POSSIBLE INHOMOGENEITIES IN THE UNIVERSE ON SCALES OF 100 - 300 MPC FROM OBSERVATIONS WITH THE 6-METER TELESCOPE

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Abstract. In 1986 the programme "The Northern Cone of Metagalaxy" has been finished with the 6-meter Telescope. In the course of the programme redshifts of all very rich compact clusters of galaxies inside the cone with galactic latitude $b^{II} > 60^0$ and indirect estimates of redshifts $Z_{LB} < 0.28$ have been measured. The total volume of the investigated region is $V \approx 500 \cdot 10^6$ Mpc^3 (we accept Hubble constant H=50 km/s Mpc^{-1}). A number of possible indications of existence of inhomogeneities in the Universe on scales greater than 100 Mpc are obtained : 1) the void of 400 Mpc in size ; 2) the flat stratum of 150 Mpc thickness and 1000 Mpc diameter ; 3) two-point space correlation function ξ (R = 200-300 Mpc) = 0.5±0.2. We found no indications that topology of the Universe is non-Euclidean on scales of 20-200 Mpc.

1. INTRODUCTION

We sketch below some results of observations of very compact clusters of galaxies obtained in the course of the programme "Northern Cone of Metagalaxy". This programme has been undertaken with the aim of testing the hypothesis of non-Euclidean topology of the Universe (Sokolov and Shvartsman, 1974; Bernshtein and Shvartsman, 1980). The second purpose of our observations was the search for inhomogeneities of Metagalaxy on scales of 100-1000 Mpc (Shvartsman, 1981). From 1981 to 1986 we have determined redshifts of 45 clusters of galaxies inside the Cone with the vertex angle of 60^0 and with the axis directed to the North Pole of the Galaxy. We observed the objects which had been classified as very rich clusters of galaxies by Abell (1958) and also as compact clusters of galaxies by Zwicky et al. (1961). The list of identifications of the objects from these two catalogues was taken by us from the paper of Karachentsev et al. (1975). The results of our observations during the period 1981-1985 have been published (Kopylov et al.,1984a-1985).

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2. NEW OBSERVATIONS

We have additionally observed with the 6-meter Telescope some of clusters inside the Northern Cone in spring of 1986; new values of redshifts are given in Table 1.

Table 1. New redshift measurements

No Abell	No Zwicky	b^{II}	z_{LB}	z_{OBS}	Number of observed galaxies
A1101	241-1	60.2	0.181	0.2322	2
A1326	214-66	69.8	0.266	0.2989	1
A1661	160-40	87.0	0.195	0.1690	4 (3 old)
A1838	219-36	70.2	0.279	0.2479	1
A1958	164-41	65.3	0.242	0.2270	2 (1 old)

All our results and the published data (see recent compilations of Schmidt (1986) and Struble and Rood (1986)) form a complete sample (N = 58) of very rich (richness class $\underline{R} \geq 2$ according to Abell) compact clusters with galactic latitude $b^{II} \geq 60^0$ and with indirect estimates of redshifts according to Leir and Van den Bergh (1977) $z_{LB} < 0.280$.

3. GENERAL PICTURE OF SPACE DISTRIBUTION OF CLUSTERS

The space distribution of the objests is shown in Fig. 1.

The connection between redshifts z and distances to objects r we have chosen in the form:

$$r = 2(1 - 1/\sqrt{1+z}) ;$$

$$R = (C/H)r \simeq 1.2\cdot10^4\cdot(1 - 1/\sqrt{1+z}) \text{ Mpc} ,$$

which corresponds to a flat model of the Universe filled by dust (deceleration parameter $q_0 = 1/2$, cosmological constant $\Lambda = 0$, Hubble constant $H_0 = 50$ km/s $\cdot$ Mpc^{-1}).

We have investigated the space distribution of objects inside the Northern Cone by different methods.

4. CLUSTER-ANALYSIS OF SPACE DISTRIBUTION

Don't confuse the sense of the word cluster in the terms "cluster - analysis" and "cluster of galaxies"! The

