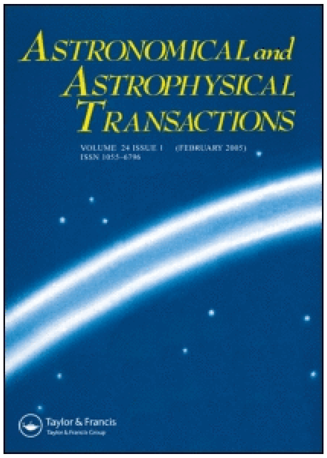

Astronomical & Astrophysical Transactions
The Journal of the Eurasian Astronomical Society
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713453505

Two types of voids and super-large scale structures in the universe?

S. A. Pustil'nik [a]; A. V. Ugryumov [a]; V. A. Lipovetsky [a]
[a] Special Astrophysical Observatory RAS, Nizhnij Arkhyz

Online Publication Date: 01 January 1994
To cite this Article: Pustil'nik, S. A., Ugryumov, A. V. and Lipovetsky, V. A. (1994) 'Two types of voids and super-large scale structures in the universe?', Astronomical & Astrophysical Transactions, 5:1, 75 - 79
To link to this article: DOI: 10.1080/10556799408245857
URL: http://dx.doi.org/10.1080/10556799408245857

Astronomical and Astrophysical Transactions, 1994,
Vol. 5, pp. 75–79
Reprints available directly from the publisher.
Photocopying permitted by license only

TWO TYPES OF VOIDS AND SUPER-LARGE SCALE STRUCTURES IN THE UNIVERSE?

S. A. PUSTIL'NIK, A. V. UGRYUMOV and V. A. LIPOVETSKY

Special Astrophysical Observatory RAS, Nizhnij Arkhyz

(14 December 1992)

From analysis of the spatial distribution of Blue Compact Galaxies we found that a significant part of such objects is situated in voids. We test the hypothesis that voids are of two types on density contrast. Our results agree with it. Moreover, the voids of each type are situated in nonrandom, and show clustering on scales of 70–100 h^{-1} Mpc.

KEY WORDS Cosmology, large-scale structure of Universe, voids, galaxies, formation.

1. INTRODUCTION

Since Joeveer *et al.* (1978) suggested the cellular structure of the large-scale distribution of luminous mass in the Universe there have appeared many observational data which evidence without any doubts to this picture (see Rood, 1988 for review).

Now LSS traced by luminous matter seems to consist of huge empty regions, called voids, and some surface-type sheets on the boundaries of the voids. The intersections of such sheets are seen as filaments with enhanced density of galaxies. There are rarer regions of strong clustering of normal galaxies—clusters of galaxies, which seemingly correspond to the intersections of filaments.

Exceptional importance of reliable knowledge of all aspects of LSS in order to test modern cosmological and galaxy formation models, based on the idea of dynamical dominancy of the Dark (invisible) Matter, explains why cosmologists are actively continuing to attack the problem from various directions.

We present here new data on void properties discovered from a study of the spatial distribution of Blue Compact Galaxies from the Second Byurakan Survey (BCGs from SBS) (Pustil'nik *et al.*, 1994). We put forward the hypothesis on the two types of voids which differ significantly on galaxy density contrast (originally suggested by Salzer, 1987) and test it using some specific statistic.

2. THE DATA

Our data set is based on the coordinates and radial velocities of all the galaxies in the most recent version of ZCAT by Huchra (1990) in and near the region of the SBS: $7^h40^m < \alpha < 17^h20^m$, $49° < \delta < 61°$, and those of all BCGs selected in the same region (Erastova *et al.*, 1992, in preparation) in the volume with $v < 10{,}000$ km/s.

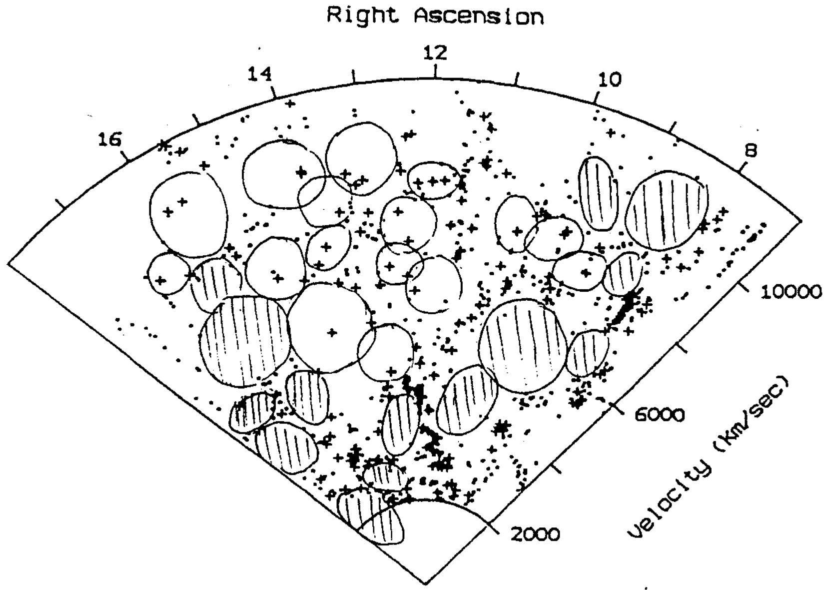

Figure 1 Wedge diagram for the SBS zone projected to central declination with positions of all normal galaxies (dots), BCGs (crosses). Voids are marked by thin contours, and those considered as "empty" are hatched.

