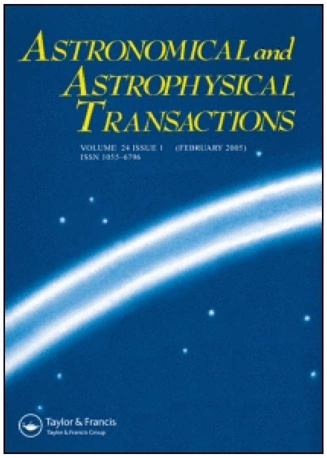

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SPATIAL DISTRIBUTION OF BLUE COMPACT GALAXIES AND GALAXY FORMATION MODELS

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(14 December 1992)

A large new sample of Blue Compact Galaxies (BCGs) consisting of 260 objects from the Second Byurakan Survey (SBS) in the zone $7^h40^m < \alpha < 17^h20^m$, $49° < \delta < 61°$ has been recently completed by Erastova *et al.* (1992). We report here preliminary results of the study of their spatial distribution and discuss them in the context of current models of galaxy formation. BCGs as a sub-group of galaxies in general trace the LSS delineated by normal galaxies. However, BCGs are distributed more uniformly and tend to populate regions of lower density than normal galaxies. 18 BCGs are found in the near voids $v < 10{,}000$ km/s. New 2 ELGs are found to populate the Bootes void in addition to 21 known ELGs. The same analysis of the spatial distribution of BCGs on the Southern sky was undertaken and similar results are obtained.

KEY WORDS blue compact galaxies, spatial distribution, voids, galaxies, origin models.

1. INTRODUCTION

In the last decade or so it has become well enough realized that Dark Matter (DM) is the most important dynamical component in our Universe and that its nonlinear evolution should determine the origin of observable large-scale structure (LSS) of the Universe and formation of galaxies in their connection (see review by Rees, 1988).

Among different types of DM, proposed for understanding of origin of observable structures in the Universe, one of the most attractive is the Cold Dark Matter (CDM) (e.g. scenario by Davis *et al.*, 1985). Some interesting predictions of this scenario seem to be correct from comparison of model simulations and observational data (the origin and segregation of Hubble types—Evrard *et al.*, 1990; the topology of LSS—Park and Gott, 1991).

One of the interesting predictions of this scenario is the biased galaxy formation and the origin of dwarf galaxies (Dekel and Silk, 1986). Dwarfs are predicted to be distributed in space more uniformly than normal galaxies and to populate as well volumes which are devoid of normal ones. This prediction challanged the series of studies aimed to check its reality (Thuan *et al.*, 1991; Eder *et al.*, 1989). The results of these authors which are based on samples of Low Surface Brightness Dwarfs (LSBD) did not evidence for the correctness of the model. On the other hand, the study by Salzer (1987) of samples of dwarf HII galaxies (similar to BCDGs) resulted in the distribution similar, at least partly, to that predicted by the CDM scenario. Salzer's study was limited by a too small region of the sky and the size of the dwarf galaxy sample.

The completion of a spectroscopic survey of galaxies from the SBS with the 6 meter telescope resulted in a large, well-sampled group of BCDGs. Our study aims to consider the spatial distribution of the BCDG sample and to compare it with that of normal galaxies and LSBDs.

2. THE BLUE COMPACT GALAXIES SAMPLE

Our sample of BCG candidates was constructed from the Second Byurakan Survey (SBS) (Stepanian *et al.*, 1987). Emission line galaxies with rather strong narrow [OIII] 5007 A line (mostly with $EW \geq 50$ A) were selected.

We did not use a limit on M_B because our study showed that there are some interesting objects of the same nature as the typical BCG but with $M_B < -18.0$ ($H = 75$). More exactly, we should call them BCGs with intensive star formation. The area of sky studied is about 1000 sq.deg., in the northern hemisphere at $\alpha = 7^h45^m - 17^h20^m$, $\delta = 49° - 61°$. The follow-up spectroscopy was carried out with the Soviet 6-m telescope of all selected galaxies and the final sample in the aforementioned zone consists of 260 galaxies as faint as $m_b = 18.5 \div 19$. The general statistical data on SBS BCGs sample will be presented elsewhere.

