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Superclusters and galaxy formation

Recent studies have demonstrated that most galaxies and rich clusters of galaxies[1] are concentrated to superclusters of galaxies, large holes are situated between superclusters[2 - 6]. In this paper we study the structure of superclusters using Zwicky clusters[7] as principal tracers of the large-scale structure of the Universe. Our study is restricted to the southern galactic hemisphere.

Using Huchra's compilation of available redshifts of galaxies we have found mean redshifts of Zwicky clusters of distance class "near" between $22^h \leq \alpha \leq 4^h$. Of the 88 clusters in the area considered 56 have measured redshifts. The redshifts of the remaining 32 clusters have been estimated on the basis of luminosity function and apparent diameter. The distribution of clusters in the sky in two redshift intervals is given in Fig.1.

The prominent triangle-shaped aggregate seen in Fig. 1a is the Perseus supercluster. Its richest cluster A426 is located at the northern tip of the supercluster. Rich clusters are situated in the western and southern tips as well, the Perseus cluster and A194, respectively. Other clusters form chains joining the tips of the supercluster. A chain is located close to the Milky Way, it forms the northern boundary of the Andromeda supercluster.

In Fig. 1b two superclusters can be seen: the Pegasus supercluster in the right-hand section of the figure and the Cetus supercluster in the lower left-hand section. In the central area of Fig. 1b there are no clusters, here lies a big hole. The hole is surrounded by superclusters from all sides: the Perseus supercluster forms a wall at the near side of the hole, superclusters seen in Fig. 1b form walls at the left and right sides, superclusters at redshifts $10000 \leq V_0 < 15000$ km s^{-1} form walls at its far side.

The distribution of redshifts of galaxies in the central area of the Perseus supercluster (where there are no clusters) is given in Fig. 2a, Fig. 2b gives the distribution of redshifts of clusters of galaxies in the whole area of the Perseus supercluster, and Fig. 2c shows the distribution of redshifts of clusters in the remaining area outside the Perseus supercluster. We see a very strong peak in Figs. 2a and 2b at the redshift 5000 km s^{-1} due to the Perseus supercluster. The distribution of redshifts of galaxies and clusters at large redshifts is also similar. This suggests that (a) galaxies situated in the central area of the Perseus supercluster form a thin stratum just at the same distance as clusters form chains, and (b) most distant galaxies belong to distant superclusters. The distribution of redshifts in Fig. 2c is completely different since it is caused by other superclusters situated at a larger distance from us.

In the direction of the Perseus supercluster there are only a few foreground and background galaxies, the vast majority of galaxies between $13.0 < m \leq 15.0$ belong to the Perseus supercluster. Thus we can use galaxy counts to estimate some numerical properties of the Perseus supercluster. The results are given in Fig. 3. N denotes the number of Palomar Observatory Sky Survey fields, L - the luminosity calculated by the method suggested by Jõeveer, Einasto and Tago[3], B is the surface brightness and %S is the per cent of spiral galaxies in the respective area. Morphological types of galaxies were taken from Nilson[8]. In the last column the number of radio galaxies is given[9].

The data given in Figs. 1 - 3 indicate that superclusters of galaxies are surrounded by chains of clusters of galaxies which join main density peaks - rich clusters. Main peaks have a low spiral percentage (most galaxies are elliptical and SO-s) and contain many radio galaxies. In central areas of superclusters the density of galaxies is small, there are no clusters here, almost all bright galaxies are spirals.

The total area covered by the Perseus supercluster is

5400 Mpc^2, its mean thickness is 7 Mpc, volume $3.8 \cdot 10^4$ Mpc^3 and mass (adopted mean mass-to-luminosity ratio 150) $2.7 \cdot 10^{16}$ $M_\odot$. The mean density in the supercluster exceeds tenfolds the critical cosmological density[6].

Neighbouring superclusters are in contact and contain common elements. For example, the chain of clusters between clusters A426 and U6 is the northern boundary of the Perseus supercluster and the southern boundary of the Andromeda supercluster.

All clusters are members of superclusters. The space between superclusters (about 98% of the total volume of the universe[6]) is void of clusters and almost void of bright galaxies.

