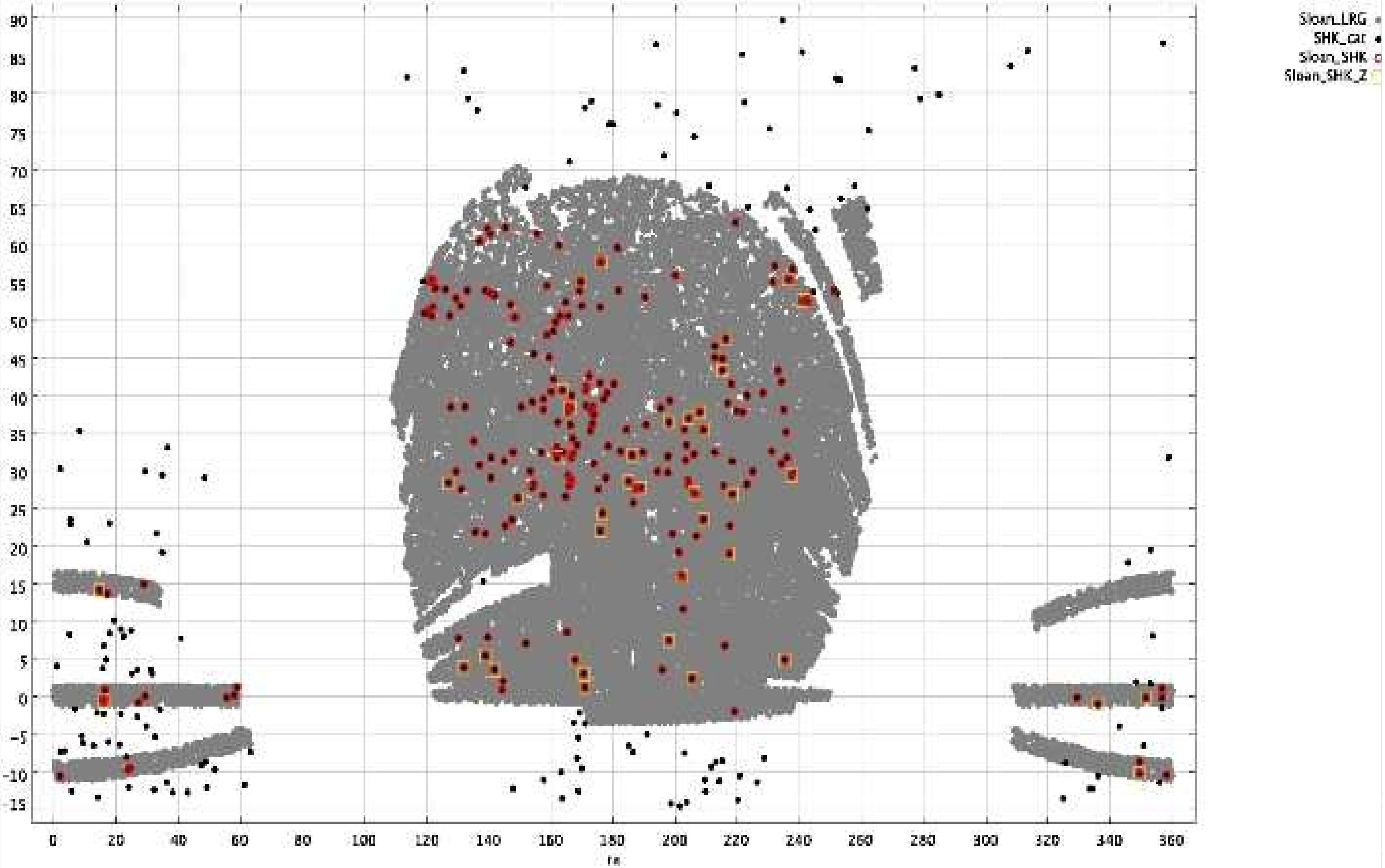


It's complemented by a spectroscopic *survey*, almost complete for galaxies with magnitude r < 17.7.

SPECTROSCOPIC SUBSAMPLE AND DATA EXTRACTION

- We updated Stoll's catalogue using the most recent literature's photometric and spectroscopic data.
- The cross-correlation of the region covered by SDSS-DR5 with the SHKGs positions, produced a list of 214 groups.
- Among these groups we considered only those for which a spectroscopic measurement of redshift was known (58 groups).
- For each of these we extracted data for each object found in a circular region centered on the SHKGs centroids and of radius R=3 Mpc.

SDSS & SHK GROUPS



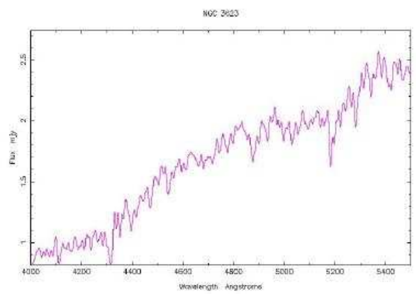
PHOTOMETRIC REDSHIFTS

- Projected data are not sufficient to identify structures

- Distance information is needed.

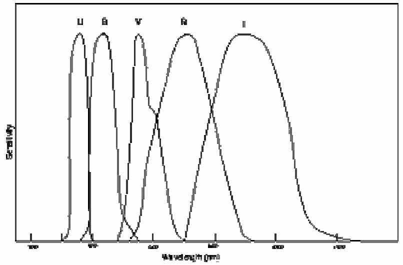
- The innovation consists in studing groups in the third dimension through Z_{phot}

Photometric redshifts



Galaxy spectrum - F(l)

×



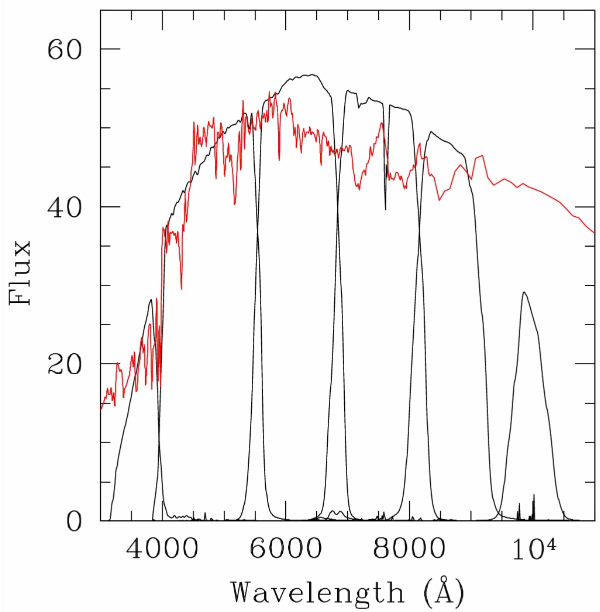
Photometric system - S_i(l)

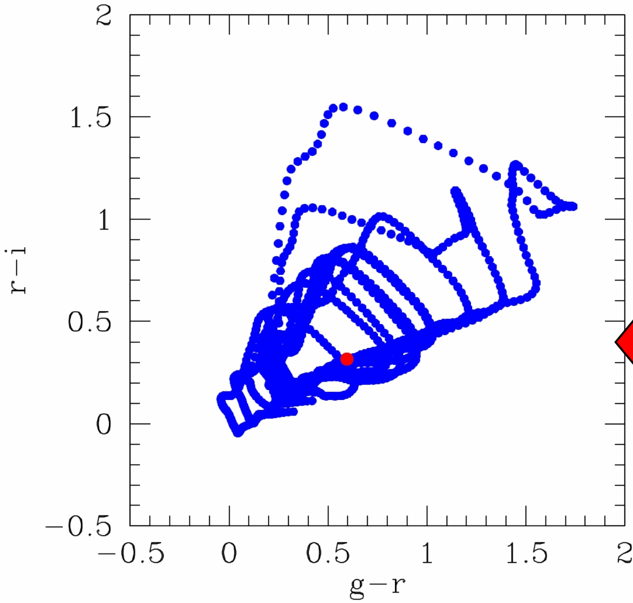
=

$$m_U = -2.5\log_{10}\frac{\int F(\lambda)S_U(\lambda)d\lambda}{\int S_U(\lambda)d\lambda} + c_u$$

$$m_B = -2.5\log_{10}\frac{\int F(\lambda)S_B(\lambda)d\lambda}{\int S_B(\lambda)d\lambda} + c_B$$

