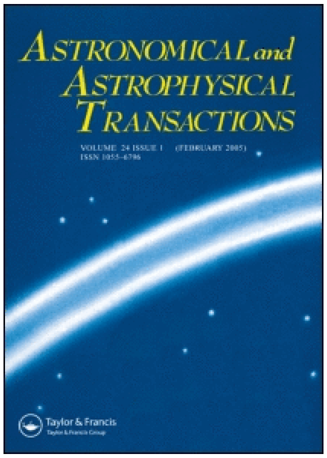

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A new galaxy supercluster?

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In this paper, the results of an analysis of galaxy positions and magnitudes in European Southern Observatory (ESO) field 606 are presented. This $5^\circ \times 5^\circ$ field centred at 23.8 h, $-19^\circ.53$, contains 29 313 galaxies with magnitudes m_F between 12.97 and 20.64. An automatic search of galaxy clusters and groups in the field was made using the Voronoi tessellation technique for two cases: firstly, for all galaxies in the field and, secondly, for galaxies within a magnitude limit of 18.3. We found 37 clusters of galaxies in the field for the first case, and nine clusters for the second case. There are seven Abell–Corwin–Olowin (ACO) clusters in this ESO field. The location of the identified structures on the celestial sphere suggests the existence of a possible galaxy supercluster in the field that covers a region measuring $4^\circ.8$ by $2^\circ.4$ centred at 23.841 h and $-20^\circ.44$. The largest clusters from both cases and five of the seven ACO clusters are in the region. The estimated size of the supercluster is $28\,h^{-1} \times 14\,h^{-1} \times 80\,h^{-1}$ Mpc for the supercluster $340\,h^{-1}$ Mpc distant.

Keywords: Galaxy clusters; Superclusters; Data analysis; Voronoi tessellation

1. Introduction

The Münster Red Sky Survey (MRSS) [1] is the observational basis for our studies involving searching for and investigating galaxy clusters and groups. The MRSS contains scans for 217 adjoining plates of the European Southern Observatory (ESO) Southern Sky Atlas R, which covers more than 5000 deg^2 and includes more than 5×10^6 galaxies. The catalogue is complete to a magnitude limit $m_F = 18.3$. Some plates have fainter magnitude limits with correspondingly greater degrees of completeness. The problem arising from different magnitude limits and their influence on the detection of galaxy clusters was discussed by Panko and Flin [2]. The difference between neighbouring plates vanishes for a limiting magnitude $m_F = 19.3$ for the galaxies considered.

The catalogue of galaxy clusters and groups compiled by Panko and Flin [3] (hereafter called the PF catalogue) was based on the analysis of a homogeneous portion of the MRSS. It includes 6188 structures, with at least ten galaxies in each. The extended version of the catalogue was

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created for a magnitude limit $m_F = 19.3$. It includes more than 11 000 structures. Analysis of structures detected below the magnitude limit of the whole MRSS survey permits us to obtain additional information about the clusters for individual ESO fields. This paper contains the results of a galaxy cluster search in ESO field 606 using two catalogues of structures: the PF catalogue and a catalogue based on all MRSS galaxies in the region.

2. Observational data and clusters search

ESO plate 606 covers the region with right ascension coordinates from 23.663 to 23.945 h and declinations from $-22^\circ.155$ to $-16^\circ.912$ and contains 29 313 galaxies above a limiting magnitude of 20.64. The brightest galaxy in the field is at magnitude 12.97. There are only 6638 galaxies in the field with magnitudes less than the completeness limit of the MRSS of 18.3. So, about 80% of the galaxies in the field lie below the limits of the completed PF catalogue. We note that this situation is atypical of the MRSS and the PF catalogue. Two fields adjoining ESO field 606 contain galaxies with limiting magnitudes of about 18.6 [2].

We performed an analysis of local variations in the galaxy density for galaxies above the completeness limit of the MRSS and for the full list of galaxies in ESO field 606 using the Voronoi tessellation technique (VTT) for our clusters search [4]. The application of the VTT has been discussed by many researchers. Ramella *et al.* [5, 6] demonstrated in their papers that the technique is completely non-parametric and therefore sensitive to both symmetric and elongated clusters, allowing correct studies of non-spherically symmetric structures. Our search was made using the procedure *kiang*, which is the core of the Voronoi galaxy cluster finder (VGCF), an automatic package for identification of galaxy clusters in photometric galaxy catalogues [5].