To test independently some of our results on the SBS BCG sample, we have also undertaken a similar analysis for HII-galaxies from Terlevich *et al.* catalog (1991). We limited ourselves by the area $\alpha = 20^h - 05^h$, $\delta = -37.5°$ to $-42.5°$, $|bII| > 28°$ and $v < 8000$ km/s. For a control sample of normal galaxies, we took the SRC catalog by Fairall and Jones (1991).

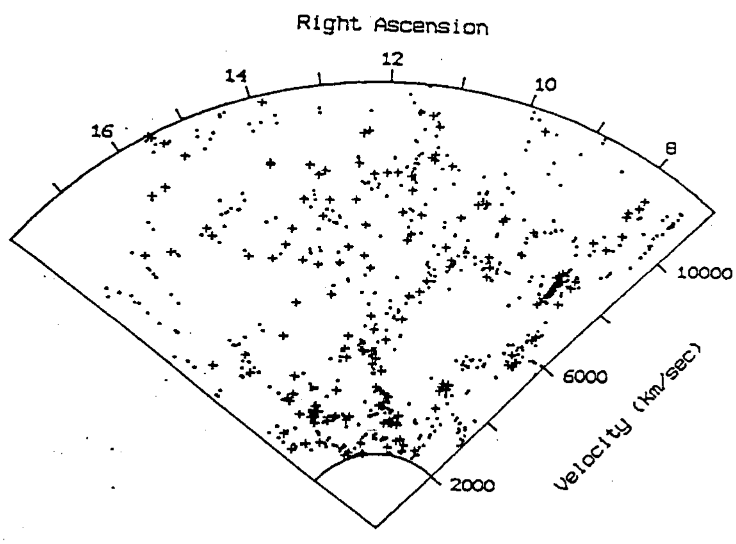

Figure 1 The wedge diagram of spatial distribution in SBS region, normal galaxies—dots, BCGs—crosses.

In order to compare the spatial distribution of our BCG sample with normal galaxies we took as a control sample a subsample from ZCAT by J. Huchra limited by the same sky area. The later sample in the region of $cz > 2000$ km/s consists mostly of normal and bright galaxies. We also added to this sample about ninety non-dwarf emission galaxies from the SBS for which we had redshift measurements. To avoid certain selection effects we excluded from our analysis the region of the Local Supercluster ($cz < 2000$ km/s). The final control sample in the range $2000 < cz < 10{,}000$ km/s consists of 279 galaxies. Their positions on the wedge diagrams are shown on Figure 1 (points) along with positions of BCDGs (crosses).

3. ANALYSIS OF THE SPATIAL DISTRIBUTION

The main question we considered was the relative spatial distribution of our BCGs and of normal galaxies. That is why we choose for analysis the parameter D_{NN}, the distance to the nearest neighbour (normal galaxy). To avoid in this analysis the effects of different distributions on the redshifts in the two samples, we limited them to $v < 10{,}000$ km/s and corrected the v-distribution of normal galaxies to that one of BCGs by selecting randomly, in each velocity bin of $\Delta v = 1000$, the number of normal galaxies proportional to the bin number of the BCGs. Total number of the BCGS in the range $2000 < v < 10{,}000$ km/s was 138.

1000 simulations were made and the results of adding all simulations are shown on the histograms of D_{NN} for the control sample, the uniform sample and the BCGs for illustration (Figure 2). It gives visual impression of a wider distribution of the BCGs than that of the control sample. We checked the hypothesis H_0 of two samples to be the representatives of the same general totality. For each simulation we constructed the empirical cumulative distribution functions of D_{NN} for various pairs of samples: 1) BCDs and randomly selected sub-group of control galaxies of the same number and the same v-distribution, 2) that sub-group of