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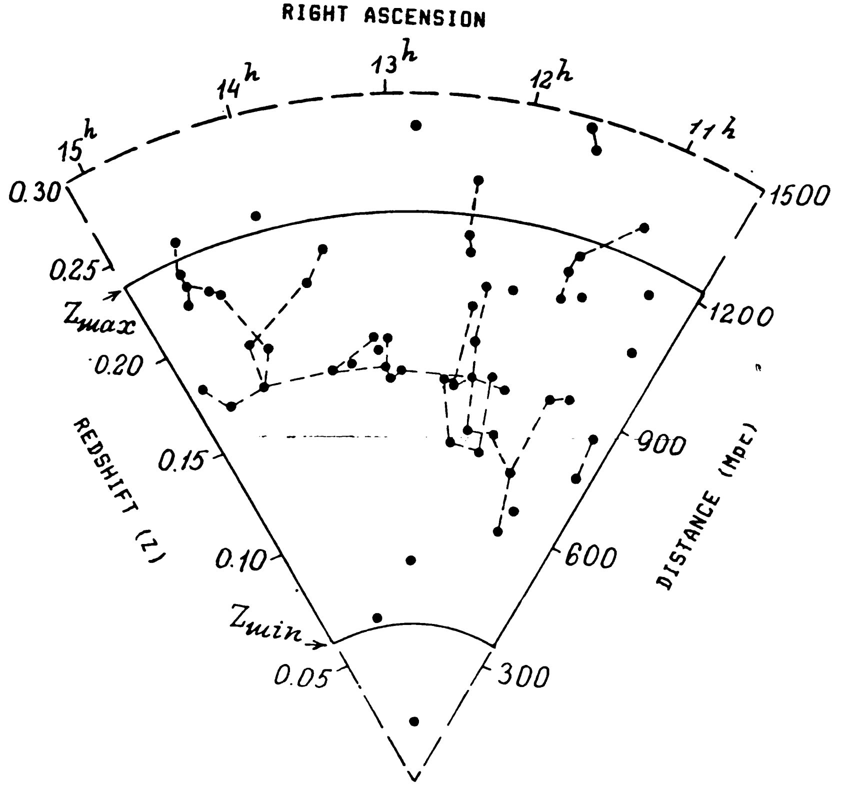

Fig. 1 The space distribution of 58 very rich compact clusters of galaxies inside the Northern Cone. The clumping parameter ℓ=180 Mpc: objects with $\Delta R \leq \ell$ are joined by dashed lines.

clustering or clumping of objects was examined by the method of cluster - analysis, i.e. by joining objects with variable clumping - parameter ℓ = K·5 Mpc, where k = 1,2,3...40. The relationship between the number m of objects joined in the most populated clump ("supercluster") and parameter ℓ in the range of ℓ=20-200 Mpc is given in Table 2.

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Table 2. The population of the greatest clump as function of the clumping parameter ℓ.

ℓ(Mpc)	20	40	60	80	100	120	140	160	180	200
m	2	3	3	5	6	6	9	12	35	39

Note, that the population of the greatest clump changes abruptly when ℓ increases from 160 to 180 Mpc only. The clumps for ℓ=180 Mpc are shown in Fig. 1 with dashed lines.

On the left side of the Fig. 1 in the region $\alpha=13^h-15^h$, z=0.07-0.16 one can see "void" with dimensions ≃ 400 Mpc. It must be added that the number density of 50 clusters of galaxies in the Cone between 0.06<z<0.24 is 1.0×10^{-7} Mpc^{-3} and the mean distances between them <R> = 216 Mpc.

5. ANALYSIS OF REDSHIFTS DISTRIBUTION

The frequency distribution of the redshifts z of 58 very rich compact clusters with z < 0.30 is shown in Fig. 2. What is the general tendency of increasing the total amount N of clusters with z?

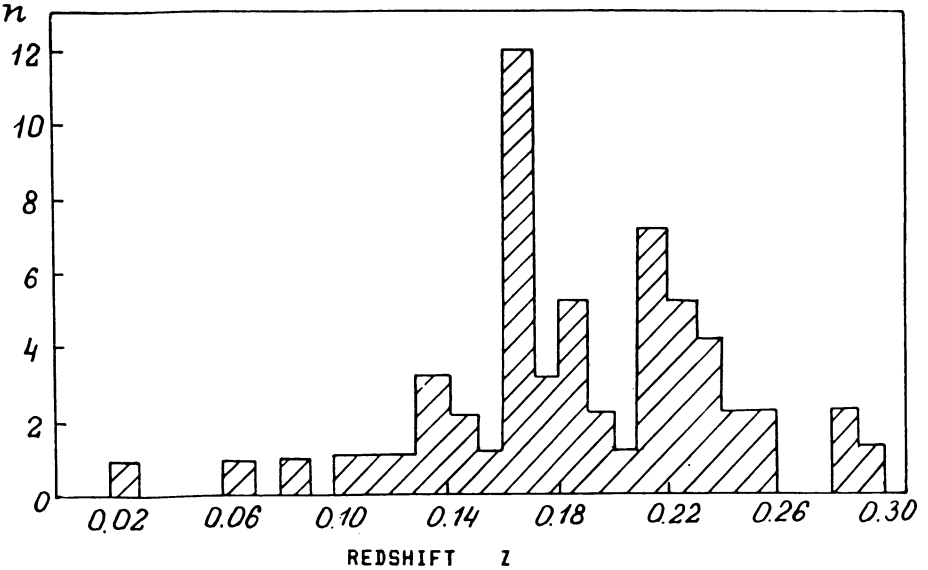

Fig. 2 Frequency distribution of 58 cluster redshifts.