A nonlinear theory of the growth of inhomogeneities suggests that the amount of matter concentrated in superclusters (initial positive density perturbations) is only a little larger than the total mass of the dark matter in big holes (initial negative density perturbations)[6]. If the density of matter associated with superclusters is $\Omega_{scl} = 0.2$[3], then the overall mean matter density is $\Omega = 0.3$. The different large-scale spatial distribution of dark and luminous matter cannot be reconciled with gravitational clustering theories[10].

On the other hand, the morphology and structure of superclusters suggest that it is impossible to form superclusters in a wholly gaseous medium. In a gaseous proto-supercluster the formation of galaxies has to begin in the central part of it and lead to a large cluster of galaxies rich in ellipticals in the center of the supercluster[11]. As the supercluster grows outwards, its edges become thinner, most galaxies should be spirals here. The observed structure is just the opposite.

This difficulty can be avoided if we suppose following Rees that the formation of galaxies was a two-stage process[12,13], but involves much larger spatial dimensions than he thought. In the first stage proto-superclusters and big holes had to form from the non-dissipative dark matter[14]. As demonstrated by numerical simulations non-dissipative matter forms eventually just the observed structure with high density tips, intermediate density chains and low density walls, if the initial spectrum of perturbations contains large scale components[15]. In the second stage hot gas, cooling and settling down into the potential wells caused by dark matter, will form galaxies and clusters of galaxies[16].

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REFERENCES

[1]Abell, G.O., Astrophys. J. Suppl., 3, 211 (1958).

[2]Jõeveer, M., Einasto, J. and Tago, E., Tartu Astr. Obs., preprint A-1,(1977).

[3]Jõeveer, M., Einasto, J. and Tago, E., Mon. Not. R. astr. Soc., 185, 357, (1978).

[4]Gregory, S.A. and Thompson, L.A., Astrophys. J., 222, 784 (1978).

[5]Tarenghi, M., Tifft, W.G., Chincarini, H., Rood, H.J. and Thompson, L.A., The large-scale structure of the Universe, p. 257, eds. Longair, M.S. and Einasto, J., D. Reidel, Dordrecht, Holland, (1978).

[6]Einasto, J., Jõeveer, M. and Saar, E., Tartu Astron. Obs. Preprint A-2 (1979).

[7]Zwicky, F., Wild, P., Herzog, E., Karpowicz, M. and Koval, C., Catalogue of galaxies and clusters of galaxies, 1 - 6, Cal. Inst. Tech., Pasadena, 1961 - 1968.

[8]Nilson, P., Uppsala General Catalogue of Galaxies, Uppsala Astron. Obs. Ann., Band 6.(1973).

[9]de Vaucouleurs, G., de Vaucouleurs, A. and Corwin, H.G., Second Reference Catalogue of Bright Galaxies, University of Texas Press, Austin and London,(1976).

[10]Aarseth, S.J., The large scale structure of the Universe, p. 185, eds. Longair, M.S. and Einasto, J., D. Reidel, Dordrecht, Holland (1978).

[11]Doroshkevich, A.G., Shandarin, S.F., Saar, E., Mon. Not. R. astr. Soc., 184, 643 (1978).

[12]Rees, M. J., The evolution of galaxies and stellar populations, p. 339, eds. B.M. Tinsley and R.B. Larson, Yale University Observatory (1977).

13 White, S.D.M. and Rees, M.J., Mon. Not. R. astr. Soc., 183, 341 (1978).

14 Saar, E., Tartu Astr. Obs., preprint A-4 (1979).

15 Doroshkevich, A.G., Kotok, E.V., Novikov, J.D., Polyudov, A.N. Sigov, Yu.G. and Shandarin, S.F., Inst. Appl. Math. Preprint No. 83 (1978).

16 Saar, E., Tartu astron. Obs, Preprint A-5 (1979).

Figure captions

Fig. 1. The distribution of Zwicky clusters (a) between redshifts $3500 \leq V_0 < 6500$ km s^{-1}, and (b) between redshifts $6500 \leq V_0 < 10\,000$ km s^{-1}. Zwicky clusters with measured redshifts have been drawn by solid lines, the clusters with estimated redshifts by dashed lines. Abell clusters have been denoted as filled circles, radio galaxies by crosses, X-ray sources by triangles.

