ASTRONOMY AND SPACE SCIENCE
eds. M.K. Tsvetkov, L.G. Filipov, M.S. Dimitrijević, L.Č. Popović,
Heron Press Ltd, Sofia 2007

Studies of Selected Voids. Faint Galaxies in the Direction of the Void 0049 +05

G.T. Petrov, **L. Slavcheva-Mihova**, **V. Kopchev**

Institute of Astronomy, Bulg. Acad. Sci., Sofia 1784, Bulgaria

Abstract.

Coordinates, multiaperture apparent B-magnitudes, diameters, position angles and some morphological parameters have been defined for 992 faint galaxies from total 2251 galaxies in the region of 1 sq. deg. in the direction of 0049+05 void. The data have been taken with the 2-m RCC telescope of the NAO "Rozhen", Bulgaria. The galaxies were selected using automatic selection and classification of the objects with the SExtractor package. Cluster analysis have been used to study the distribution of different parameters of galaxies in the sample. The traces of 5 selfstructured subgroups have been marked. Some foreground galaxies are located in this direction. There is no meaningful preferable orientation of the galaxies in this region. Probably Giant Low Surface Brightness Galaxies and Active galactic nuclei candidates are selected.

1 Introduction

The presence of voids in the distribution of galaxies has been discovered in early redshift surveys of galaxies – see *e.g.* Chincarini & Rood ([1]), Gregory & Thompson ([2]). Further studies show that the largest voids are those delineated by rich clusters and superclusters of galaxies – Oort ([3]), Rood ([4]). Here we inspected an area of ca. 1 sq.deg in the direction of **0049 +05 void** based on photographic plates obtained with 2-m RCC telescope at NAO "Rozhen" (Bulgaria). The data have been taken after reduction of the NAO_plate No. 1867. ORWO ZU-21 emulsion together with Schott GG385 filters have been used to determine the standard Johnson & Morgan B-system. The exposure time was 150 min, so the limiting magnitude of the plate is further than POSS ones. Neutral wedge have been exposed for 40 min to calibrate the data in intensities. After scanning with PDS 2020 GMPlus machine in Muenster with 25×25 mkm square slit and 20 mkm step we got 14400×14400 sq.pix with scale 0.25 arcsec/pixel.The image was converted to intensity via INTEN/AIP MIDAS implementation of AIP package.

2 Analysis of the results

In the field of interest 1957 manually selected galaxies and 2251 automatically chosen by the INVENTORY were catalogised. Details of these data are presented in [5]. Here an analysis of the data after E. Bertin's SExtractor [6] is analyzed. From the whole list 992 galaxies are selected to define as much as possible morphological parameters for future calibration and classification of galaxies. Benne Holwerda's implementation of Abraham's assymetry, index of concentration *etc.* [7] in SE ver. 2.3.2 is used below. The parameters defined (amongst many) are as follow:

# 1 NUMBER	Running object number
# 2 X_IMAGE	Object position along x [pixel]
# 3 Y_IMAGE	Object position along y [pixel]
# 4 MAG_ISOCOR	Corrected isophotal magnitude [mag]
# 5 MAG_APER	Three Fixed aperture magnitude vector [mag]
# 8 MAG_AUTO	Kron-like elliptical aperture magnitude [mag]
# 9 KRON_RADIUS	Kron apertures in units of A or B
# 10 PETROSIAN_MAG	The magnitude within petrosian radius [mag]
# 11 FLUX_RADIUS	Fraction-of-light 30, 50, 80, 90% radii [pixel]
# 16 MU_MAX	Peak surface brightness above background [mag /sqr.arcsec]
# 17 X_WORLD	Barycenter position along world x axis [deg]
# 18 Y_WORLD	Barycenter position along world y axis [deg]
# 19 A_IMAGE	Profile RMS along major axis [pixel]
# 20 B_IMAGE	Profile RMS along minor axis [pixel]
# 21 THETA_IMAGE	Position angle (CCWx) [deg]
# 22 ELONGATION	A_IMAGEB_IMAGE
# 23 ELLIPTICITY	1 - B_IMAGEA_IMAGE
# 24 FWHM_IMAGE	FWHM assuming a Gaussian core [pixel]
# 25 CLASS_STAR	S/G classifier output
# 26 CONCENTRATION	Abraham concentration parameter R_30/R_total
# 27 CONTRAST	Abraham contrast parameter version2
# 28 ASYMMETRY	Point-Asymmetry index (absolute difference)
# 29 MAJOR_AXIS_ASYM	Major Axis Asymmetry index
# 30 MINOR_AXIS_ASYM	Minor Axis Asymmetry index
# 31 RA(2000)	Right Ascension [hms]
# 32 DEC(2000)	Declination [dms]
# 33 SB_holmb	Surface Brightness close to Holmberg system [mag/sqr.arcsec]
# 34 CI	Concentration Index R_90/R_50