Etc…





Color indexes

$U - B \equiv m_U - m_B$

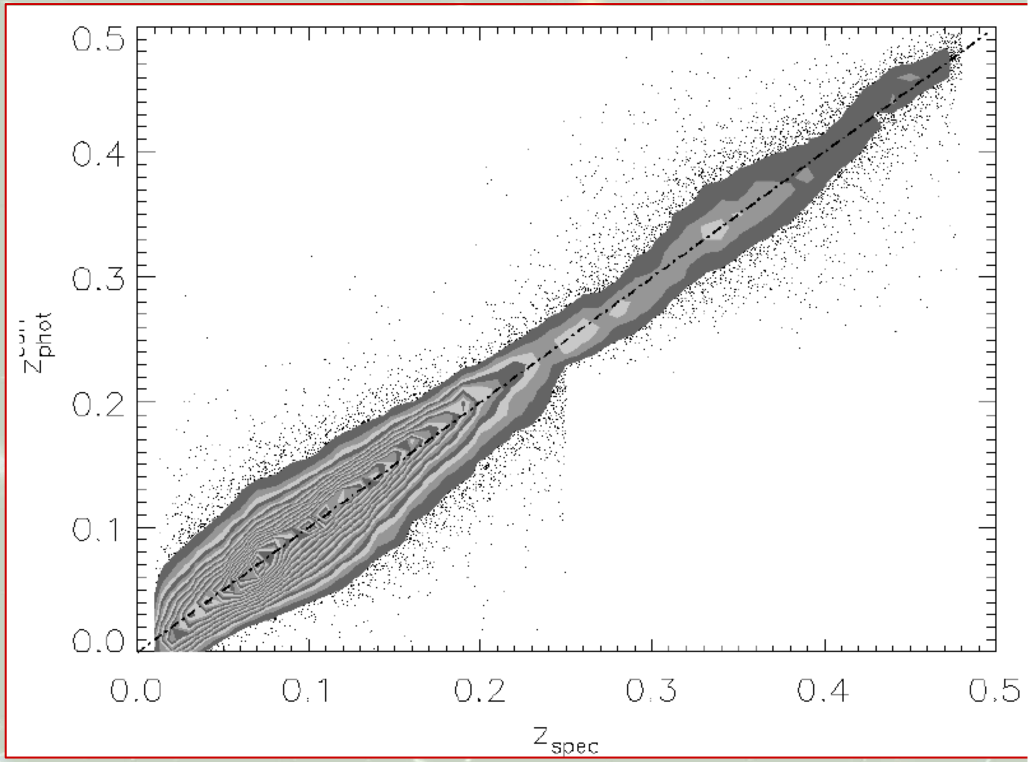
$B - R \equiv m_B - m_R$

etc.

PHOTOMETRIC REDSHIFTS

- They are an economical way, in terms of observing and computing time, to obtain redshift estimates for large samples of objects and to evaluate distances when spectroscopic estimates are of low quality.

- They are of much lower accuracy than spectroscopic ones but even so, if available in a large number and for statistically well controlled samples of objects, they still provide a powerful tool for deriving a three-domensional map of the Universe.



- We used Z_{phot} estimates provided by D'Abrusco et al (2007). $\sigma_z = 0.02$.

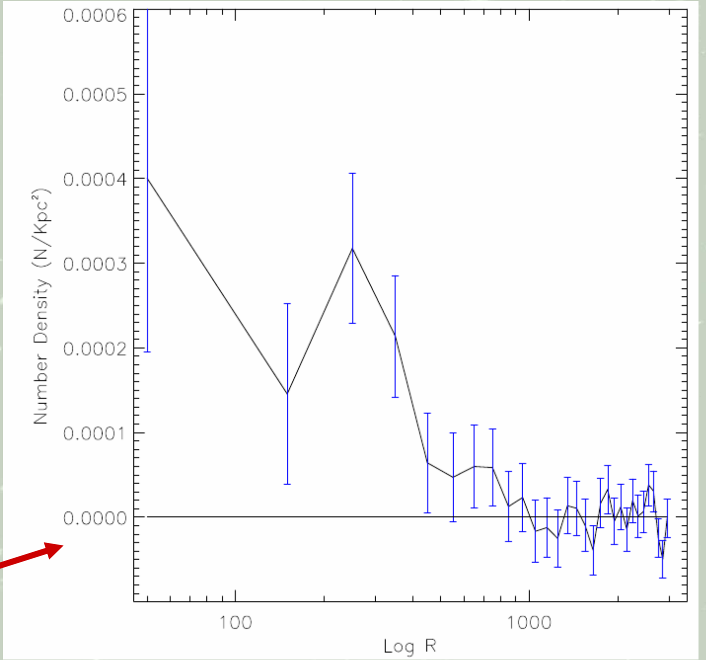
DATA ANALYSIS

For each group:

1. Check of the accuracy of the star-galaxy classification performed by the *SDSS PHOTOMETRIC PIPELINE* through a comparison with the classification obtained the application of (Yasuda et. al 2001) alternative classification criteria. Misclassification < 1 %.
2. Projected density maps
3. Projected and spatial radial profiles
4. Check of the presence af a Red Sequence in colour-magnitude diagrams
5. "3-D" maps of the group
6. Surface brightness profiles
7. Derivation of fundamental individual (richness, size, f(E) etc.) and global parameters

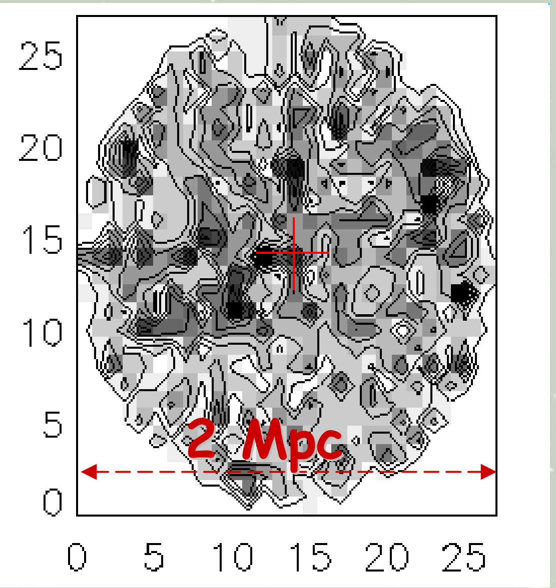
Numeric Density Radial Profile

Background subtracted numeric surface density radial profile.