A visual inspection of the wedge diagram projected to the central declination $\delta = 55°$ plane reveals many well delineated voids, which we marked by light contours in Figure 1. We further notice those voids for which our previous study resulted in the detection of BCDs with large enough distance to the nearest neighbouring normal galaxy D_{NN}. We selected this BCGs on the criterion $D_{NN} > 5\,h^{-1}$ Mpc, which follows from the comparison of the histograms for normal and blue compact galaxies in the previous work and from the characteristic scale in the correlation function of normal galaxies (Vogeley *et al.*, 1991). Thus we consider these BCGs to be inside voids, and visa versa, those voids in which we detected BCGs, we shall consider as voids filled with BCGs. We denote them as "F"-voids. The remaining voids in the region of SBS boundaries we shall consider as "empty" ones and sign them as "E"-voids.

3. THE HYPOTHESIS AND ITS TESTING

At the first impression this division could seem the artificial and this concrete realization of F and E voids be a some random one affected by small numbers of the voids themselves and the BCGs detected in them.

However, because the hypothesis on existence of two types of voids is not senseless, at least in some models of the origin of the LSS, such as the CDM one, it is tempting to test this on our material. Moreover, evidences in favour of this hypothesis could put severe limitations on the explosion models (Ostriker and

Cowie, 1981). In order to test it we formulate the Null hypothesis that all the voids are from the same general totality and their property to be of "F" or "E" type is an effect of a random realization.

For there were no effects of observational selection in both the CfA survey of galaxies and the SBS selection of BCGs in this sky region, we would expect a random distribution of F and E voids on the field of all voids under consideration.

Further we simplify our analysis by taking as a material for modelling the array of the centers of voids' Cartesian coordinates in projection onto the central plane of the layer studied ($\delta = 55°$). Finally we have an array of $(x(i), y(i))$ for the centers of 30 voids, 17 of which singed as "F" and 13 ones as "E".

To test the Null hypothesis we introduced the quantitative geometrical statistic 'AND' (averaged normalized displacement), characterizing each configuration of voids and then simulated random and nonrandom configurations to see the distribution of the parameter 'AND'.

To compute 'AND' we calculated for each realization the average pair distance between all the representatives of the two types $\langle D(f, e)\rangle$ and analogous parameters for each type separately $\langle D(e, e)\rangle$ and $\langle D(f, f)\rangle$. The distribution of the final parameter $\text{AND} = 2\ \langle D(e, f)\rangle / (\langle D(e, e) + \langle D(f, f)\rangle)$ after 1000 simulations for random configurations is shown in Figure 2 by solid line.

We studied also the distribution of the parameter 'AND' for non-random configurations of F and E voids. Two of these also obtained from 1000 simulations are shown in Figure 2. They are significantly wider than that for random realizations.

The distributions of 'AND' for random and nonrandom configurations differ radically and we can easily discriminate between these two hypothesises. We choose a significance level to discard the Null hypothesis on a random configuration of the two types of voids to be 0.001. Taking 'AND' for the

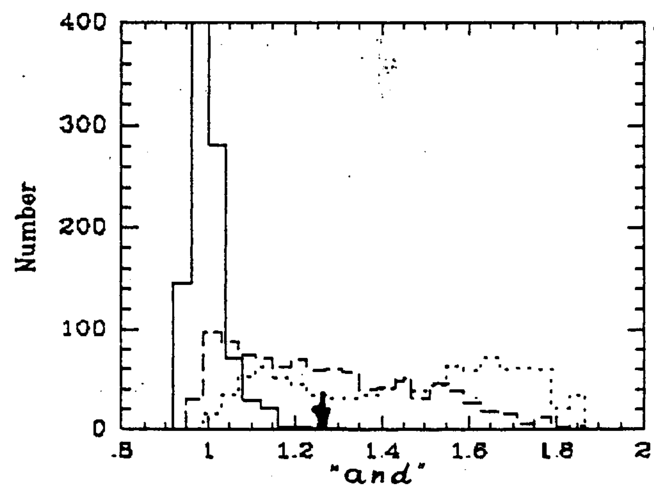

Figure 2 The histograms of the distributions of the parameter 'AND'—averaged normalized displacement for simulated random (solid line) and non-random configurations. The arrow marks the value of AND_{obs}.

observed configuration ($AND_{obs} = 1.26$), the H_0 is discarded. Moreover, we can roughly estimate, from the simulated distributions of 'AND' for nonrandom configurations, the most probable value of the clustering parameter. For the region under analysis, the size of a F-void cluster should be of the order of $100\ h^{-1}$ Mpc.