The histogram of the distribution of "stars" – empty regions and "galaxies" – filled regions as they have been separated by the MIDAS context INVENTORY and after SExtractor selection is shown in Figure 1a. Figure 1b presents 2000 $\times$ 2000 sqr.pix from the field to illustrate some steps and results after SExtractor.

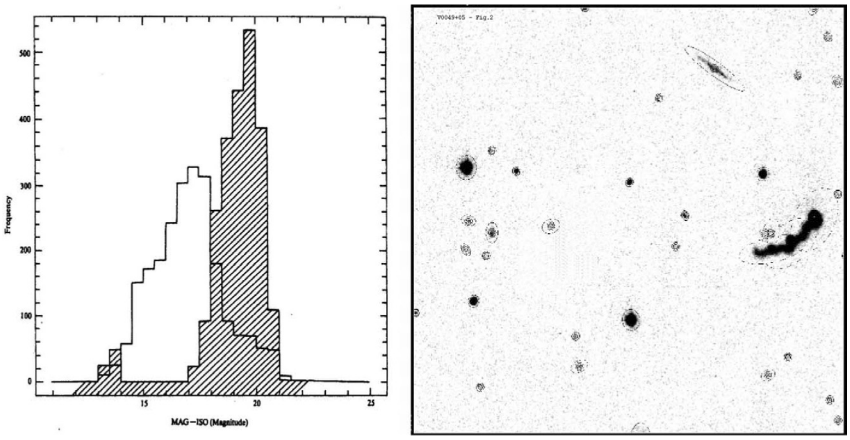

Figure 1. Star and galaxies distribution (left); example of isophotal ellipses for magnitude determination with SExtractor (right).

Inner circular appertures are almost "seeing" – 2–2.5 arcsec for this plate. Larger circular or elliptical appertures are Kron and Petrosian radii to determine the total magnitudes.

Figure 2 presents distribution of large diameters A, Axis-Ratios B/A (marked here as "1/elong") and Position angles PA_ccw (*i.e.* "counter clock from west", as the program determined it) of the galaxies in question. Goodness-of Fit test for axis ratio distribution rejects the probability it is normally distributed, but obviously it is close to this.

In astronomy **cluster analysis technique** is used in wide field of investigation – from classification and star-galaxy separation to the photometrically defined

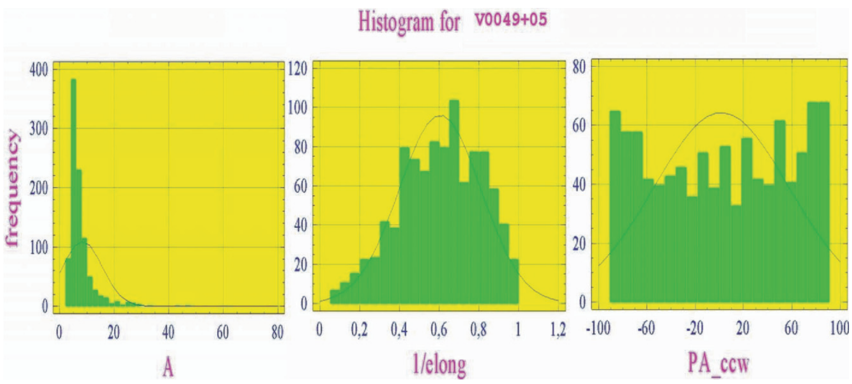

Figure 2. Distribution of large diameters, Axis-Ratios and Position angles of the galaxies.

spectral classes, taxonomy construction and distribution of asteroids, stars and galaxies. Some examples and bibliography can be found in [8] and [9].

