

Isolated galaxies

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Received May 9, accepted August 2, 1985

Summary. Using a catalogue of galaxies complete to $m_z \leq 14.5$, we investigate the possibility of extracting a sample of nonclustered galaxies and identifying it with a homogeneous background of objects. We conclude, in agreement with previous findings, that such a background does not exist observationally and stress the fact that the sample of isolated galaxies listed here represents galaxies whose properties do not depend on an environmental related evolution.

Key words: galaxies – cosmology

1. Introduction

The distribution of galaxies in space has been characterized in various surveys by clustering on large scale, superclusters or chains, and voids, regions of space where galaxies have not been detected (Oort, 1983; Vettolani et al., 1984). Nowadays there seems to be agreement on the fact that a uniform background of galaxies upon which clusters and groups of galaxies are superimposed as conceived by Hubble and Zwicky does not exist. From statistical analysis of galaxy catalogues, Peebles and Hauser (1974), and observationally, Chincarini (1978) and Tarenghi et al. (1979), it can be inferred that at most 5–10% of objects in a catalogue of galaxies complete to some limiting magnitude are part of such a background.

The galaxies which form a hypothetically homogeneous background superimposed to the clustering should, according to the observational findings, be characterized by very low density distribution so that they could also define a system of “isolated galaxies” and not be influenced by the clustering phenomena. In other words, their clustering time, that is the time to cluster among themselves or the time it would take to join a larger agglomerate (since they always feel density perturbations) is larger than the Hubble time.

In addition to the cosmological significance of so defined “isolated” galaxies, such objects are operationally interesting, if detected, since they should reflect properties which are characteristics only of their formation and clustering independent evolution. In other words these objects are not affected during their evolution by the interaction with nearby objects.

How to detect such galaxies or how to define the sample is a real problem because the characteristics of the sample will, in fact, reflect the selection criteria.

A perused sample, for instance, is the catalogue of isolated galaxies compiled by Karachentscheva (1973). In this listing a galaxy is selected as isolated if the nearest companion of diameter d_1 is at a distance $r > 20d_1$. The companion diameter d_1 is related to the diameter d of the sample galaxy by the relation $1/4d < d_1 < 4d$. The selection criterium, in other words, takes into account in a semiempirical way the distance of the companion even if the sample is selected from the projected distribution of the Zwicky galaxies on the celestial sphere. While this listing has been useful for various research purposes, it should be used with caution. It can be shown, see Fig. 1, that in the Karachentscheva sample, galaxies are highly correlated indicating clustering (Chincarini, 1982; Haynes and Giovanelli, 1983).

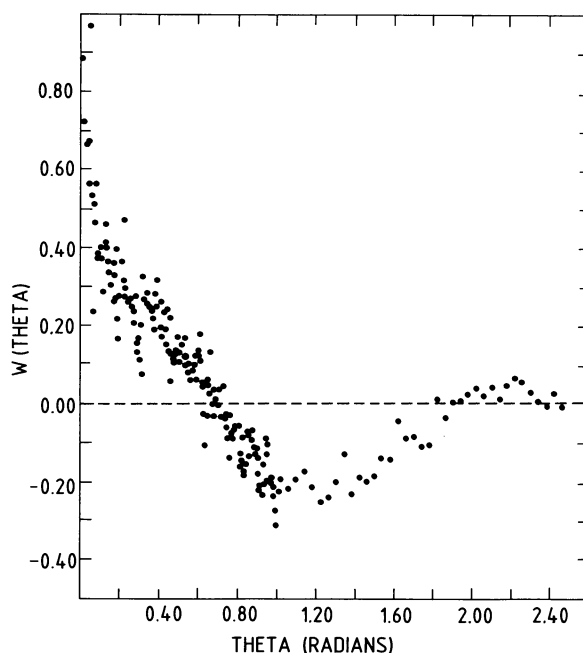


Fig. 1. Autocorrelation function $w(\theta)$ for isolated galaxies from the catalogue of Karachentscheva and in the declination range $0 < \delta < 38^\circ$

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The sample generated by Turner and Gott (1975, 1976) as a by-product of their selection of groups has also been shown to be spurious by various authors, in particular by Huchra and Thuan (1977) who completed the redshift survey for that subsample.