2. DISCUSSION

The existence of voids of two types and their clustering on scales up to $100\ h^{-1}$ Mpc can be understood, in principle, in mixed CDM + HDM models. These models were suggested by many authors, on one hand, to explain the LS correlation function on scales $r = (10 - 100)\ h^{-1}$ Mpc and, on the other hand, from theoretical reasons in theory of broken symmetry of quark and lepton generations (Berezhiani and Klopov, 1991). In the mixed models, the spectrum of primordial fluctuations at the epoch of decoupling can be very wide. Thus nonlinear interactions of modes of various scales causing, on one hand, a bias in the LS distribution of luminous matter, can, on the other hand, affect the properties of voids. If the position of a typical void-scale negative fluctuation coincides with a minimum of the longer-scale mode, the final gravitational well can be weakened so that even fluctuations of 2 or 3 σ of galaxy-mass scale will not develop into gravitationally bound system. It is natural to consider such voids as absolutely empty. If however a negative fluctuation of a typical void-scale turns out to coincide in space with a positive wave of the longer-scale mode, this can result in a suitable gravitational potential for nonlinear condensation at least of the strongest peaks (2–3σ) of the galaxy-mass scale. Such voids will appear as partly filled with galaxies.

In such a picture, we can expect the distribution of voids to be modulated by the long-scale modes of primordial fluctuations which will appear as filled and empty voids.

On the other hand, the origin of voids in the explosion models (Ostriker and Cowie, 1981) does not seem to reproduce voids of different properties to be correlated on greater scales. So if our result on a super-large scale correlation of void properties will be confirmed in other studies, this will put severe constraint on the explosion models of the LSS origin.

The most indefinite aspect of our analysis is the subjective choice of voids on the wedge diagram of the area studied. The crucial parameter for confidence level to discard the Null hypothesis is the total number of voids in the simulated configuration. Under other choice this confidence level can change to only 0.01. But in any case the analsyis presented above opens a new direction of studies of large-scale structures in the Universe.

An important development of this study would be a similar analysis but for a sample of voids selected by some objective algorithm. Unfortunately, the only one known to us (Kaufmann and Fairall, 1990) does not seem to be very successful, even to be capable to find voids in some galaxy configurations. We would like to hope to further progress in creation of objective algorithms for selection of voids in galaxy spatial distribution. From our side we shall attempt to create a new large sample of BCGs in a different part of the sky and to study this topic on an independent sample.

5. CONCLUSIONS

We draw from our analysis the following conclusions:

- The voids in the LS-distribution of galaxies seem to be of two types with different density contrasts (as suggested earlier by Salzer, 1987).
- The two types of voids called conventionally "filled" and "empty" ones are situated in space in nonrandom. They are gathered in clusters of voids of the same type with the characteristic size of 70 to 100 h^{-1} Mpc.
- The clustering of voids pointed out in the previous point agrees with the finding of the super LS clustering of rich clusters of galaxies (Kopylov *et al.*, 1988) and puts severe constraints on the explosion models of the LSS origin.

ACKNOWLEDGEMENTS

We are grateful to A. Doroshkevich for stimulating discussions and useful advises in the course of this study and to M. Khlopov for a useful discussion of results. We thank also V. Gorokhov for consultations on statistics. Authors are thankful to J. Huchra for providing a version of ZCAT.

References

Berezhiani, Z. G. and Khlopov, M. Yu. (1991). *Z. Phys. C. Particles and Fields*, **49**, 73.
Joeveer, M., Einasto, I. E. and Tago, E. (1978). *M.N.*, **185**, 357.
Kaufmann, G. and Fairall, A. P. (1991). *M.N.*, **248**, 313.
Kopylov, A. I., Kuznetsov, D. Yu., Fetisova, T. S. and Shvartsman V. F. (1988). *Large Scale Structures of the Universe*, eds. J. Audouze *et al.*, p. 129.
Ostriker, J. and Cowie, L. (1981). *Ap. J. Lett.*, **243**, L127.
Pustil'nik, S. A., Ugryumov, A. V. and Lipovetsky, V. A. (1994). (this issue).
Rees, M. (1988). *Highlights of Astronomy*, vol. 8, 45.
Rood, H. H. (1988). *A.R.A.A.*, v. 26, 245.
Salzer, J. J. (1987). Ph.D. Thesis, Univ. of Michigan.