The K-means algorithm, probably the first one of the clustering algorithms proposed, differs from hierarchical clustering in many ways. In particular:

(i) There is no hierarchy, the data are partitioned. You will be presented only with the final cluster membership for each case.

(ii) There is no role for the dendrogram in K-means clustering.

(iii) You must supply the number of clusters (k) into which the data are to be grouped.

Here we present the cluster analysis of faint galaxies in the direction of the 0049+05 void.

Our program calculates a number of global parameters for every galaxy. Some of these may be useful for morphological galaxy classifications – [7, 10–14]. A particularly useful parameter is the concentration index, defined as the ratio of the radii containing 90% and 50% of a galaxy's light. For the classical de Vaucouleurs profile (E-S0 galaxies) CI is $\tilde{5}.5$ and for pure exponential disks (S-galaxies) CI$\tilde{2}.3$. These values are valid for the idealized seeing-free case. Simple cluster analysis from the "Large Diameters A – Concentration Index, Surface Brightness, Axis Ratio" *etc.* and "Magnitudes – Surface Brightness", "Surface Brightness – Concentration Index" *etc.* demonstrates the possibilities for detecting of some group of galaxies (see Figure 3).

An interesting aspect of this study is the identification of a substantial number of probably *luminous distant galaxies* with Low surface Brightness. In Figure 3 from the relations between the large diameters, the effective surface brightnesses $\mu_{\rm eff}$ and the integrated magnitude some LSBGs could be selected there - bright galaxies with B$\sim$15.5–17 mag or such ones with large diameters ($>$ 30 arcsec).

Amongst them are Edge_on galaxies – these with very small axis ratio. Some additional information is included in the data – Active galactic nuclei candidates could be hidden amongst the objects with small effective radius R_50 and comparatively large diameters A, primeval Low Surface Brightness Galaxies amongst these with large diameters and low SB *etc.* In this paper Surface Brightness is defined as [15]

$$\rm SB\_h = mag\_au - 0.25cosec\|bII\| + 2.5Lg(\pi * A/B) + 0.22 * (A/B) + 0.73,$$

i.e. the system is close to the Holmberg's one.

Giant Low Surface Brightness Galaxies: Bright galaxies (*i.e.* with lower magnitudes) with large diameters could be a good candidates for LSBG group.