The software searched for overdense regions in the field and then identified galaxies belonging to each overdense region. Two types of structure were identified as overdense regions: galaxy clusters and groups of galaxies. For each structure we obtained estimates for the radius and area and also the number of background galaxies. Structures with 50 and more members in the magnitude limits m_3 and $m_3 + 3$ were considered to be galaxy clusters, while others (less numerous) were termed galaxy groups. For each structure the covariance ellipse was inscribed, considering only galaxies within the above-mentioned magnitude limit. That allowed us to determine the ellipticity and the position angle of the structures by the standard method, described in [3].

3. Analysis and discussion

For the cluster search of galaxies with a limiting magnitude brighter than 18.3 we found nine groups and nine clusters of galaxies; three clusters have more than 100 members. The results of the search are presented in figure 1(a) as grey open circles. All structures are in the PF catalogue. When all galaxies taken from MRSS are considered, we find 22 groups and 37 clusters (figure 1(b)), with 13 clusters in this case containing more than 100 members. Both lists of galaxy clusters are given in appendix A as tables A2 and A3, respectively.

A comparison of the clusters present in the lists given in tables A2 and A3 shows that clusters in the PF catalogue are of larger size, while some of the structures from table A3 fully correspond to the structures in table A2. For structures with 50 or more members from table A2, only cluster 2392-1819 does not have an analogue in table A3, but at the same time three groups from the PF catalogue appear in table A3 as clusters. There are only seven

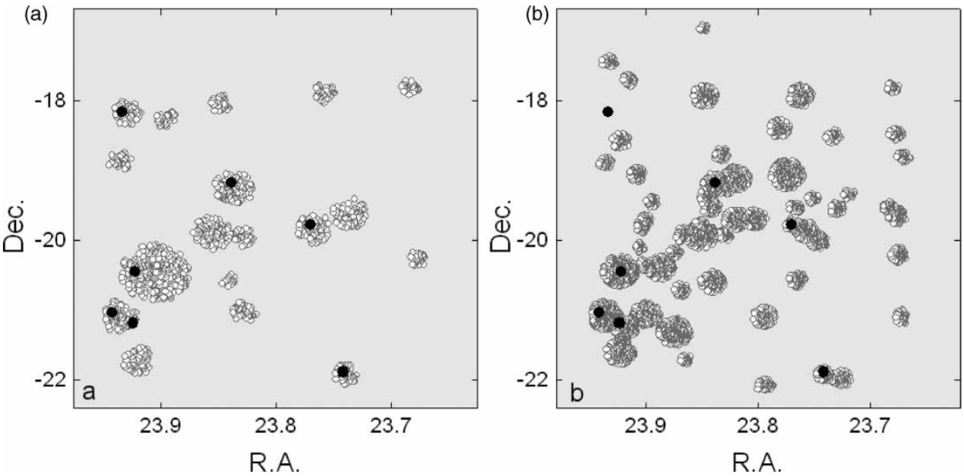

Figure 1. Galaxy clusters and groups (a) from the PF catalogue and (b) from the full list for ESO field 606. The grey open circles represent individual galaxies belonging to the structures, and the black full circles show the centres of ACO clusters.

Abell–Corwin–Olowin (ACO) [7] galaxy clusters, and there are no clusters in the automated plate measurement (APM) catalogue [8] in this field. The centres of ACO galaxy clusters are depicted in figures 1(a) and (b) as black full circles. All ACO clusters have counterparts in our lists. The counterparts of ACO clusters in both our lists are presented in table 1. The identifications, the radii in arcseconds estimated by the VTT, the number of galaxies in the magnitude limits m_3 and $m_3 + 3$, and $m_{\rm F}$ for the tenth-ranked cluster members are given for the newly found clusters.

The cluster 2393-2110 covers two ACO clusters, but ACO S1163 has a counterpart only in table A2. ACO clusters 2655, 4032 and 4045 are close to two or three clusters in table A3, as shown in figure 2. The symbol sizes correspond to the relative sizes of the clusters. We conclude that the largest clusters have complex structures. Moreover, it is possible that these clusters are part of a complex structure of higher order. In the projection on the celestial sphere the structure appears as an ellipse with axes roughly 4°.8 by 2°.4 centred at 23.841 h, −20°.44, with the position angle of its semimajor axis (measured clockwise from north) at about 51°. The ellipse contains seven of nine clusters from table A2 and 23 of 37 from table A3. In addition, five of seven ACO clusters in ESO field 606 are in the region.