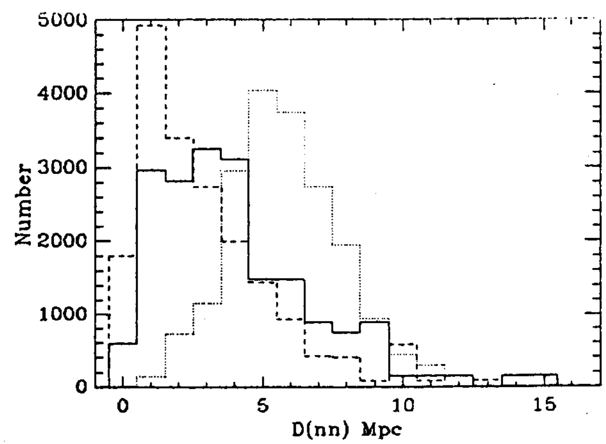

Figure 2 The histogram for distance to nearest neighbour in velocity range 2000–10,000 km/s, normal galaxies—dashed, BCGs—solid, random uniform catalog—dotted (100 simulations).

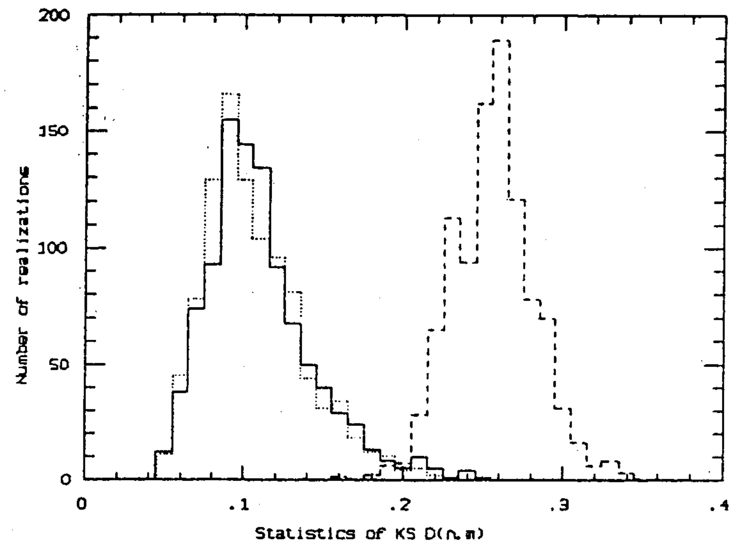

Figure 3 The histogram for KS statistic D(n, m) for 1000 realizations of normal galaxies (128 from 266)—solid, for BCGs (128 objects)—short dashed and 1000 realization from random uniform catalog (127 from 265)—dotted.

control galaxies and the rest part of the control sample, and 3) analogous two sub-groups as in 2), but from a random uniform sample in the same region of space and the same numbers of galaxies.

The difference of cumulative distributions can be measured by the statistics of Kolmogorov-Smirnov D(KS). We computed D(KS) for all three pairs of samples for each of 1000 random simulations and display their distributions in Fig. 3. For cases 2) and 3), the appearance of the distribution D(KS) must be close to the theoretical one in the case of H_0 is valid. And they actually almost coincide. The distribution of D(KS) for 1) (pairs with BCGs) is shifted from 2) significantly. The hypothesis H_0 is equivalent to the hypothesis H_1 on the uniformity of two samples represented by histograms for the cases 1) and 2) in Fig. 3. H_1 and respectively H_0 is rejected on the confidence level better than 0.001.

From the histogram in Fig. 2 the relative excess of BCGs in comparison with the control sample is evident for $D_{NN} > 5$ Mpc (or $D_{NN} > 4\,h^{-1}$ Mpc).

We checked the influence of clusters of galaxies with known radial velocities onto the distribution of D_{NN} for the control sample by removing the objects from regions within 3 Mpc ($H = 75$) from the centers of 38 clusters. There was no practical effect of this.