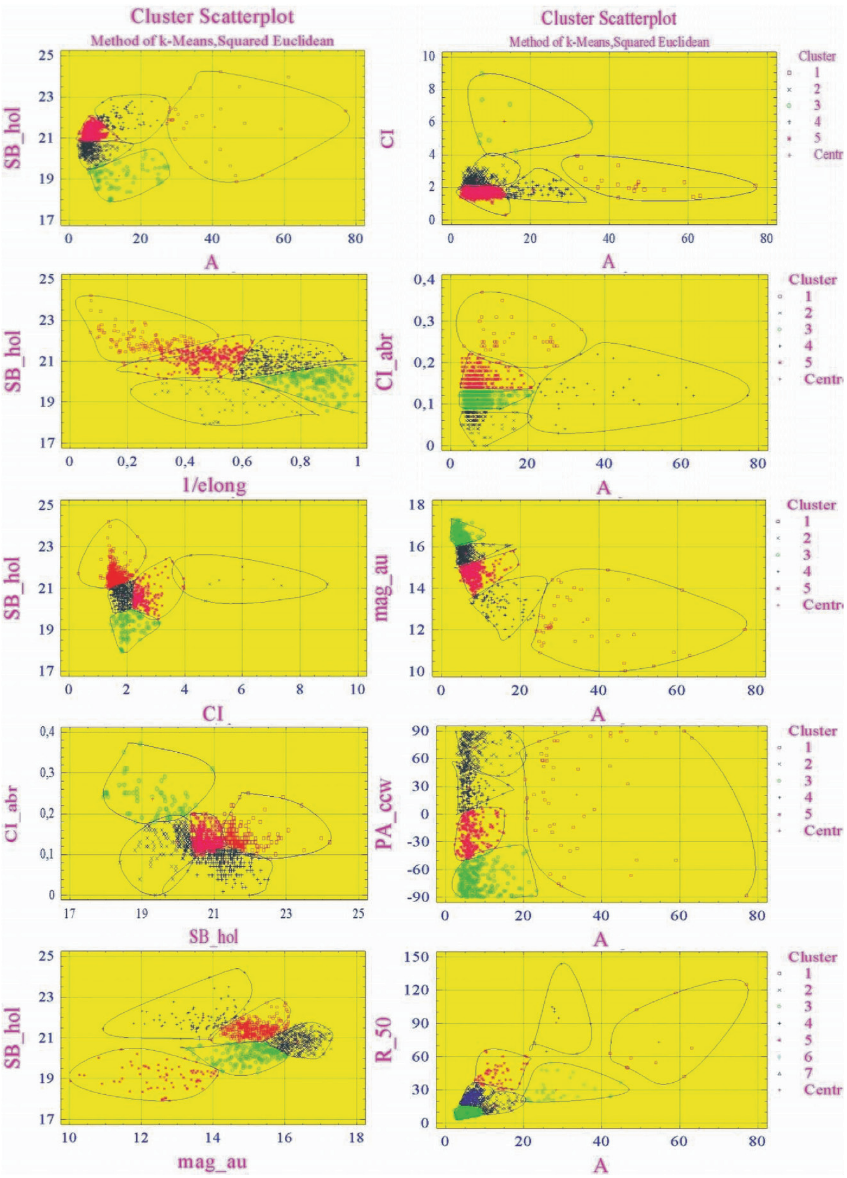

Figure 3. K_means cluster analysis of the basic observational parameters of galaxies in the direction of void V0049+05.

Selecting of probably Active galactic nuclei. Potencial AGN could be hidden amongst the objects with small effective radius ($R_{\rm eff}, R_{50}$) and comparatively large diameters $Large\_D$.

3 Conclusions

Here we present some preliminary analysis of the photometric, astrometric and "morphology" parameters from cluster analysis of an area of ca. 1 sq.degree in the direction of 0049+05 void with automatic object detection software.

1. Astrometric and photometric parameters for ca. 2000 galaxies are determined, these for 992 are analyzed here.
2. Using cluster analysis method for simple morphological classification of galaxies – the groups of E-S0 galaxies and SB-Sd galaxies are outlined.
3. Cluster analysis results allow us to select a group of edge_on galaxies.
4. Using cluster analysis group of AGN candidates is selected.
5. Galaxies with different magnitudes-diameters tend to be grouped acc. to axis ratio.

Remarks: All the observational data for galaxies in question are stored in FITS_table **v0049gal.fts**.

References

[1] G. Chincarini, H. J. Rood, and L. Thompson (1981) *ApJ* **249** L47.

[2] S. A. Gregory and L. A. Thompson (1982) *Sci. Am.* **246** 106.

[3] J. Oort (1983) *Ann. Rev. A & Ap.* **21** 373.

[4] H. J. Rood (1988) *Ann. Rev. A & Ap.* **26** 631.

[5] G. T. Petrov, B. Kovachev and H. Elsaesser (1997) *C. r. Acad. Sci. Bulg.* **50** No. 11–12.

[6] E. Bertin and S. Arnouts (1996) *A & Ap* **117** 393.

[7] Abraham et. Al. (1994) *ApJ* **432** 75.

[8] F. Murtagh and A. Heck (1987) Kluwer Academic Publishers, Dordrecht "Multivariate data analysis".

[9] F. Murtagh (2002) Multivariate data analysis, WEB course.

[10] M. Doi, M. Fukugita and S. Okamura (1993) *MNRAS* **264** 832.

[11] Bershady, Matthew A.; Jangren, Anna; Conselice, Christopher J. M. A. Bershady, A. Jangren and C. J. Conselice (2000) *AJ* **119** 2645.

[12] C. J. Conselice, M. A. Bershady and A. Jangren (2000) *ApJ* **529** 886.

[13] I. Strateva et al., Z. Ivezi¸ G. R. Knapp *et al.* (2001) *AJ* **122** 1861.

[14] C. J. Conselice (2003) *ApJ Suppl.* **147** 1.

[15] M. A. Arakelian (1975) *Contr. Bjurak. Obs* **47** 3.