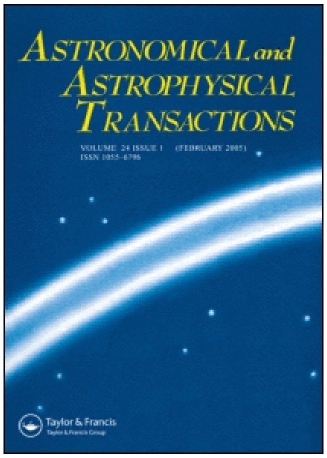

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A search for galaxy clusters in the Münster Red Sky Survey

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The Voronoi tessellation technique is useful for finding galaxy structures in a two-dimensional galaxy distribution. The technique was used on a fragment of the Münster Red Sky Survey and yielded 7280 such structures in an area consisting of 2760 square degrees. The spatial positions of structures containing at least 30 members were compared with those of galaxy clusters from the Abell–Corwin–Olowin catalogue and resulted in a good correlation for rich objects. Large structures with numerous members frequently consist of smaller substructures.

Keywords: Galaxies; Galaxy clusters; Detection

1. Introduction

In order to investigate the properties of clusters of galaxies we need galaxy clusters extracted in the same way from a homogeneous set of data. We have used the Münster Red Sky Survey (MRSS) [1] as the observational basis for our work. The MRSS contains scans of 217 adjoining plates of the ESO Southern Sky Atlas R covering more that 5000 deg^2. The catalogue includes 5 524 245 galaxies to a limiting magnitude of $r_{\mathrm{F}} = 18.3$, and all possible sources of systematic error were carefully studied in the analysis.

We adopted the Voronoi tessellation technique (VTT) in searching for galaxy groupings. At present there are three basic cluster detection algorithms: the matched filter algorithm [2], the adaptive matched filter algorithm [3] and the VTT [4–7]. The VTT is completely non-parametric and therefore sensitive to both symmetric and elongated clusters, allowing correct studies of non-spherically symmetric structures. For a distribution of seeds, the VTT creates polygonal cells containing one seed each and enclosing the whole area closest to its seed. The natural partitioning of space by the VTT has been used to model the large-scale distribution of galaxies. Kim *et al.* [8] made a comparison of the various cluster-finding algorithms, using a Monte Carlo application with simulated clusters. We checked the validity of the application of the VTT on a small portion of the MRSS [9]. We also determined the optimal input parameters for cluster searches [10]. The VTT permits us to extract structures with different numbers

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of galaxies and various shapes within the same statistical approach. In order to establish the reliability of our catalogue of galaxy clusters we compared the position of our objects with those of Abell–Corwin–Olowin (ACO) [11] clusters.

2. The Voronoi tessellation technique and galaxy structure

We performed a galaxy cluster search [10] using the Voronoi Galaxy Cluster Finder (VGCF) package, an automatic procedure for the identification of galaxy clusters in photometric galaxy catalogues [12]. The application of that procedure yields the following: the coordinates of the centre of the overdense region, the number of galaxies in the region, the estimated number of background galaxies, and the area of the structure. For the present we have terminated the structure search to the region with the right ascension (RA) from 0 to 5 h 45 m and the declination (Dec) from $-17°$ to $-49°$. This region occupies 2760 deg^2 and contains 7280 structures identified by our procedure.

Local contrast (the cluster signal-to-noise ratio) above background was an additional parameter obtained with our procedure. As a result, the minimum number of galaxies per structure is seven with a local contrast of about ten. In figure 1, we plot the number of structures for a given number of member galaxies. The most frequent (about 50%) are small galaxy groups containing fewer than 30 objects.

The resulting list of galaxy structures in our catalogue contains the following: the identification number of the structure, the equatorial coordinates RA_{2000} and Dec_{2000} of the structure centre, the radius of the circle representing the structure in arcseconds, the area covered by the structure in square arcseconds, N_{vor} (the number of galaxies in the structure field computed before fitting it by a circle), N_{bg} (the number of background galaxies in the structure field computed before fitting it by a circle), N_{fit} (the number of structure galaxies in the structure field computed after fitting it by a circle and accounting for the computed background density), N_{bgfit} (the number of background galaxies in the structure field computed after fitting it by a circle and accounting for the computed background density), the confidence level and contrast above the background, and the density of the structure defined as the number of galaxies per structure area. The last column is reserved for notes, usually other descriptions of a structure.

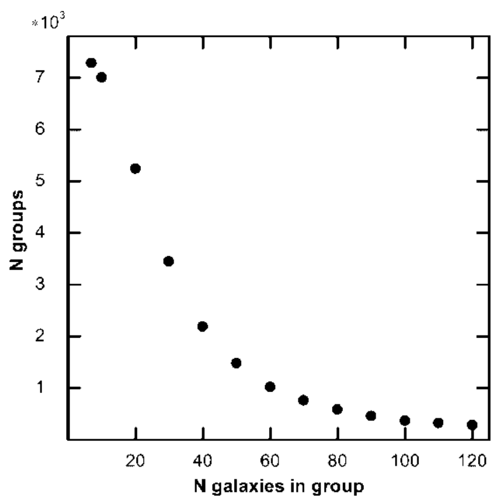

Figure 1. The number of structures for a given number of member galaxies.