4. BCGS IN VOIDS

Even though the voids have been known in cosmology for more than a decade, their properties still are not well studied. Their sizes range from $10\,h^{-1}$ to (50–60) h^{-1} Mpc (Rood, 1988; Kaufmann & Fairall, 1990). Thus to test for the possible appearance of BCGs in the voids determined by normal galaxies, we checked all the BCGs with $D_{NN} > 5\,h^{-1}$ Mpc (6.7 Mpc for $H = 75$). Actually, this value is a bit larger than the threshold D_{NN} of the histogram in Figure 2, starting from which the relative number of BCDs becomes significantly higher than that of the control sample. The same threshold selects BCDGs which Salzer (1987) identified as being in a void. This sub-group of 18 objects we consider as BCGs filling-in well delineated voids.

5. DISCUSSION

Despite of the large diversity of dwarf galaxy properties, there were some attempts to treat them as objects of common origin which are connected by evolution links (e.g. Thuan 1985). In hierarchical models of galaxy formation the dwarfs can form either as original low-mass objects or as products of larger galaxy strong interactions at earlier epochs of higher spatial galaxy density. The approach taking into account the galaxy interactions for the origin of DGs was recently elaborated by Lacey and Silk (1991). If all types of dwarfs are of a common origin, it is natural to suggest them to show similar spatial distributions. Alternatively in a scheme like that by Lacey & Silk, different types of dwarfs can have rather different connections with the elements of the LSS.

The studies of spatial distribution of LSBDs recently performed by some groups (Thuan *et al.*, 1991; Eder *et al.*, 1989) all resulted, according to the author's in the same conclusions: LSBDs as a group of galaxies follow close the LS structure delineated by brighter galaxies and do not fill in the voids.

The results of our study of a large sample of BCGs in an extended, well situated area of the sky show unambigiously the results similar to those of Salzer, but at a high level of confidence. They indicate certainly that BCGs at least partly originate in regions of lower density. BCDGs seem to be the best candidates to dwarfs predicted by Dekel & Silk in their CDM model.

There are however some evidences which suggest that some LSBDs can also originate in regions of low luminous mass density and to be close relatives of BCDGs (Salzer, 1989, Eder *et al.*, 1989). We do not discuss here the results of a similar analysis of HII-galaxies from the Tololo survey, because of no space, but they agree with those presented here for the SBS sample. One of the reasons caused large difference in conclusions reached from studies of BCGs and LSBD could be some specific selection effect connected with the clustering of two types of voids (Pustil'nik *et al.*, 1992).

In conclusion we suggest that both kinds of dwarfs—LSBDs and BCDs are evidently inhomogenuous groups in their origin. In order to match different theoretical models of dwarf galaxies with observational data we need an extensive study of different sorts of DGs in the vicinity of the main archetype elements of the LS distribution. In particular, it can be fruitful to check predictions of the CDM biasing model by Dekel & Silk by a special search for gas-rich LSBDs in voids near BCGs.

Finally, if dwarfs appear to be better tracers of the total mass distribution, filling in voids, they can be used for a study of the voids themselves and of the possible differences in their properties. We consider this topic in an accompanying article (Pustil'nik *et al.*, 1992).

6. CONCLUSIONS

We can draw the following conclusions from our analysis:

• BCGs as a subgroup of galaxies trace in general the large-scale structure of the Universe delineated by normal galaxies. However, BCGs are distributed more uniformly and tend to occupy regions of lower density than normal galaxies do.

• We found 18 BCGs to lie in some voids outlined by normal galaxies, which comprise 13 per cent of the sample size. Another 2 ELGs are found to populate the Bootes void in addition to the 21 known ELGs.

• A more uniform spatial distribution of BCGS differs from that obtained for Low Surface Brightness Dwarfs by Thuan *et al.* (1991) and Eder *et al.* (1989) and seemingly reflects some selection effects and (or) the difference in the origins of these two types of DGs contrary to the discussed concept of their common origin and evolution links.

• The data accumulated allow to suggest even a more radical hypothesis: both groups of dwarfs are heterogeneous on their origin. But BCDGs are met more often (maybe because of selection effects) in low density regions as they would originate from primodial low-mass seeds.

• Our results support the predictions of the CDM biased galaxy formation model. Additional evidences for it could be a detection of LSBDs in the vicinity of BCGs in voids.

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