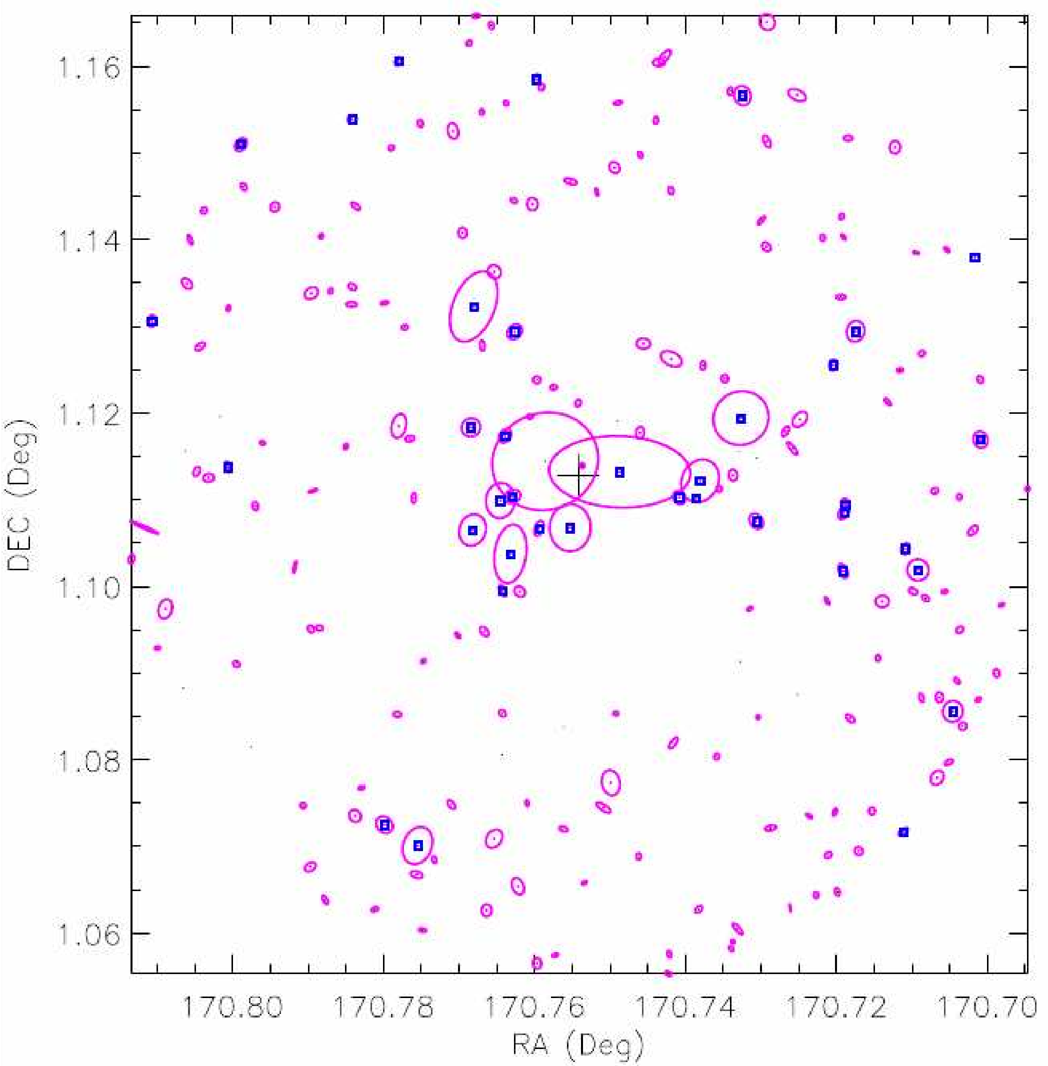


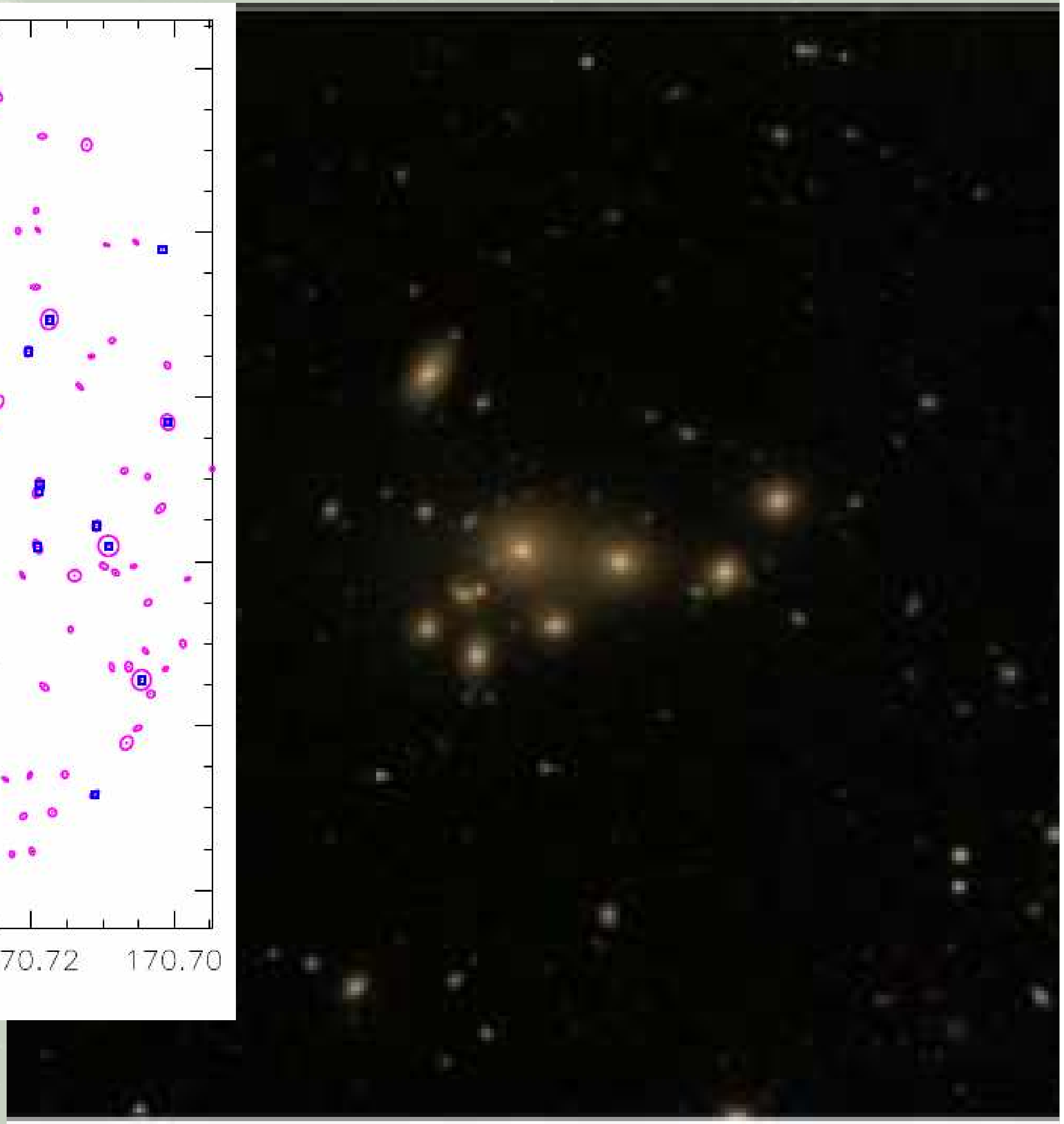
Background level

Density map for all galaxies within 1 Mpc. Isodensity levels are superimposed.