Fig. 2. The distribution of redshifts of (a) galaxies in the central area of the Perseus supercluster (10 Palomar survey fields), (b) Zwicky clusters in the whole Perseus supercluster area, and (c) Zwicky clusters outside the Perseus supercluster area.

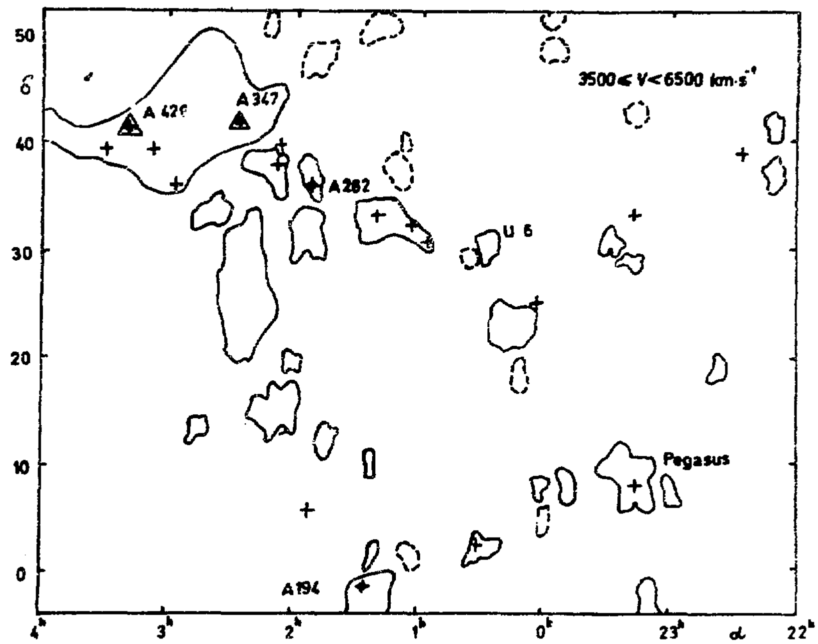
3500 ≤ V < 6500 km s⁻¹
A 426
A 347
A 262
U 6
Pegasus
A 194
δ
α
50
40
30
20
10
0
4h
3h
2h
1h
0h
23h
22h

Fig. 1a

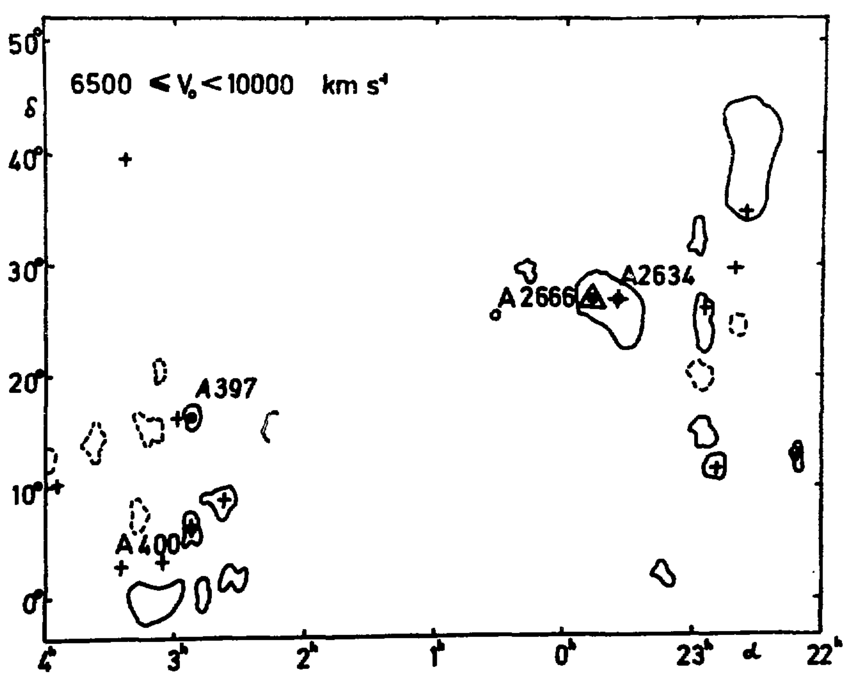
6500 ≤ V₀ < 10000 km s⁻¹
A397
A400
A2666
A2634
δ
α
50°
40°
30°
20°
10°
0°
4h
3h
2h
1h
0h
23h
22h