In this paper we compile a new list of isolated galaxies with the purpose of a) determining whether or not a true isolated sample can be selected, b) estimating if it may define a background component of galaxies and c) determining the properties of the sample of isolated galaxies selected according to the criteria outlined in Sect. 2.

In Sect. 3, we discuss the statistical properties of the sample we isolated and conclude in Sect. 4.

2. Characteristics of the sample

2.1. The sample selection and the catalogue

The sample used to generate a subsample of isolated galaxies consists of all UGC galaxies with $m_z \leq 14.5$ at a declination $\delta > 0^\circ$ and galactic latitude $|b| > 30^\circ$, constraint A . A further cut has been applied to the sample galaxies, that is after a sample has been selected according to the above cuts and the procedure described below, demanding that an "isolated galaxy" should be at a distance from the equator (boundary of our source catalogue) larger than the size of the sweeping vector R , we will refer to this as constraint B . This is to avoid calling "isolated" a galaxy with a possible companion at $\delta < 0^\circ$.

The redshift-distances are known for all the sample galaxies and have been taken from the literature, Palumbo et al. (1983) and CFA Survey, Huchra et al. (1983). A small number of redshifts has been taken from unpublished observations by Focardi et al. (1984) and by Giovanelli et al. (1983). The whole sample of 2584 galaxies has been analyzed using a percolation algorithm with a percolation sweeping vector R defined by the relations:

$$R = R_0 S_v$$

$$S_v = [\Gamma(\alpha + 1, \mu_0) / \Gamma(\alpha + 1, \mu)]^{1/3} \quad (1)$$

$$\mu = \text{dex} [0.4(M^* + 5 \log(V/H) + 25 - m_i)]$$

to account for the fact that the sample is magnitude limited. By using this equation we keep constant the probability of finding a galaxy in a given volume regardless of distance (see Vettolani et al., 1985 and references therein). Here R_0 is the length of the sweeping vector at the distance (about 55 Mpc) for which $\mu = \mu_0$. After selecting chain and clusters, we are left with a listing, for each R_0 , of single (non-connected) galaxies.

If a uniform background exists, isolated galaxies should neither be part of other agglomerations nor should they show clustering characteristics among themselves. Using, therefore, a nearest-neighbor algorithm at a given characteristic value of the sweeping vector we should observe a transition between samples showing clustering characteristics and an unclustered sample. This transition could, in principle, be detected through the two point correlation function. However, in the process of selecting the samples at large percolation radii, the number of nonconnected galaxies decreases considerably and the statistics become rather uncertain. Therefore, the data being too noisy, we cannot determine accurately the coefficients of the two point correlation function.

We preferred therefore to define a galaxy as a good candidate for a sample of isolated galaxies if the object has no companion closer than $R_0 = 6$ Mpc in a sample complete to a 14.5 limiting

Table 1. Sample statistics for isolated galaxies

R_0 (Mpc)	N	$N(A)$	$N(A+B)$
4	375	213	211
5	221	120	110
6	119	64	43

apparent magnitude. Once the sample has been selected we analyze its characteristics and further check for possible companions. The preference of a 6 Mpc radius has been dictated 1, empirically from the analysis of the samples we obtained using a range of sweeping vectors, and 2, because to a galaxy with a peculiar velocity of 100 km s^{-1} it would take 6 h^{-1} Hubble times ($H_0 = 100 \text{ h}$) to cover such a distance.

Samples were also selected at $R_0 = 4$ and $R_0 = 5$, however we will not publish the catalogue. The interested reader can request them directly from the authors.

The number of nonconnected objects (N) as a function of the sweeping parameter (R_0) is listed in Table 1 where $N(A)$ and $N(A+B)$ are the total numbers of objects after introducing constraint A and constraints $A+B$.

In Table 2 we list the catalogue of objects isolated using a sweeping parameter $R_0 = 6$ Mpc. Here the listed velocities have been corrected for the motion of the local group using the standard relation $\Delta V = 300 \sin i / \cos b$. Once the catalogue had been derived we searched on the POSS prints, over 1 percolation radius circle centered on each catalogue galaxy, to determine the quality of the sample, the effects of the cut in apparent limiting magnitude and catalogue incompleteness and to evaluate the characteristics of the galaxies we isolated. As the catalogue of isolated objects is selected based on a magnitude limited sample it could happen that an object we call isolated has a companion fainter than the limiting magnitude of the sample. We also searched for fainter galaxies of known redshift within one percolation radius, using the listing of Palumbo et al. (1983).