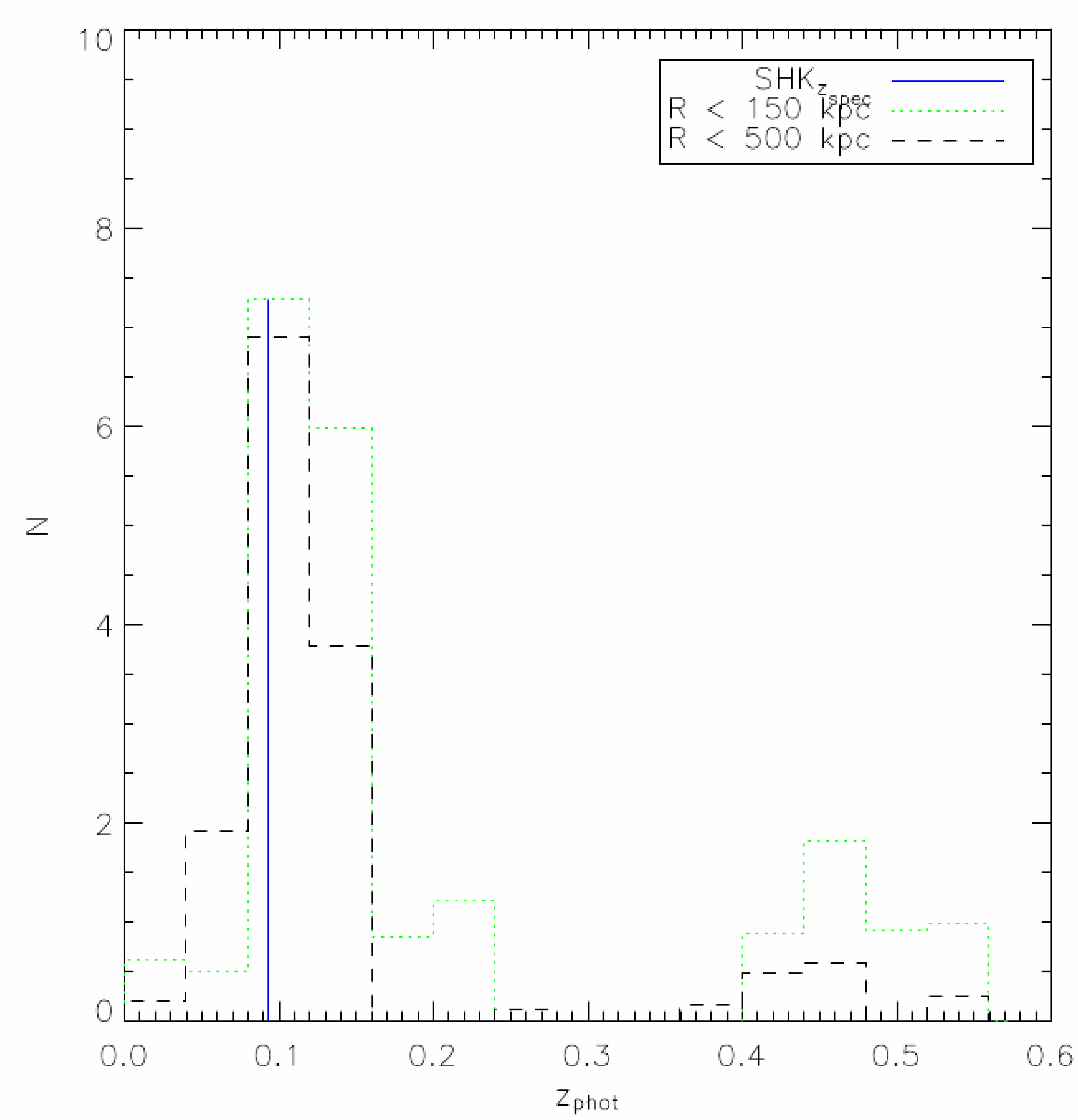
Group's Map





- $|Z_{phot} - \bar{Z}_{spec}| < 3\sigma_{zphot}$

Spatial selection using z-phot



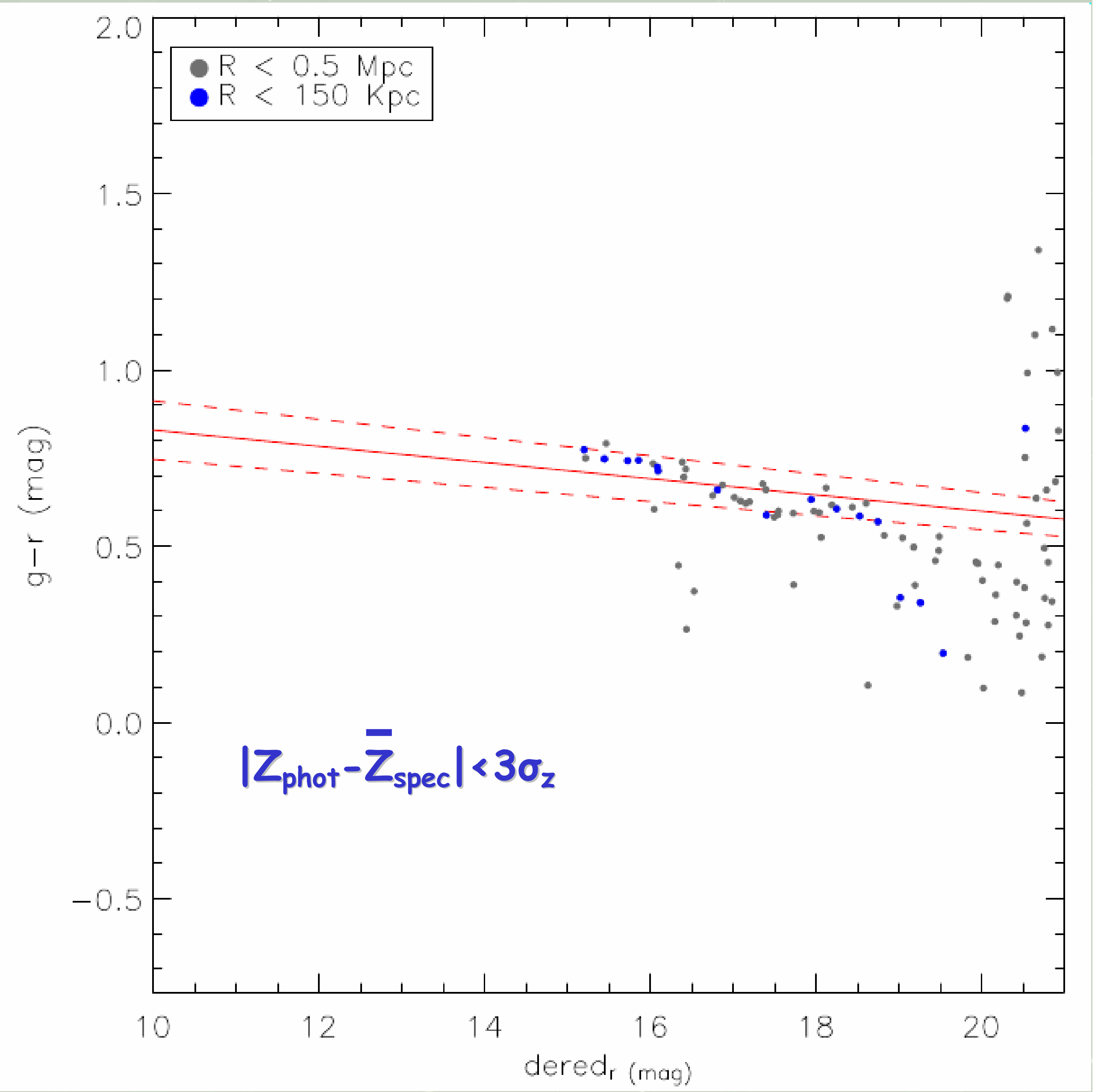
Inner 500 kpc

Inner 150 kpc

Mean spectroscopic redshift

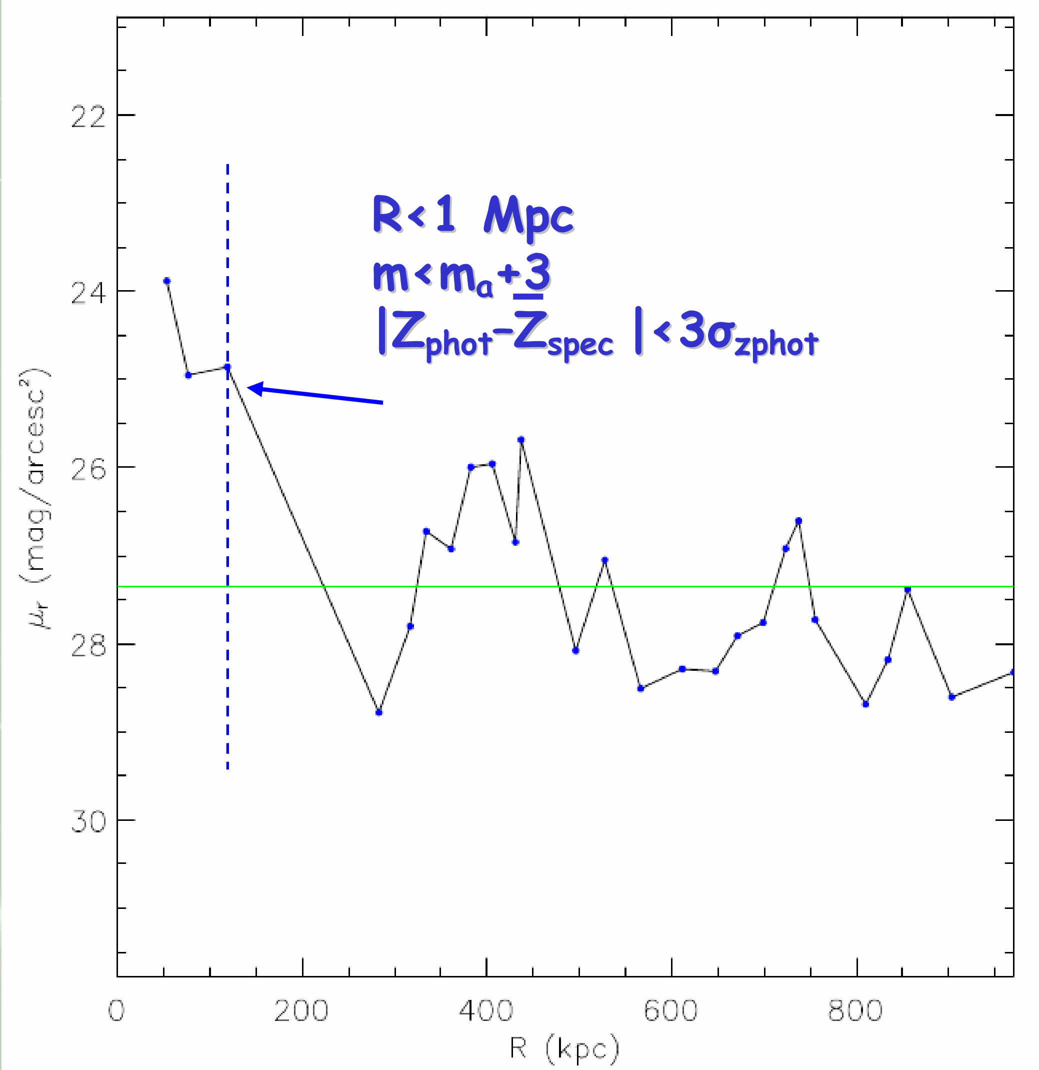
Colour-magnitude diagrams

- **Full red lines represent the ETS predicted at the group's redshift by Bernardi et al. (2003).**



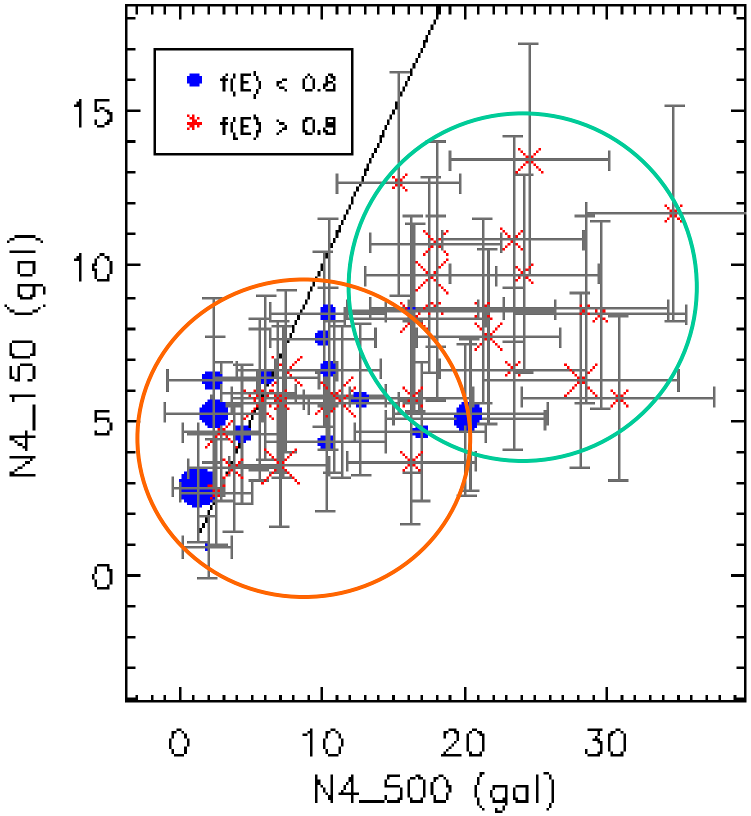
- m_a is the brightest galaxy among them within R < 150 kpc.

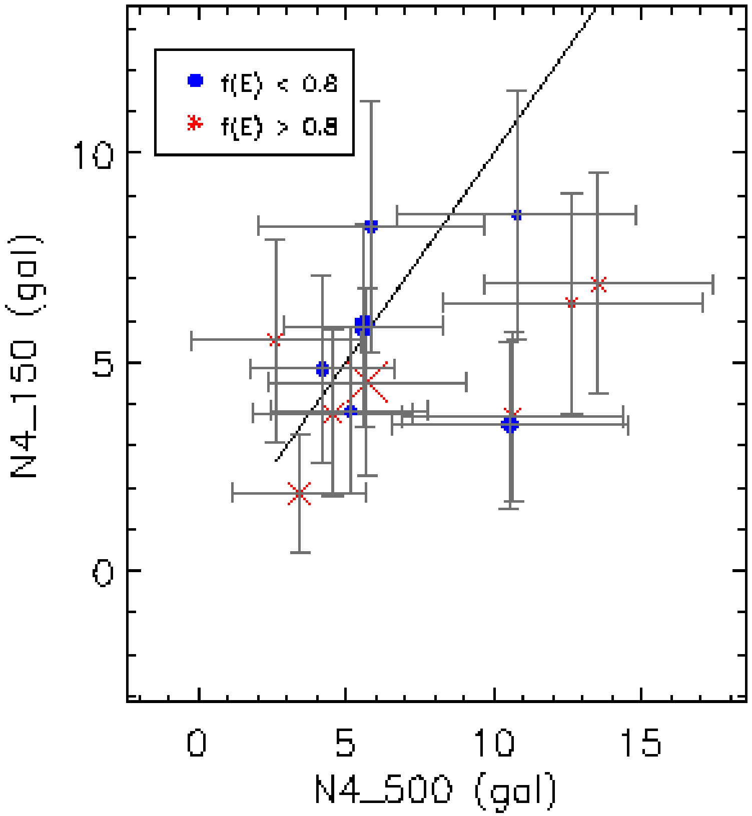
- The radial distance of the last galaxy among those for which $\mu > \mu_{back} - 2.5 \log(1.5)$, $(F_{back} + 50\%(F_{back}))$, is considerd as the group size. We obtained two different size estimates.



RESULTS

- About 75% of our sample shows:
  - The presence of a projected over-density.
  - Excess in the photometric redshift distribution.
  - Compatibility between literature's spectroscopic and our photometric values of mean redshift.
  - Most of them present a well-defined CMR if compared with that obtained by Bernardi et al. 2003 .
- For the remaining 25% we find several case studies:
  - Group is not real, but only a projection effect.
  - Group is very close and largely contaminated by the background, so that, since the low S/N ratio, cannot be detected with our tools.
  - Spectroscopic and photometric redshift measurements are not consistent and there's no structure at the spectroscopic redshift value. We can reveal other structures at a redshift different from the spectrosopic one.
  - There's more than one excess in the photometric redshift distribution, revealing the superposition of different structures at different distances.