When we count clusters located in the above region and considered as possible supercluster members in the ellipse, the difference beteen the magnitudes m_{10} of the brightest and faintest

Table 1. ACO clusters and their counterparts for the 606 ESO field.

ACO cluster	Abell type*	Table A2	R	N_1	$m_{\rm F,10}$	Table A3	R	N_1	$m_{\rm F,10}$
2655†	RI	2373-2192	553	59	16.93	2374-2193	717	62	17.23
4032	RI	2376-1984	748	71	17.36	2376-1980	351	64	18.14
4045†	RI	2383-1927	867	108	16.78	2383-1920	552	120	17.06
2679†	R	2390-2048	1490	274	16.29	2392-2045	793	240	17.00
4055†	I	2393-2110‡	799	119	16.93	2391-2128	514	104	17.92
S1163	IR	2392-1819	629	55	16.68	–	–	–	–
2680†	R	2393-2110‡	799	119	16.93	2393-2109	739	201	16.93

*R, regular; I, irregular; RI, IR, intermediate.
†Member of a possible supercluster.
‡Cluster 2393-2110 corresponds to two ACO clusters.

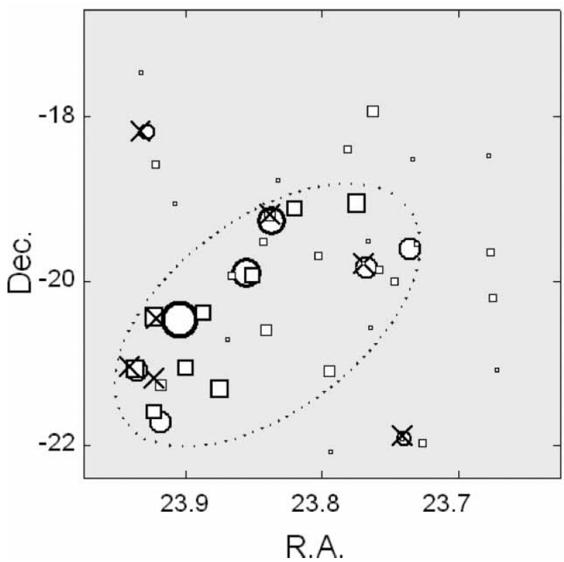

Figure 2. A comparison of the positions for ACO clusters (crosses), for clusters from the PF catalogue (open circles) and for full list clusters from ESO field 606 (open squares). The possible supercluster is depicted by the dotted ellipse.

objects listed in table A2 is 1.00, while it is 1.50 for the objects in table A3. The greater difference for objects in the table A3 obviously arises from the fainter magnitude limit of the list. The important point is that the difference between structure distances, as estimated from m_{10}, is rather small.

The distance classes, according to the classical papers by Abell [9] and Corwin [10], are estimated as classes 5–6 from the magnitude m_{10} for table A2 clusters, excluding the largest, 2390-2048, and as classes 5–7 for table A3 clusters. The average magnitude values of 16.98 and 17.70 correspond to estimated distance limits of $280\,h^{-1} - 390\,h^{-1}$ Mpc. We adopt a probable distance to the supercluster of $340\,h^{-1}$ Mpc. Only one cluster, ACO 2655, of seven ACO clusters with measured $z = +0.1122$ [11] lies in ESO field 606. Unfortunately, it does not lie in the region discussed here. The magnitude of the tenth galaxy corresponding to this cluster in table A3 is 17.23, corresponding to distance class 6. That corresponds to an estimated distance of $337\,h^{-1}$ Mpc, very close to the estimate that we obtained above. In Friedmann–Lemaître–Walker–Robertson metrics for that distance, the angular size of the supercluster corresponds to $28\,h^{-1} \times 14\,h^{-1}$ Mpc, while the estimated depth for a magnitude of 1.00 is $80\,h^{-1}$ Mpc.

The possible supercluster discussed here is not listed in the supercluster catalogue published by Einasto *et al.* [12], or in other supercluster lists.