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In Fig. 3 the distribution of the amount of clusters N_i is given versus the index i of consecutive spherical strata inside the cone; the volume of each stratum is $\Delta V = 26 \cdot 10^6$ Mpc^3. It is clear from the Fig. 3 that there is no regular trend of objects density N_i up to $z_{max} \approx 0.24$ (i.e.the total amount N is proportional to z^3 roughly). However, on smaller scales the z - distribution is significantly irregular. For example, 19 objects (33 % of the sample) are located between $z_1 = 0.161$ and $z_2 = 0.184$, i.e. in the approximately flat stratum of 100 Mpc thickness and of 1000 Mpc diameter. It must be note that these objects form rather two - dimensional than one - dimensional structure (see Fig. 4); in any case there are no obvious filaments in the picture.

6. THE SPATIAL TWO-POINT CORRELATION FUNCTION

The correlation function was calculated for 50 clusters that are located inside the cone in the range of $z_{min} = 0.06$ and $z_{max} = 0.24$:

$$\xi (R) = [N_0 (R) / N_p (R)] - 1 ,$$

where N_0 (R) is the observed fraction of pairs of clusters in the sample with the distances from R to R+dR, and N_p (R) is the respective fraction of pairs in a Poisson catalogue having the same geometrical boundaries as the observed sample. In our case the values N_p(R) are the mean quantities for 500 random catalogues generated by Monte Carlo method according to D. Lemer algorithm (see Sobol, 1985).

The values of ξ (R) together with the standard deviations $\sigma (\xi)$ for pure Poisson case are given in Table 3.

However, real clusters of galaxies are strongly clumped on a scale of $R \lesssim 50$ Mpc (Klypin and Kopylov,1983. Bahcall and Soneira,1983). and for this reason the calculation of confidence level for deviations ξ(R) from zero on scales of 100-1000 Mpc is not a simple task. One of the ways is the simultation of the catalogues with the artificial clustering of objects (see Kuznetsov and Lipovetsky, 1987).

As can be seen from Table 3 and Fig. 5 , the difference of correlation function ξ(R) from zero on a scale of 200-300 Mpc is quite statistically significant, and the most probable value is

$$\xi (R = 200 - 300 \text{ Mpc}) \approx 0.5 \pm 0.2 .$$

This result is in accordance with the conclusion of our previous paper (Kopylov et al., 1984b) which was based on the smaller sample of rich compact clusters of galaxies.

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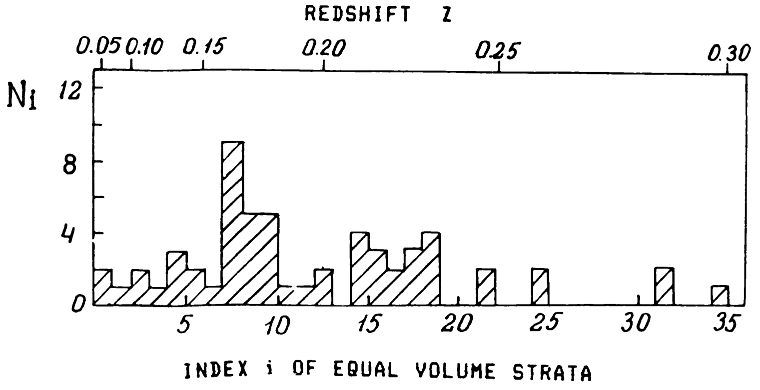

Fig. 3 Distribution of the amount of clusters N_i versus index i of consecutive spherical strata with the same volume $\Delta V=26\cdot10^6$ Mpc^3.