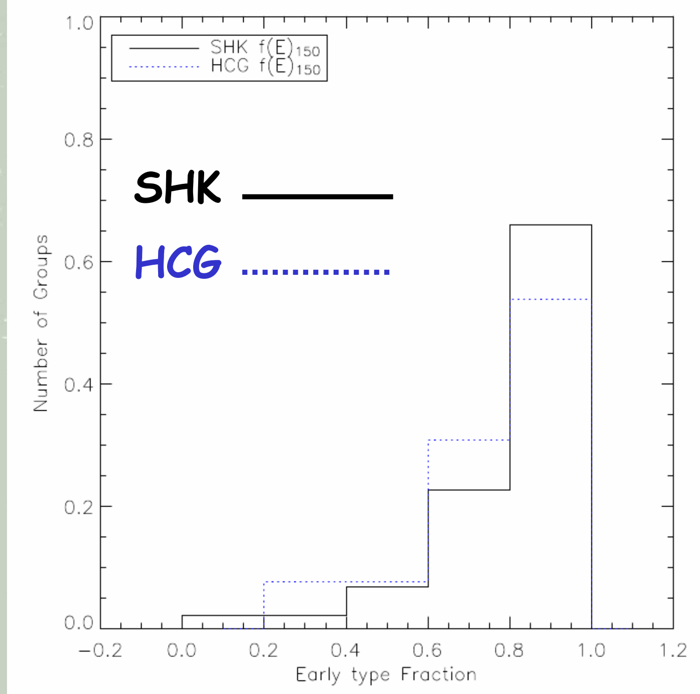


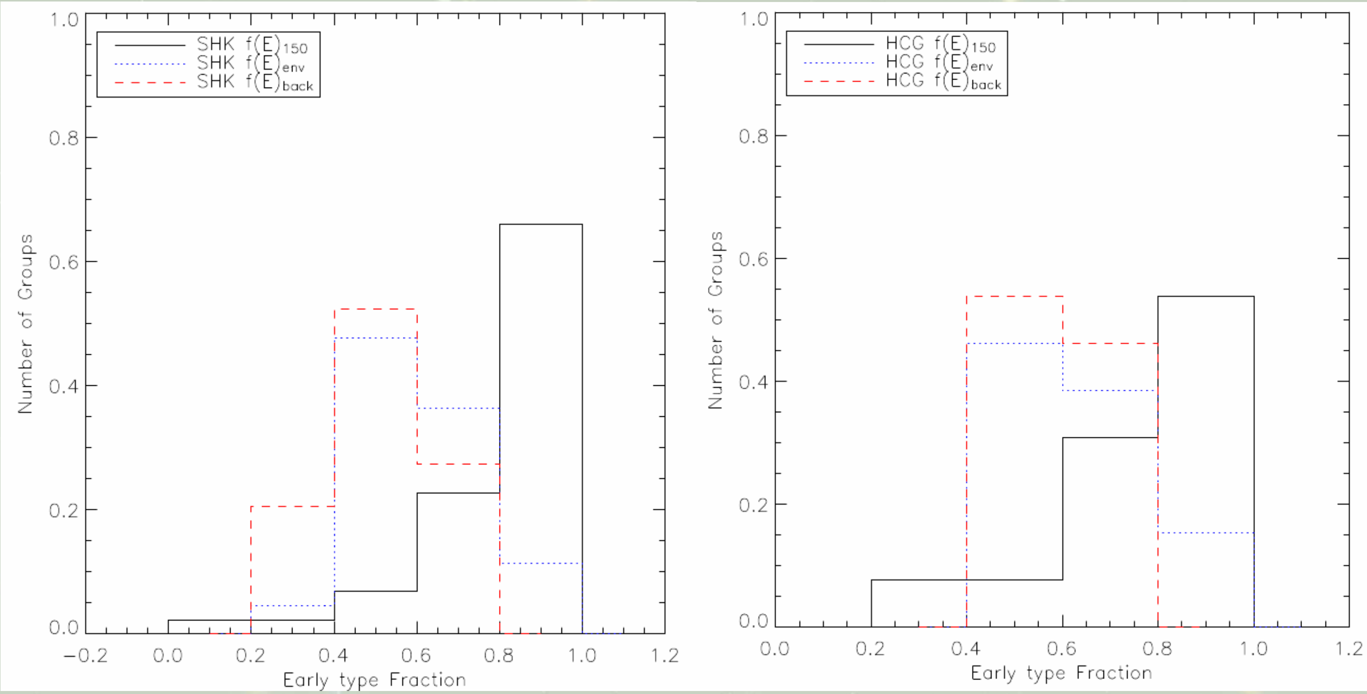


- Comparison among richness measurements obtained for 44 SHKGs and for 13 HCGs. Hints at the existence of two classes of groups:
  - Compact and isolated
  - Embedded inside more extended and disperse structures.
- The belonging at one of these two classes it's indipentent from redshift.

- About 65% of SHKGs has f(E)≥0.8 against ~55% for the HCG sample.

- When f(E) is derived for outer regions, late-type galaxies become dominant. This can be seen for both SHKGs (lower left panel) and HCGs (lower right panel)