We find that 15 objects (see the comments below) have galaxies within 1 percolation radius. Obviously this number is only a lower limit.

2.2. Comments to the individual catalogue ($R_0 = 6$ Mpc) galaxies

If a galaxy is not listed below it means that no other object has been found on the POSS within a percolation radius (hereafter: p.r.) from the unlisted galaxy and/or that no particular remark is needed.

1. UGC 80. A small galaxy is present at a separation of $3'$.
2. UGC 106. Two small objects at a separation of $1'$ and $5'$.
4. UGC 463. A binary system, KDG 14 $\equiv$ U 312 + U 418, is located at a distance of 1 p.r.
5. UGC 1554. Small object at a distance of $4'$.
6. UGC 4229. The galaxy is a Seyfert type, Afanasiev et al. (1980). No other galaxy is visible in the area searched.
7. UGC 4273. Small object at a separation of $3'$.
8. UGC 4503. The Uppsala catalogue indicates that the galaxy forms a pair with UGC 4484, however the difference in redshifts is of 1450 km s^{-1} .
9. UGC 4627. Small object at $3'$ separation. MRK 96, $m = 15.5$, is at a distance of 1 p.r.

Table 2. The catalogue of isolated galaxies for percolation radius of 6 Mpc. All galaxies marked with an asterisk have a faint companion

N	UGC	Type	Mag.	V_0	Notes
1	80	NGC 16	SB0	12.5	3341
2	106	NGC 36	SAB(rs)b	14.5	6271
3	221	Pec	14.5	4292	
4	463	NGC 234	SAB(rs)c	13.5	4620
5	1554	NGC 803	Sc	13.5	2214
6	4229	Mrk 622	...	14.4	7067
7	4273	NGC 2543	SB(s)b	12.7	2488
8	4503	NGC 2619	Sb/c	13.6	3406
9	4627	NGC 2676	S0	14.3	6041
10	4718	NGC 2719	Pec	13.7	3082
11	4757	NGC 2744	SA(s)...pec	13.7	3382 *
12	4880	IC 530	Sa-b	14.3	4750
13	5103	NGC 2916	S...	12.3	3449
14	5119	Pec	14.5	5977	*
15	5152	NGC 2908	S...	14.2	600 *
16	5342	MRK 712	S...	14.3	4403 *
17	5345		S...	14.4	3772
18	5577	Pec	14.3	14.3	2799
19	5749	Compact	14.2	4357	
20	5953	Mrk 155	Pec	13.2	1828
21	6255	S...	13.6	5400	*
22	6376	NGC 3646	PecSA(r)bc	11.5	4198 *
23	6542	NGC 3725	SB.c	13.6	4621 *
24	6722	NGC 3863	Sb-c	14.0	4450
25	8264	7ZW 501	Pec	14.5	4893
26	8400	(SB)?	14.5	3478	*
27	8867	NGC 5452	SAB(s)d	14.2	2272
28	9476		SAB(rs)c	13.9	3388 *
29	9794		Sbc-Irr	14.3	6531 *
30	9923	NGC 5966	E	13.9	5684 (*?)
31	9948	NGC 5981	Sb-c	14.2	1921
32	10033	NGC 5996/94	SB + Comp.	13.2	3162 *
33	10161	S...	14.1	3507	*
34	10200	Mrk 1104	...	13.6	2163 *
35	10205	Sa	14.4	6758	
36	10356	NGC 6131	Sc/SBc	14.2	5241
37	10359	NGC 6140	SBc	12.6	1147 *
38	10439	NGC 6181	SAB(rs)c	12.7	2298
39	10747	NGC 6308	SAB(r)c	14.4	8880 *
40	10752	NGC 6314	SAa:	14.3	6929
41	10770	ARP 32A	Double Sys.	14.3	1420
42	10790	NGC 6339	SBc	13.7	2336
43	12045	NGC 7290	SABc	13.8	3142

10. UGC 4718. The galaxy is the brightest member of the system Arp 202 (Arp, 1966) and the companion galaxy, NGC 2719A, is at the same redshift, Page (1970). Another possible companion, UGC 4726 with $m = 14.8$, has no redshift. No other object is visible within 1.7 p.r. and the system is isolated.