4. Conclusions

From the analysis of galaxy positions and magnitudes in ESO field 606 we found a region with a higher concentration of galaxies that covers a region of sky measuring $4^{\circ}.8 \times 2^{\circ}.4$ centred at 23.841 h and $-20^{\circ}.44$. The region was detected both from galaxies with a brightness magnitude greater than 18.3 and from a full list of galaxies in the field considered. The region also contains five ACO clusters. We interpret this region as a possible new galaxy supercluster that includes at least 23 galaxy clusters. The estimated dimensions of the supercluster are $28\,h^{-1} \times 14\,h^{-1} \times 80\,h^{-1}$ Mpc at a distance of $340\,h^{-1}$ Mpc. There are no measured red shifts z for galaxies in this region, which seem essential to demonstrate that it is truly a supercluster.

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Appendix A: Galaxy clusters in ESO field 606

Table A1 gives further information about the column headings of tables A2 and A3.

Table A1. Explanations of the column headings in tables A2 and A3.

Ident	Structure identification, formed from the first digits in R.A. and Dec. * – notes possible supercluster members.
R.A., Dec.	Right Ascension and Declination for 2000.0
R	Equivalent radius in *arcseconds* for full area of structure estimates by *kiang*.
S	The area of the structure in square *arcseconds*.
N	The number of all galaxies in the field of the structure.
N_3	The number of galaxies in the field of the structure within the magnitude limit $m_3, m_3 + 3^m$.
N_{bg}	The estimated number of background galaxies from *kiang*.
a, b	The major and minor semi-axes of the fitted ellipse.
E	The ellipticity of the structure.
PA	The position angle of the semi-major axis of the structure. The angle is measured from north clockwise.
m_1, m_3, m_{10}	The m_F magnitude for the first, the third, and the tenth-ranked cluster members, as given in MRSS.

Table A2. Galaxy clusters for a limited selection.

Identification	RA	Declination	R (arcsec)	N_{bg}	N	N_3	a	b	E	PA	m_1	m_3	m_{10}
2373-1962*	23.735 630 5	−19.612 110	785	43	66	66	771	696	0.10	75.9	15.75	16.37	17.01
2373-2192	23.739 485 4	−21.918 708	553	21	59	59	556	388	0.30	151.3	16.03	16.41	16.93
2376-1984*	23.767 314 6	−19.839 542	748	39	71	71	795	632	0.20	149.5	16.32	16.69	17.36
2383-1927*	23.836 691 6	−19.266 349	867	53	108	108	848	754	0.11	76.3	15.57	16.42	16.78
2385-1991*	23.855 070 9	−19.904 566	847	50	98	98	828	742	0.10	121.1	15.55	16.14	16.91
2390-2048*	23.904 516 6	−20.471 960	1490	156	274	274	1565	1306	0.17	91.8	14.94	15.69	16.29
2391-2173*	23.918 584 7	−21.720 847	717	36	61	61	769	577	0.25	28.4	15.89	16.67	17.06
2392-1819	23.928 460 1	−18.184 797	629	27	57	55	650	572	0.12	118.9	15.25	15.55	16.68
2393-2110*	23.935 744 4	−21.094 545	799	45	119	119	798	565	0.29	132.3	14.93	16.17	16.93

*Possible supercluster members.

Table A3. Galaxy clusters for the full list of galaxies.