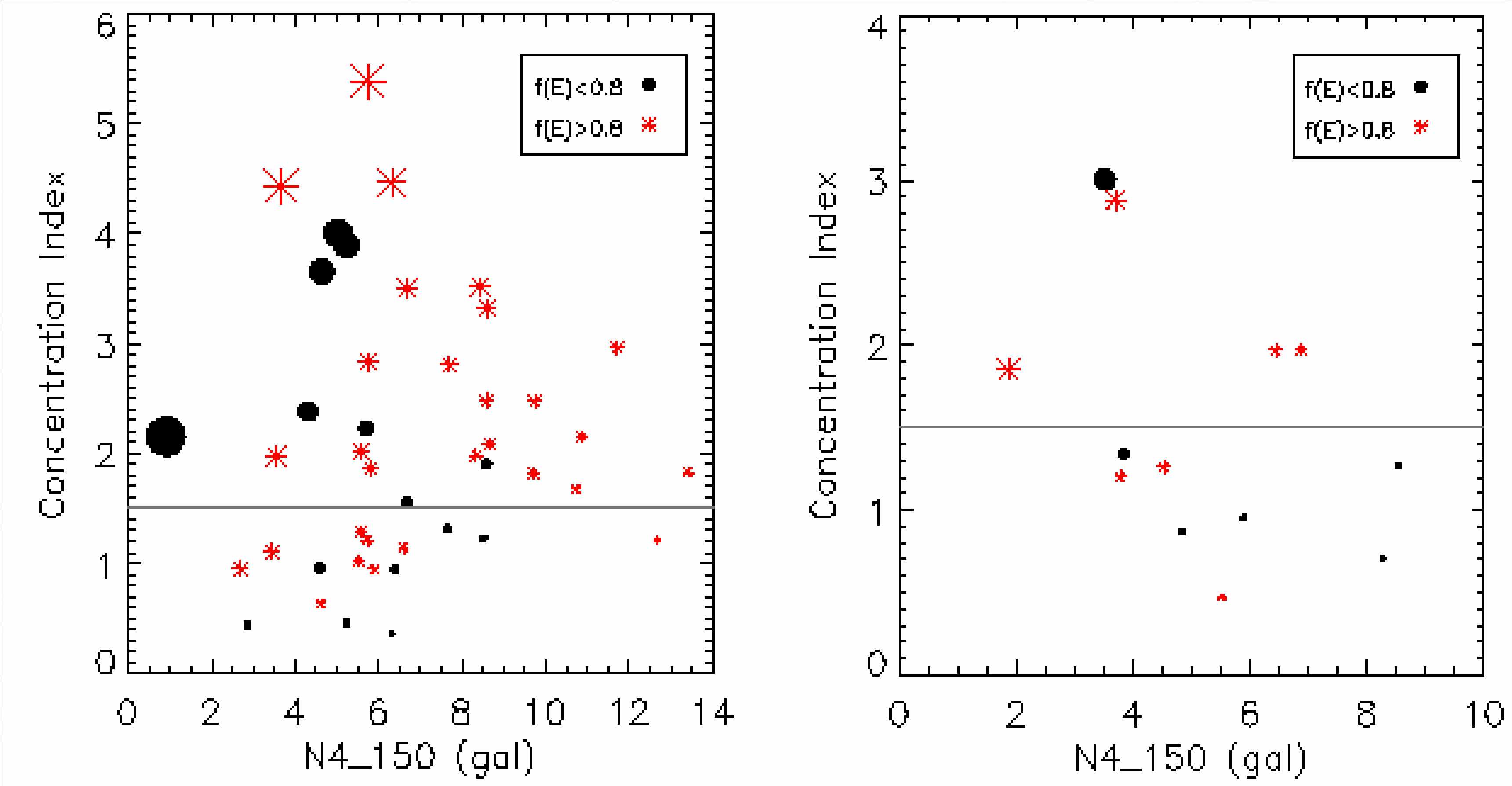




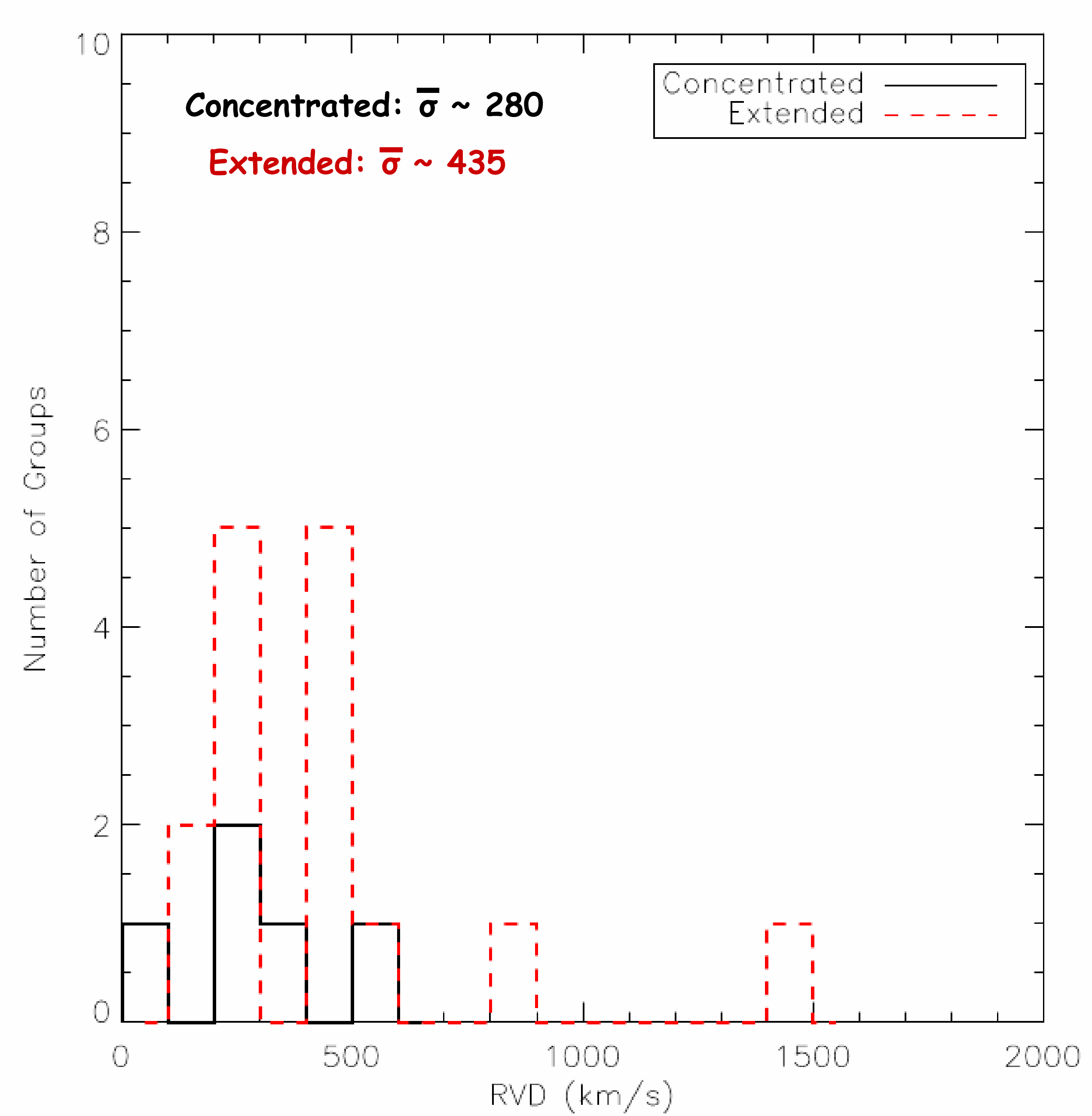
——— Inner zone

.... Local Environment

— — — Local background

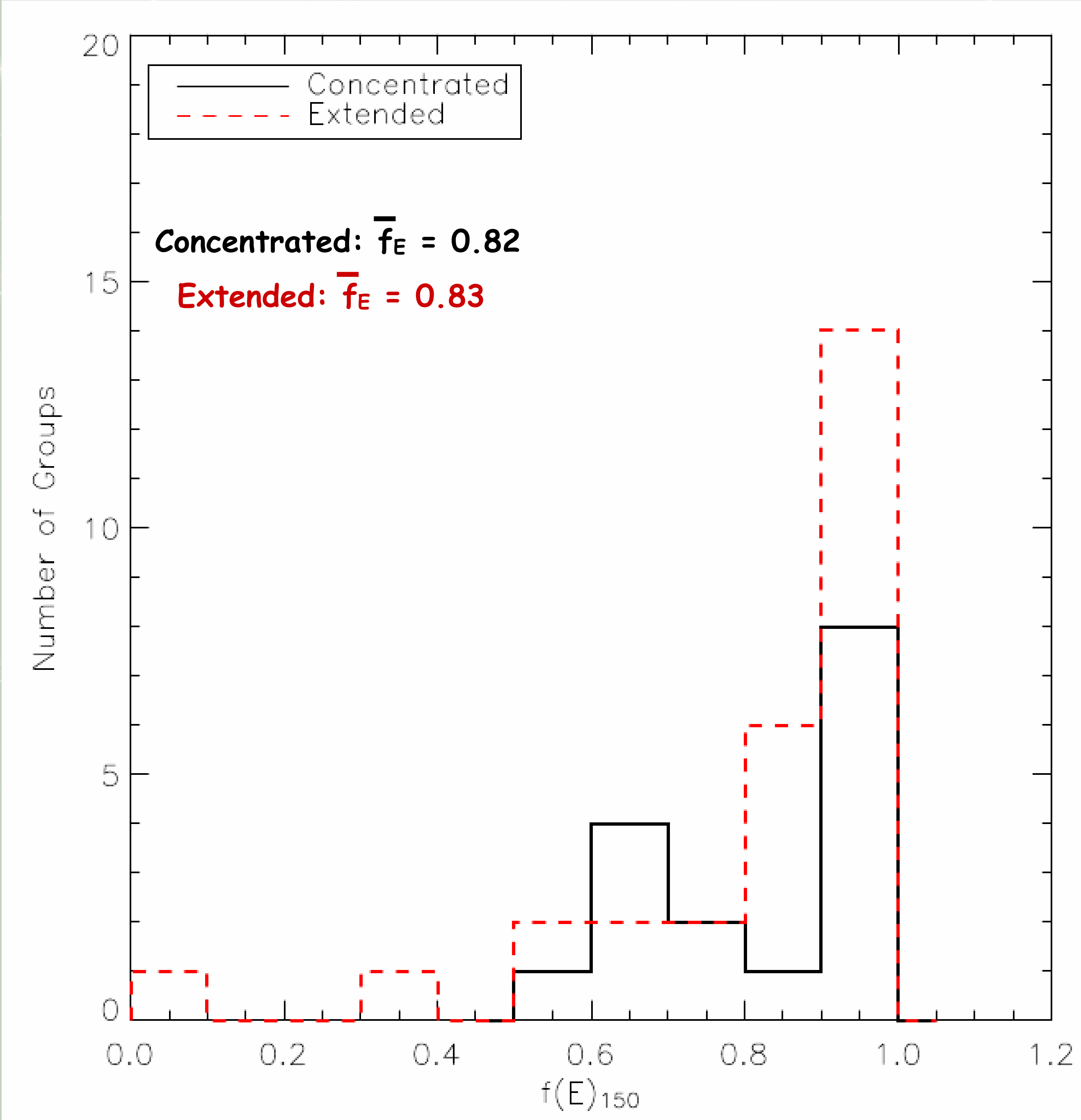


We used the ratio $N4_{500}/N4_{150}$ as a concentration index. Groups with $N4_{150} < 7$ can be both concentrated and extended structures, while groups with $N4_{150} \geq 7$ are predominantly extended structures with concentration index > 1.5 (horizontal line) and f(E) that can be only greater than 0.8.



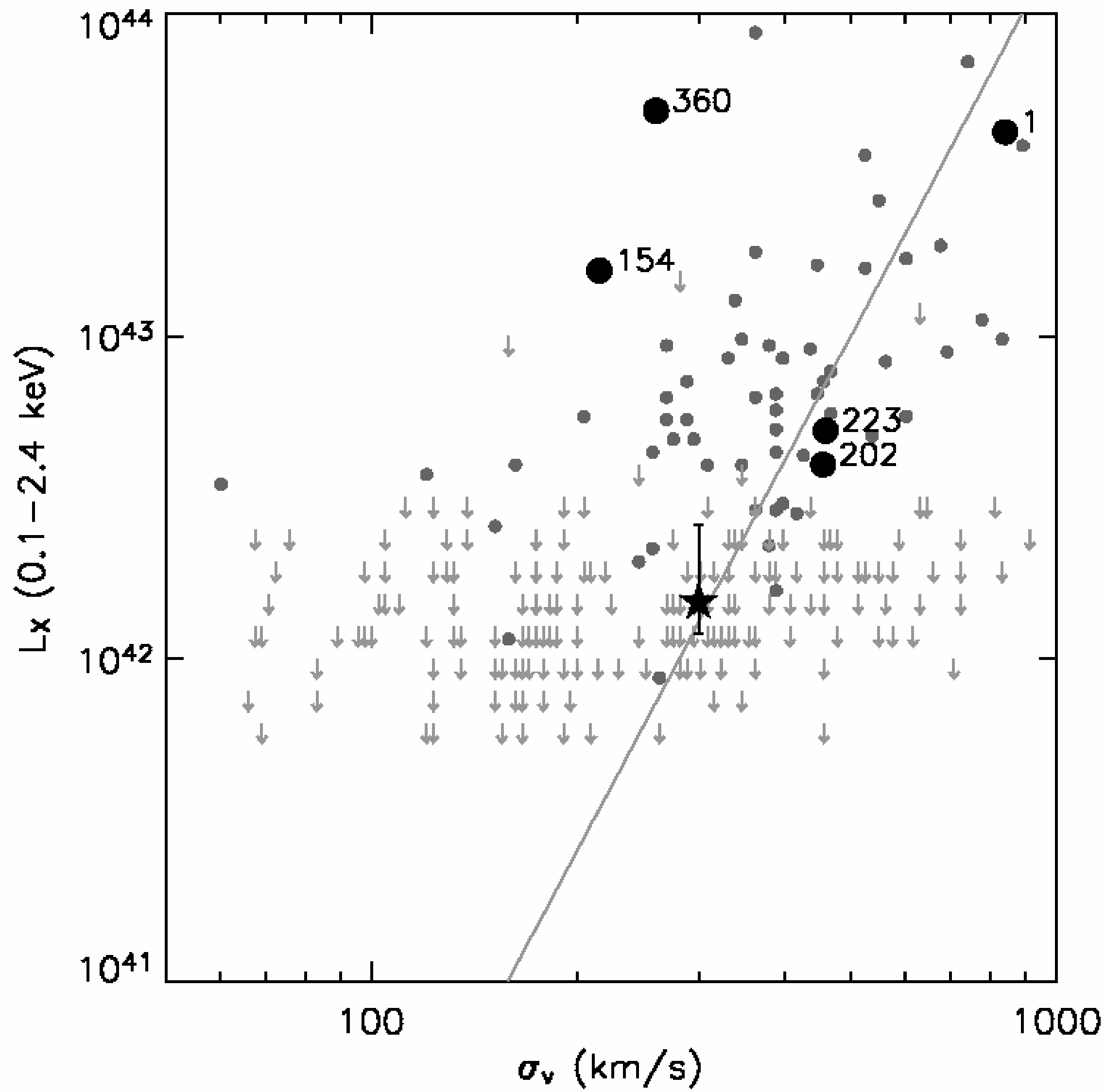
RVD distributions for compact and extended structures.
RVDs are available only for a very few SHKGs and sometimes measurements are based only on 3-4 galaxies.

f(E) distributions for compact and extended structures.



- Combined pointed and RASS data. Our results are compared with the L_X-σ_v plot of (Mahdavi et al. 2000), based on 0.1-2.4 keV band RASS data.

- L_X vs σ_v distribution of SHKGs (black dots) on Mahdavi sample (grey symbols). Star is the stacked SHK sub-sample below the RASS detection thereshold.



CONCLUSIONS

Our study shows:

- **Our study confirms that 76% of SHK groups are real, gravitationally-bound structures, with a well defined red sequence, richness between 3 and 13 galaxies and a large early-type fraction ($\bar{f}_E$=0.84) similar to that of the HCGs sub-sample analysed in this work. SHKGs are slightly richer in early-type galaxies.**
- **SHKGs can be split in 2 sub-samples: truly compact isolated groups (Concentration Index ≤ 1.5) and poor groups, part of larger structures (Concentration index > 1.5). Furthermore SHKGs with $N4_{150} \geq 7$ can be only extended structures and can have only $f_E \geq 0.8$, while groups with $N4_{150} < 7$ distribute among both classes of structures and can have both $f_E < 0.8$ and $f_E \geq 0.8$. Extended and high f_E groups could be galaxy clusters.**
- **Our analysis suggests that morphology-radius relation might be already in place in poor, dense systems. In addition we don't find any relationship between SHKGs properties and their z. Instead their properties depend on the sky region they inhabit, that influences their dynamical evolutionary status and the morphology of their member galaxies through the triggering of gravitational interactions among them.**

FUTURE WORK

- We plan to extend the analysis to the other 166 groups contained into the region covered by the SDSS and to evaluate the results obtained in this work using a larger sample.
- We want to observe the galaxies of the groups spectroscopically, aiming to better analyse their membership and to obtain RVDs and mass estimates.
- Performing X-Ray observations, in order to investigate the diffuse X-Ray emission from the objects in our sample. This would allow to probe the presence of a hot diffuse gas trapped into the gravitational potential well of the groups and therefore their reality.