11. UGC 4757. At a distance of 0.8 p.r. we have Mrk 1221. The galaxy is not part of the NGC 2749 group as suggested in the Uppsala catalogue.

12. UGC 4880. A small object is present at a separation of 1'.4.

13. UGC 5103. A small object is present at a 2' separation, a fainter galaxy, $m = 15.6$, is at a distance of 5'.

14. UGC 5119. The double system KDG 208 is located at 0.2 p.r., an anonymous object at 0.7 p.r., Dibai et al. 1976, NGC 6263 ($m = 14.6$), KDG 193 and an anonymous object (Barbon et al., 1979) at 0.9 p.r.

15. UGC 5152. The galaxy is a dwarf with an absolute magnitude of $M \simeq -15$. Together with the galaxies DDO 87 and DDO 112 at 0.7 p.r. and with a fourth galaxy UGC 8959 at 0.9 p.r. the listed isolated is actually a member of a group of dwarf galaxies. NGC 2908 has the highest surface brightness. The group is remarkable on its own account. We also notice that were it not for this group we would have detected a void of about 200 Mpc³. Only a coincidence? At twice their distance these galaxies would have been undetectable.

16. UGC 5342. The galaxy is peculiar with a double nucleus, Petrosyan et al. (1980).

18. UGC 5577. Disrupted spiral pattern. No companion.

21. UGC 5749. Small object at a separation of 3'. UGC 6257 ($m = 14.7$) is located at 0.2 p.r.

22. UGC 6376. UGC 6386 $\equiv$ N3649 ($m = 14.7$) is at a separation of 0.4 p.r.

23. UGC 6542 (Mrk 179). Mrk 145 is located at a separation of 0.7 p.r. According to the UGC catalogue it forms a pair with UGC 6730; however, the two objects differ in redshift by 1250 km s⁻¹.

24. UGC 6722. Optical pair with UGC 6730. The difference in redshift is 1700 km s⁻¹.

25. UGC 8264. Blue post-eruptive galaxy with a companion ($m = 18$) attached. Large plume at PA = 90°.

26. UGC 8400. 1 galaxy at 0.7 p.r. (Mrk 267).

28. UGC 9746. Companion ($m = 14.8$) at 3'. Binary system KDG 432.

29. UGC 9794. Two objects within 1 p.r., KDG 452 A and B.

30. UGC 9923. NGC 6013, with $v_0 = 4664$ km s⁻¹, is at a separation of 0.5 p.r. and a small object at 3'. According to the UGC catalogue it may be associated to IC 4563 ($m = 15.1$); however, no redshift is available. This is the only elliptical galaxy in the sample.

31. UGC 9948. The UGC catalogue assigns this galaxy to the group NGC 5985. The redshift difference is, however, about 1000 km s⁻¹.

32. UGC 10033. Also Arp 72. It belongs to the class of "spiral galaxies with high surface brightness with companions on arms ..." (Arp, 1966). The two galaxies have the same redshift. The nearest object is at 1.5 p.r.

33. UGC 10161. The double system NGC 5954/5999 is at 0.9 p.r.

34. UGC 10200. The galaxy is a member of the double system KDG 482. KDG 482B ($m = 15.0$) is at a separation of 1'8 and at the same redshift. An anonymous galaxy is located at 0.8 p.r.

36. UGC 10356. Small companion at 2'. The cD NGC 6166 (A2199 cluster) is located at 0.9 p.r.

37. UGC 10376 ($m = 16.5$) and an anonymous object are located within 1 p.r.

38. NGC 6035 is at 1 p.r.

39. UGC 10747. 5 objects have been detected within 1 p.r.: an anonymous galaxy at 0.1 p.r., the system KDG 507A and 507B (UGC 10787, $m = 14.6$) at 0.5 p.r., NGC 6265 ($m = 15.4$) at 0.7 p.r. and Mrk 1108 at 0.9 p.r. It is not a member of the group NGC 6314 as suggested in the UGC catalogue since it differs in redshift by about 2000 km s⁻¹.

40. UGC 10752. Pair with NGC 6315 ($v = 6672$ km s⁻¹) at 0.1 p.r. The redshift difference with UGC 10747 suggests they are not forming a group as suggested in the UGC catalogue.