Identification	RA	Declination	R (arcsec)	N_{bg}	N	N_3	a	b	E	PA	m_1	m_3	m_{10}
2367-2110	23.671 518 9	−21.094 135	368	42	59	59	368	250	0.32	174.2	16.09	17.18	18.83
2367-2021	23.673 828 5	−20.207 887	409	52	80	80	402	298	0.26	15.4	17.20	17.52	18.19
2367-1966	23.675 977 8	−19.652 797	444	62	104	96	420	309	0.26	4.5	16.34	17.00	17.90
2367-1849	23.676 907 3	−18.484 634	330	34	55	52	287	268	0.06	1.9	16.80	17.19	18.42
2372-2198	23.726 069 9	−21.975 821	433	59	84	77	420	359	0.15	70.5	15.84	16.79	17.56
2373-1956*	23.730 093 3	−19.557 101	357	40	66	63	340	263	0.23	42.5	16.64	17.14	18.43
2373-1852	23.733 323 8	−18.517 149	365	42	55	55	310	269	0.13	45.3	15.64	17.90	18.60
2374-2193	23.740 937 8	−21.920 864	374	44	84	62	361	298	0.17	148.9	16.03	16.41	17.23
2374-2002*	23.746 744 5	−20.011 256	453	64	106	100	446	369	0.17	101.4	16.71	16.94	17.88
2375-1987*	23.757 899 0	−19.869 884	494	77	119	119	463	454	0.02	173.5	16.69	17.28	17.87
2376-1795	23.762 127 9	−17.942 376	542	92	121	82	550	481	0.13	20.5	15.94	16.51	17.35
2376-2058*	23.764 483 6	−20.570 736	396	49	73	50	379	336	0.11	154.2	15.63	16.51	17.68
2376-1953*	23.765 899 7	−19.524 814	320	32	51	51	332	231	0.30	105.7	16.44	17.55	18.10
2376-1980*	23.769 192 8	−19.791 808	351	38	64	64	249	223	0.11	6.1	16.32	17.33	18.14
2377-1907*	23.774 089 0	−19.065 225	750	177	242	167	768	706	0.08	0.9	16.21	16.52	17.27
2378-1841	23.780 631 1	−18.406 135	474	71	94	94	455	406	0.11	103.0	16.92	17.24	17.87
2379-2209	23.793 780 0	−22.082 141	391	48	69	69	361	279	0.23	80.8	17.45	17.58	18.28
2379-2110*	23.794 502 0	−21.099 683	519	85	108	81	508	461	0.09	29.9	15.80	16.73	17.70
2380-1970*	23.802 354 9	−19.694 790	497	78	108	108	496	430	0.13	154.1	15.41	17.77	18.09
2381-1913*	23.819 327 7	−19.121 097	603	114	174	154	608	552	0.09	150.3	16.14	16.89	17.50
2383-1879	23.832 212 9	−18.780 814	346	37	52	52	341	263	0.23	13.0	17.79	18.01	18.67
2383-1920*	23.838 283 9	−19.199 982	552	96	158	120	512	423	0.17	42.6	15.57	16.70	17.06
2384-2061*	23.840 549 6	−20.600 434	551	95	131	109	517	493	0.05	135.4	16.41	16.76	17.51
2384-1953*	23.842 310 9	−19.524 296	428	58	87	87	425	378	0.11	147.5	17.23	17.85	18.29
2385-1994*	23.850 511 7	−19.937 898	675	143	218	187	638	616	0.03	66.9	15.55	16.81	17.55
2386-1994*	23.865 982 7	−19.932 516	412	53	65	63	397	264	0.33	177.2	16.65	17.11	18.11
2386-2072*	23.868 701 2	−20.717 233	341	36	55	55	315	281	0.11	7.6	14.28	17.27	18.25
2387-2132*	23.874 306 3	−21.319 458	720	163	259	135	727	622	0.14	105.6	15.32	16.24	17.62
2388-2040*	23.886 932 5	−20.395 193	616	119	169	79	641	544	0.15	53.3	15.87	16.05	17.14
2389-2107*	23.899 520 1	−21.064 229	608	116	163	159	606	587	0.03	110.0	16.60	17.18	17.97

(*continued*)

Table A3. Continued.

Identification	RA	Declination	R (arcsec)	N_{bg}	N	N_3	a	b	E	PA	m_1	m_3	m_{10}
2390-1907	23.907 631 4	−19.060 519	383	46	71	67	368	323	0.12	155.1	15.83	17.14	18.21
2391-2128*	23.917 700 2	−21.272 530	514	83	113	104	521	393	0.25	153.2	16.31	17.02	17.92
2392-1860	23.922 144 3	−18.590 832	427	57	73	73	419	324	0.23	40.3	16.86	17.37	18.14
2392-2160*	23.922 656 3	−21.598 385	646	132	210	93	689	644	0.06	132.0	15.89	16.20	17.21
2392-2045*	23.922 750 5	−20.447 386	793	198	377	240	751	675	0.10	120.2	14.94	16.41	17.00
2393-1747	23.932 892 0	−17.460 120	344	37	53	53	339	245	0.28	110.0	16.76	17.07	18.22
2393-2109*	23.936 318 1	−21.082 704	739	172	391	201	712	574	0.19	126.7	14.93	16.17	16.93

*Possible supercluster members.