Fig. 1b

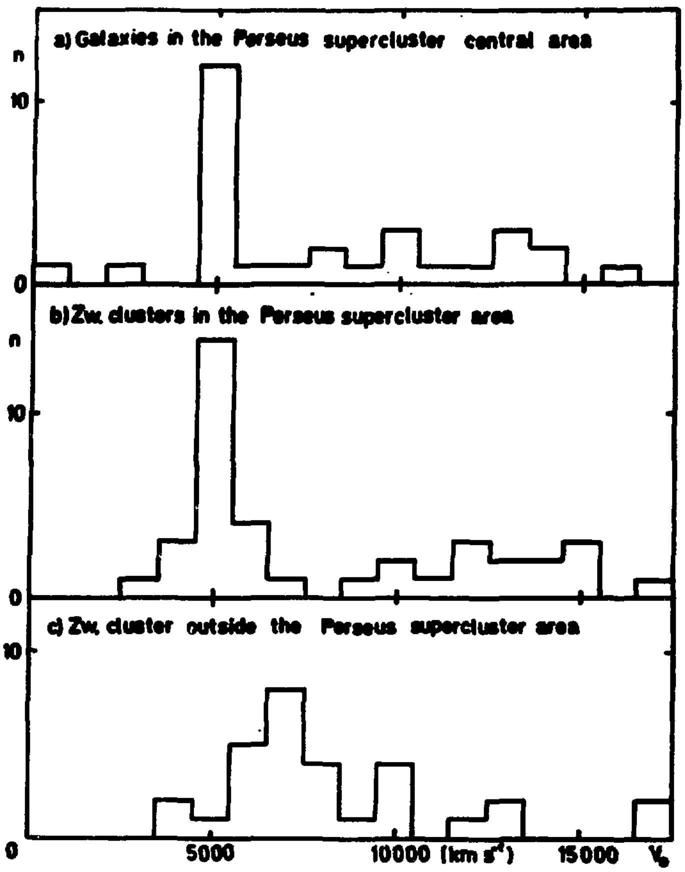
a) Galaxies in the Perseus supercluster central area
n
10
0
b) Zw. clusters in the Perseus supercluster area
n
10
0
c) Zw. cluster outside the Perseus supercluster area
10
0
5000
10000 (km s⁻¹)
15000
V₀

Fig. 2

Fig. 3. Data on the Perseus supercluster

Supercluster region	N	L ($10^{12} L_\odot$)	B ($10^9 L_\odot$ Mpc^{-2})	%S	$n_{r.gal.}$
Main peaks	3	30	79	52	4
Cloud around A426	8	39	39	58	5
Perseus chain	7	60	68	68	6
Other chains	15	43	23	79	2
Central area	10	9	8	85	0
Total	43	181	33	68	17

СВЕРХСКОПЛЕНИЯ И ОБРАЗОВАНИЕ ГАЛАКТИК

Эйнасто Я., Йыэвээр М., Саар Э.

Резюме. Изучается пространственное распределение галактик и скоплений галактик в южном галактическом полушарии. Богатые скопления галактик, содержащие много эллиптических галактик и радиогалактик, соединены между собой цепочками бедных скоплений с умеренным содержанием эллиптических галактик и радиогалактик. Плоское образование, соединяющее пики плотности и промежуточные цепочки, целесообразно называть сверхскоплением. В центральной области сверхскоплений также имеется тонкий слой галактик, содержащий в основном только спиральные галактики. Соседние сверхскопления соприкасаются, пространство между сверхскоплениями не содержит скоплений галактик и почти не содержит галактик. Показано, что такая структура, по-видимому, образовалась до образования галактик.

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