41. UGC 10770. This object has been classified by Arp (1966) as: "integral sign spiral galaxy" with a companion. The companion is at the same redshift. A dwarf galaxy, DDO 206, is at 0.5 p.r.

42. UGC 10790. Small object at 3'.

43. UGC 12045. According to the UGC catalogue, the galaxy UGC 12044 may be a companion, however the redshift of this object is unknown.

3. Statistical characteristics of the sample

We now consider the sample characteristics using the whole set of galaxies extracted from the magnitude limited catalogue.

According to a $V/V_{\max}$ test

$$\langle V/V_{\max} \rangle = \frac{1}{N} \sum_{i=1}^N 10^{0.6(m_i - m)} \quad (2)$$

(the associated error is $1/\sqrt{12N}$), the sample of galaxies we isolated can be considered uniform and complete for $m \leq 14.5$, Fig. 2.

The distribution in apparent magnitude follows accurately the relation expected for a uniform distribution, $N(\leq m) = N_0 10^{0.6m}$. This relation, with normalization at $m = 14.5$, is shown by the continuous line in Fig. 3. The dots and crosses refer to the samples $R_0 = 6$ and $R_0 = 4$ Mpc.

The distribution in redshifts for the sample galaxies is given in Fig. 4 and compared with the one, continuous line, expected from an homogeneous distribution

$$N(V_i, V_j) = \int_{V_i}^{V_j} \chi^2 N(<M) d\chi \int_0^\infty N(<M) d\chi. \quad (3)$$

The agreement is satisfactory and apparent differences are not statistically significant. Evidence of clustering is not found by dividing the sample over various regions of the sky, however we face here difficulties due to poor statistics. The same result is illustrated, always assuming that the luminosity function of isolated galaxies does not differ from the luminosity function of great clusters, by the distribution in magnitudes. The observed distribution, sample $R_0 = 6$ Mpc, is again in good agreement with the distribution of absolute magnitudes expected for a homogeneous magnitude limited sample, using a Schechter luminosity function

$$N(M) = -\frac{2I_n 10}{5\Gamma\left(\frac{5}{2} - \alpha\right)} \text{dex} \left[\left(\frac{2}{5} \alpha - 1 \right) (M - M^*) \right] \cdot \exp[-\text{dex}(-0.4(M - M^*))] \quad (4)$$

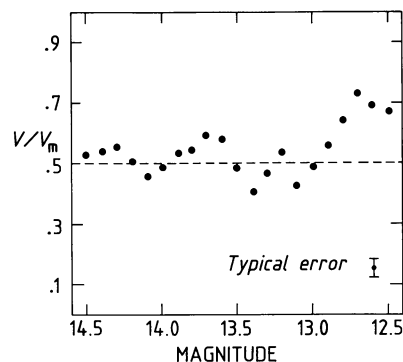


Fig. 2. $V/V_{\max}$ versus apparent magnitude for the sample of galaxies listed in Table 2. Filled circles refer to $R_0 = 6$ Mpc

(line in Fig. 5). Using this test we can specify in a different way the criterion of isolation, that is: *we do not expect to find, for the galaxies listed in Table 2, a companion with $M \leq -19.1$ within a 6 Mpc distance.*

The above results are all in agreement with a random and homogeneous distribution of isolated galaxies, however, they do not contradict the possibility that such objects may belong to the very low density outskirts of superclusters of galaxies as characterized by the two point angular correlation function. If we use the

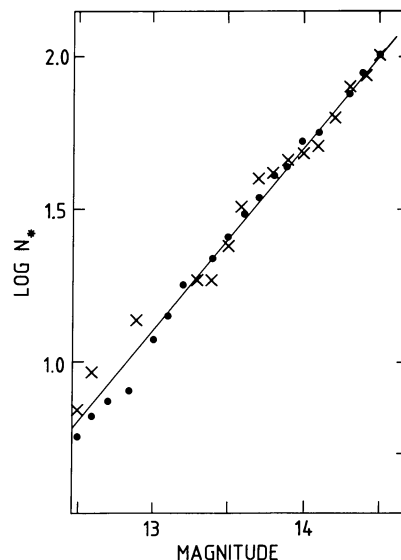


Fig. 3. Distribution of apparent magnitudes for the sample isolated using the percolation algorithm. In the ordinates we have $\log N_* = \log(N_{\text{bin}}/N_{\text{tot}} * 100)$, where N_{bin} is the number of objects per bin, versus magnitudes. The continuous line is the relation $N(\leq m) = N_0 10^{0.6m}$ normalized at $m = 14.5$. Dots refer to $R_0 = 6$ Mpc and crosses to $R_0 = 4$ Mpc