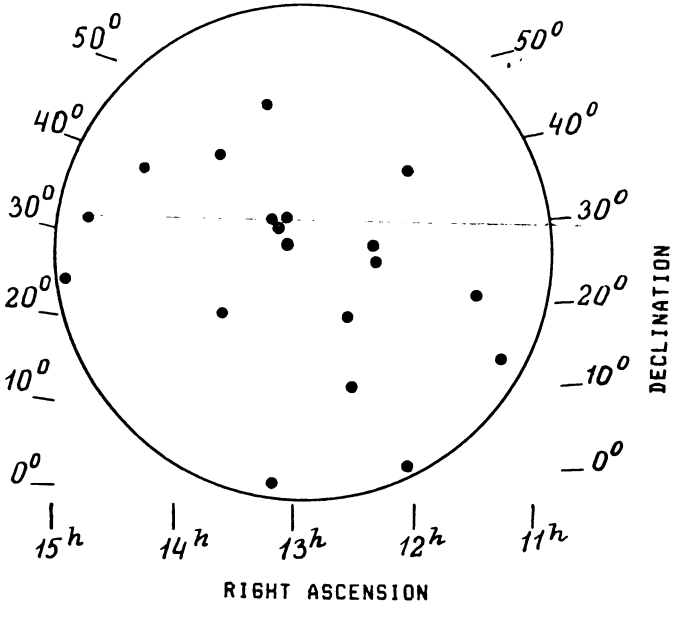

Fig. 4 Distribution of clusters in the stratum of 100 Mpc thickness and of 1000 Mpc diameter inside the Northern Cone (19 objects with 0.161<z<0.184).

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Table 3. The spatial correlation function ξ (R) for 50 clusters of galaxies (b^{II} > 60°, 0.06 < z < 0.24)

R (Mpc)	ξ(R)	σ(ξ)	R (Mpc)	ξ(R)	σ(ξ)
50	6.45	0.86	550	-0.15	0.11
100	1.22	0.36	600	-0.23	0.10
150	-0.10	0.23	650	-0.16	0.10
200	0.01	0.19	700	-0.09	0.12
250	0.49	0.17	750	-0.36	0.15
300	0.50	0.16	800	0.09	0.20
350	0.09	0.14	850	0.22	0.26
400	-0.10	0.14	900	0.44	0.31
450	-0.04	0.13	950	0.06	0.42
500	0.02	0.12	1000	-0.31	0.58

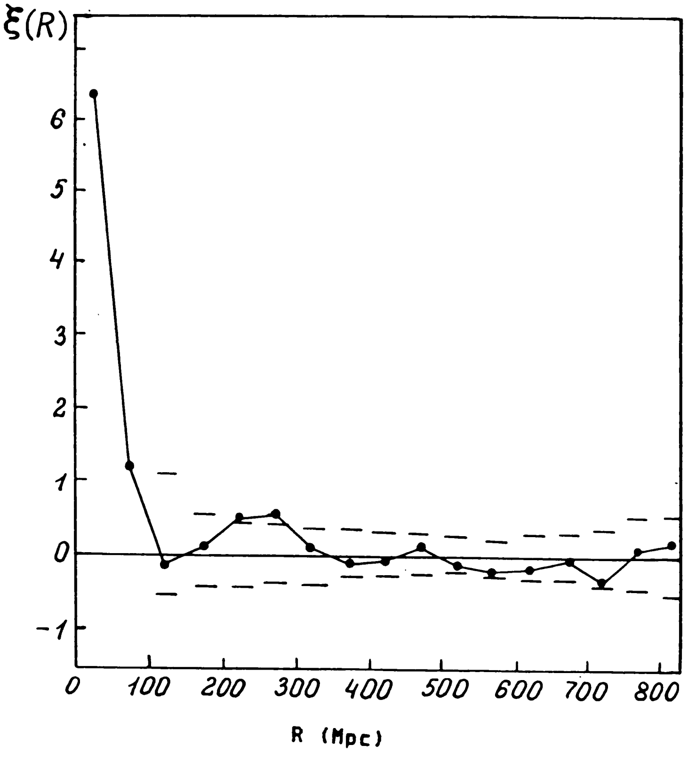

Fig. 5 Space correlation function for 50 very rich compact clusters of galaxies (b^{II}>60°, 0.06<z<0.24). The dashed lines show the 95% confidence level calculated by special method of simulation (see Kuznetsov and Lipovetsky, 1987).

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7. CONCLUSIONS

The great positive value of correlation function $\xi(R)$ on a scale of 200-300 Mpc as well as indications at inhomogeneities up to scales of 500 Mpc (see sections 3-5) contradict the current theoretical schemes describing the formation of large - scale structure in the Universe (see, for example, review of Einasto et al.,1987). These results are to be confirmed on the basis of more observational data. On the other hand, we did not find indications of non - Euclidean topology of the Universe up to scales of 200 Mpc; this result also needs confirmation.

Rich compact clusters of galaxies are good tracers of very large-scale structure in the Universe (see , for example, Einasto et al. 1980 ; Schmidt,1983 ; Batuski and Burns, 1985 ; Kalinkov et al., 1985, Bahcall and Burgett, 1986 ; Tully, 1986). More redshift measurements of these objects are of great importance. At the present moment the observations with the 6-meter Telescope of the complete sample of very rich compact clusters of galaxies with $b^{II} \geqslant 50$, $z_{LB} \leq 0.28$ are near their finish. A preliminary analysis of space distribution of these objects leads to interesting conclusions...

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