Table 1. Our catalogue of structures.

Identification	RA_{2000}	Dec_{2000}	R_{str} (arcsec)	Area (arcsec^2)	N_{vor}	N_{bg}	N_{fit}	N_{bgfit}	Density	Notes
0011–1807	0.110 481 7	−18.068 577	322	134 480	19	10	24	25	1.5×10^{-4}	Sabell 2712
0012–1821	0.120 785 8	−18.205 282	674	1 014 200	110	79	128	111	1.68×10^{-4}	
0021–1722	0.212 417 3	−17.219 625	204	48 185	15	3	18	10	2.14×10^{-4}	Poor S 15
0021–1713	0.211 967 6	−17.123 074	366	149 710	20	11	23	32	1.3×10^{-4}	
0157–2753	1.577 69	−27.520 22	881	2.4553×10^6	213	185	313	184	2.04×10^{-4}	Rich 2926 Rich 2927 Rich 2928 Poor S 168
0166–2771	1.666 62	−27.703 73	375	42 356	12	3	29	33	1.4×10^{-4}	Poor S 172
0170–2493	1.705 67	−24.926 71	712	1.1826×10^6	103	89	131	120	1.57×10^{-4}	–

As an example, in table 1, we present a list of seven structures from our catalogue. Owing to space limitations, two values are omitted, namely the confidence level and the local contrast. The second list identifies the galaxies that are structure members. Moreover, we have the additional list which identifies all the galaxies that are structure members.

3. Comparison and analysis

From our resulting catalogue of galaxy structures we extracted those objects containing at least 30 members for comparison with the ACO catalogue. Our extracted groups greatly outnumber the clusters that are listed in the ACO catalogue (3448 versus 288). Next the positions of our

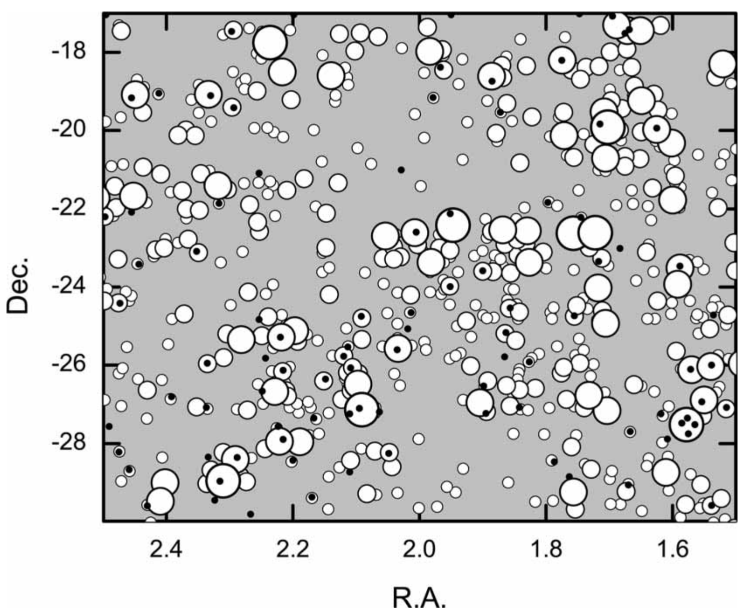

Figure 2. A comparison of the positions for MRSS structures (open circles) and ACO clusters (full circles). The size of each circle corresponds to the structure sizes, but the true dimensions of our structures are not equivalent to the circle diameters.

galaxy structures were compared with the positions of ACO clusters. The structures appear to be spatially coincident when the distance between their centres is smaller than the radius R_{str} of our structures. About 40% of our structures coincide with ACO objects and about 90% of ACO objects coincide with our structures. As can be seen in figure 2, quite often we have several structures located very close to each other and those structures are situated close to the centres of ACO clusters. When we increase the distance between our structures and ACO centres to $1.5R_{str}$, the coincidence level improves, but we have noticed that multiple clusters occur much more frequently. We note also a one-to-one correspondence for some structures. For other structures we find that two or more ACO clusters coincide with one of our structures and, vice versa, some of our multiple structures correspond to only one ACO cluster. Examples of such cases are given in table 1.

4. Conclusions

A comparison of the more abundant galaxy structures extracted by us from the MRSS displays good correspondence to clusters listed in the ACO catalogue. For very many structures the correspondence is unequivocal, while for some structures quite often two objects in our catalogue correspond to one ACO cluster and, vice versa, two or more very close ACO structures correspond to one structure extracted by our algorithm. Such discrepancies are quite natural, when one considers the distinctly different methodologies used for structure identification and background discrimination. Moreover, we find that larger structures are frequently composed of galaxy groups. The preliminary results presented here demonstrate the suitability of our methodology for the creation of a new catalogue of galaxy clusters. We expect the catalogue to be a very useful database for the study of properties for nearby galaxy groups. The next step of our investigation will entail construction of a complete catalogue of structures contained in the entire area encompassed by the MRSS and to compare the resulting structures with Automatic Plate Measuring Machine (APM) Survey structures.

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