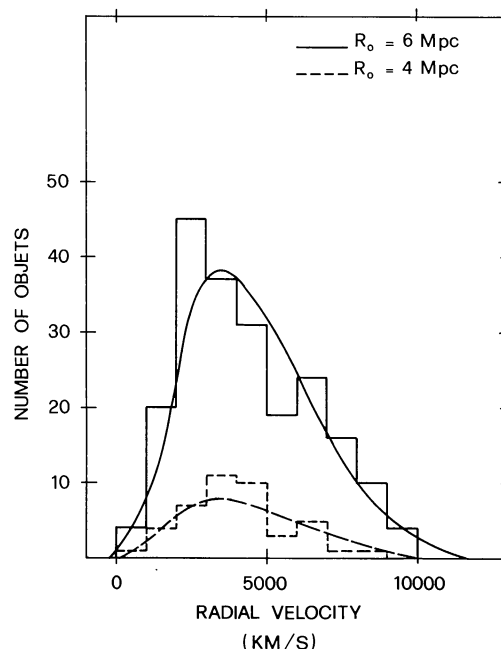


Fig. 4. Distribution in redshifts for $R_0 = 4$ Mpc and $R_0 = 6$ Mpc. The continuous and hatched lines are the expected distributions for a spatially homogeneous sample

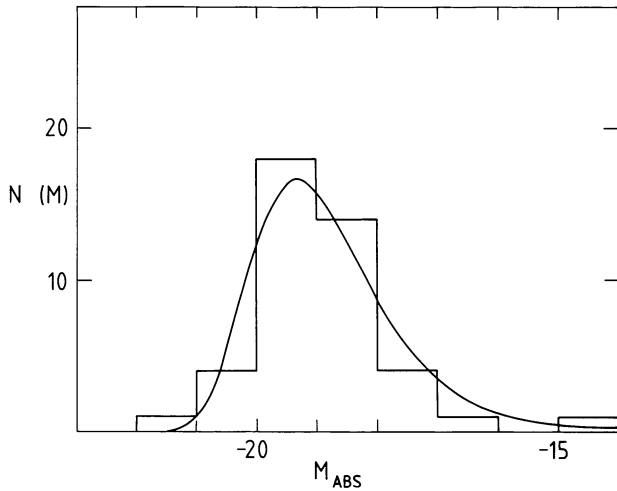


Fig. 5. Distribution in absolute magnitudes M_{abs} for the sample $R_0 = 6$ Mpc listed in Table 2. The continuous line is what is expected from a spatially homogeneous sample obeying a Schechter luminosity function

galaxy-galaxy correlation function in the form derived by Peebles and collaborators (see e.g. Peebles, 1980)

$$\xi(R) = (R_0/R)^\delta \quad (5)$$

with $R_0 = 4$ Mpc and $\delta = 1.77$, then we can derive the equation to compute the probability to find the nearest neighbour at a distance d from a given galaxy, which is given by

$$\delta P = 4\pi r^2 \langle n \rangle dR e^{-\langle n \rangle \frac{4}{3}\pi R^3} f \quad (6)$$

Peebles, 1980, Eq. (39.17)) where $\langle n \rangle$ is the mean density of the catalogue of galaxies and f is a correction function to a Poisson statistics. Such function includes the autocorrelation functions of all orders. To estimate in first approximation the integral of Eq. (6) we have considered in f only the correlation function of the 1st and 2nd order and find that the probability that the first neighbour is at a distance larger than R is given by:

$$Q(R) = 1 - P(R) = e^{-N} \left\{ 1 - \frac{3}{3-\delta} \left(\frac{N_0}{N} \right)^{\delta/3} N + \frac{9 \cdot 2^{2-\delta}}{(3-\delta)(4-\delta)(6-\delta)} (N_0/N)^{\delta/3} N^2 \right\},$$

where N is the number of objects in a volume V and N_0 the number of objects within the volume $4/3\pi R_0^3$. For the catalogue used $\log \langle \text{mean density} \rangle = -2.41$ gal/Mpc³ and $N_0 = 1.043$. The function $Q(R)$ is acceptable, in the case we consider, only for $R \geq 5.5$ Mpc. In fact due to the large contribution of the power law to the integral at small R , the function becomes negative and unphysical. A way around this could be to modify the power law at very small separations.

In this way we determine that about 7% of the galaxies of a catalogue should have their first neighbour at a distance larger than 6 Mpc. At this separation, the correlation function remains well determined and above the noise, $\xi(R) = 2.05$.

In the $R_0 = 6$ Mpc sample the number of galaxies with this separation ranges between 2% (43 objects) and 4% (119 objects without any constraint) in rather good agreement with the above estimate.

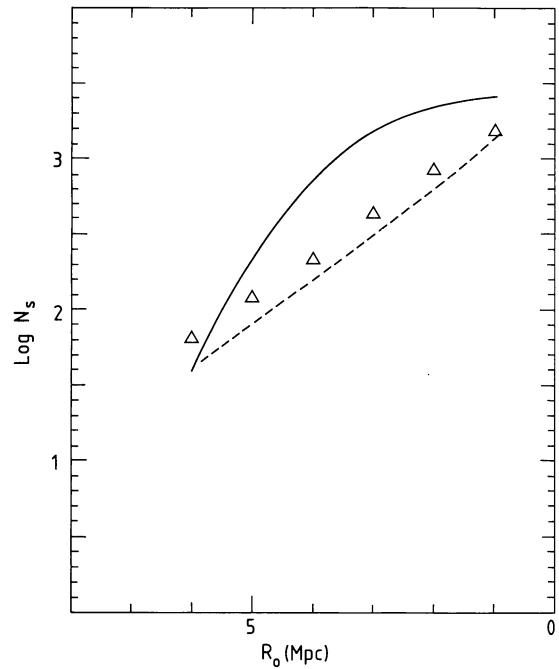


Fig. 6. Number of isolated galaxies against percolation radius. Triangles represent the real sample, crosses the hierarchical simulation, and the dashed line what is expected in a homogeneous universe

We have also applied the percolation algorithm to the results of hierarchical simulations obtained according to the “final model” of Soneira and Peebles (1978) (see Vettolani et al., 1985 for a comprehensive description).

In Fig. 6 are plotted the numbers of isolated galaxies detected as a function of the percolation radius both in the observed sample and in one simulation. Apart from a normalization constant, both samples show the same behaviour, which differs remarkably from what is expected in a homogeneous universe (continuous line).

We conclude that the selected sample and related statistical properties are also consistent with the hierarchical picture of the distribution of galaxies.

4. Discussion and conclusion

This study emphasizes that it makes little sense to discuss a system of isolated galaxies in an absolute sense, that is, as objects forming a background of galaxies completely unrelated to the clustering properties of other galaxies. The conclusion is not completely new and partly contained in previous autocorrelation studies and in the upper limit estimates derived from various redshift surveys.

An unclustered background seems to be observationally, and operationally, meaningless. Clustering dominates in all regions of space (for small z at least).

It is important, however, that we isolated a sample of objects whose environment density is $\leq 4.63 \cdot 10^{-3}$ gal/Mpc³. Such galaxies cannot have interacted with other objects in a Hubble time and had some probability of interaction with other objects only at the time of formation. Without the 15 objects of Table 2 which turned out to be non-isolated we are left with 1 elliptical (quite probably isolated), 2 lenticular and 25 spirals, many of which are peculiar galaxies. For the reasons specified above the list of

“isolated galaxies” is also a list of isolated evolution and phenomena which occur without the influence of the “visible” environment. The fact that the early morphological types are represented in our sample (even if in small numbers) is very strong evidence against environment-related formation of early type galaxies. This adds to the various arguments in the same direction by Sandage (1983), Dressler (1984), Chincarini (1984), Ostriker (1980), and de Souza et al. (1985).

It is also remarkable that in the sample we have a considerable number of peculiar objects, one Seyfert galaxy and various Markarian galaxies. It seems hard to avoid the conclusion that these phenomena are unrelated to the environment, unless explained by the presence of dwarf companions, and are rather due to intrinsic characteristics which developed at the time of formation, a point stressed also by Fairall and Winkler (1984) for Seyfert galaxies. On the other hand whatever determines the difference in morphological types, and probably in other parameters, must be influenced by the environment at the time of formation since it is a well established fact that 1) the percentage of types is a function of the density environment, Dressler (1980), Melnick and Sargent (1977), Chincarini (1984) and 2) early types are more strongly correlated than later types, Davis and Geller (1976).

References

- Afanasiev, V.L., Lipovetsky, V.A., Markarian, B.E., Stepanian, J.A.: 1980, *Astrophys. J.* **16**, 119
- Arp, H.: 1966, *Atlas of Peculiar Galaxies*, Caltech, Pasadena
- Barbon, R., Capaccioli, M., Tifft, W.G.: 1979, *Astron. Astrophys. Suppl.* **36**, 129
- Chincarini, G.: 1978, *Nature* **272**, 515
- Chincarini, G.: 1982, III Escola de Cosmologia e Gravitação – CBPF, Rio de Janeiro (and unpublished autocorrelation, Fig. 1)
- Chincarini, G.: 1984, *Astronomy with Schmidt-Type Telescopes*, ed. M. Capaccioli, p. 511
- Davis, M., Geller, P.: 1976, *Astrophys. J.* **208**, 13
- Dibai, E.A., Doroshenko, V.T., Terebizh, V.Yu.: 1976, *Astrophysics* **12**, 459
- Dressler, A.: 1980, *Astrophys. J.* **236**, 351
- Dressler, A.: 1984, *Ann. Rev. Astron. Astrophys.* **22**, 185
- Fairall, A.P., Winkler, H.: 1984, *Clusters and Groups of Galaxies*, ed. Mardirossian, F. et al., p. 23
- Focardi, P., Marano, B., Vettolani, G.: 1984 (in preparation)
- Giovanelli, R., Haynes, M.P., Chincarini, G.: 1985 (unpublished)
- Haynes, M.P., Giovanelli, R.: 1983, *Astrophys. J.* **275**, 472
- Huchra, J., Thuan, T.X.: 1977, *Astrophys. J.* **216**, 694
- Huchra, J., Davis, M., Lathan, D., Tonry, J.: 1983, *Astrophys. J. Suppl.* **52**, 39
- Karachentscheva, V.E.: 1983, *Soobshch. Spets. Astrofiz. Obs.* No. 8
- Melnick, J., Sargent, W.L.W.: 1977, *Astrophys. J.* **215**, 401
- Oort, J.H.: *Ann. Rev. Astron. Astrophys.* **21**, 373
- Ostriker, J.P.: 1980, *Comments on Astrophys.* **8**, 177
- Page, T.: 1970, *Astrophys. J.* **72**, 821
- Palumbo, G.G.C., Tanzella-Nitti, G., Vettolani, G.: 1983, *Catalogue of Radial Velocities of Galaxies*, Gordon & Breach, New York
- Peebles, P.J.E., Hauser, M.G.: 1974, *Astrophys. J. Suppl.* **28**, 19
- Peebles, P.J.E.: 1980, *The Large Scale Structure of the Universe*, Princeton University Press
- Petrosyan, A.R., Saakyan, K.A., Khachikyan, E.E.: 1980, *Soviet Astron. Letters* **6**, 144
- Sandage, A.: 1983, in *Internal Kinematics and Dynamics of Galaxies*, ed. E. Athanassoula, Reidel, Dordrecht, p. 327
- de Souza, R., Vettolani, G., Chincarini, G.: 1985, *Astron. Astrophys.* (in press) (ESO preprint 346)
- Soneira, R.M., Peebles, P.J.E.: 1978, *Astron. J.* **83**, 845
- Tarenghi, M., Tifft, W.G., Chincarini, G., Rood, H.J., Thompson, L.A.: 1979, *Astrophys. J.* **234**, 793
- Turner, E.L., Gott III, R.J.: 1975, *Astrophys. J.* **197**, 289
- Turner, E.L., Gott III, R.J.: 1976, *Astrophys. J. Suppl.* **32**, 409
- Vettolani, G., de Souza, R.E., Marano, B., Chincarini, G.: 1986, *Astron. Astrophys.* (in press) (ESO preprint 352)