A GUTENBERG – RICHTER LAW-TYPE IN GALAXY CLUSTERING

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This paper presents a study of the large-scale distribution of galaxy clusters. The goal of the survey is to find a relation between the cluster's magnitude (quoted by the number of bright galaxies in the cluster) and the multiplicity of this magnitude in the analised sample.

Several aspects of the results are compared with similar description specific for chaotic phenomena.

Key words: cosmology, galaxies: clustering - numerical methods, nonlinear phenomena..

1. INTRODUCTION

In the last twenty-five years, the research on galaxy distribution has shown that at large scale the galaxy dynamics leads to the formation of clusters connected by "slices" and "bridges" and surrounding "voids" with low-density [1]. The topology of these structures suggests a fractal object with typical scale-invariance, self-similarity and specific Haussdorff dimension $D_H \approx 2$ [2]. In some pictures [3] these large-scale structures develop by the amplification of small perturbation in the early universe (which also predicts a scale-invariant spectrum) allowing the possibility of accretion and formation of structures. According to this model, the evolution can cause dissipative phenomena: the matter accreting on high-density regions becomes radiative. It is well-known that this is the first stage for nonlinear phenomena.

Gott, Mao, Park and Lahav [4] developed and applied an algorithm for quantitative characterisation of the topology of large-scale structures. The algorithm is based on transforming the discrete distribution of galaxies into a smooth density field, using a Gaussian convolution and studying the isodensity curves, which bound surfaces of equal density. Their conclusions are consistent to a random-phase scenario for early density perturbations.

In a picture with cosmic strings as base for structure formation, an important feature is that the fluctuations are not in the form of waves with random phases [3]. We make no speculation about the chaotic evolution of the early structures.

2. THE SAMPLE AND METHOD

Because of the scarcity of the data, it is very important the way in which the sample of galaxies is selected. In respect of this, the mainly problem is that there is difficult to make measurements on the galaxies with declinations into the range of region obturated by our own galaxy. Using the "C.f.A. redshift survey" catalogue, we choose to make our analyses on a 5840 galaxy sample covering the right ascension range $8^h \leq \alpha \leq 17^h$ –in the region of the Coma Berenices-Virgo chain and redshift $z \leq 20.000$ km/s.

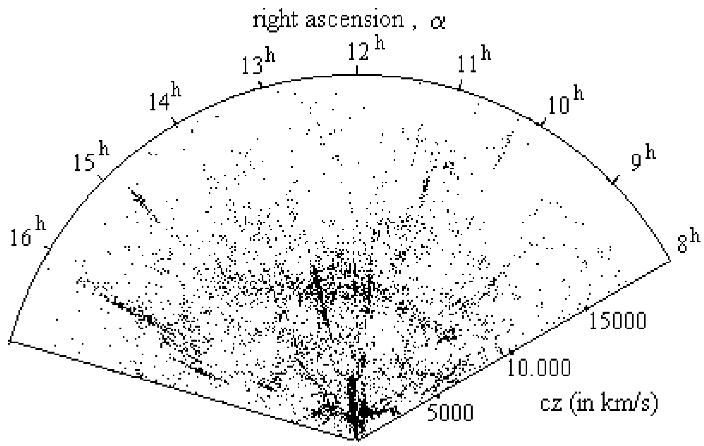


Fig. 1. Two-dimensional projection of galaxy distribution. 5840 galaxies are plotted, covering the declination range $0^o \leq \delta \leq 45^o$. Note the topology of the distribution, marked by galaxy clusters along entire sample.

Fig. 1 shows a two-dimensional projection of this sample. We can see that the massive clusters, containing a large number of galaxies, are less encountered than smaller ones. We call "cluster" a group of galaxies for which the correlation length is $r_0 < 6\ h^{-1}$ Mpc [5] with $0.5 \leq h \leq 0.75$ km/s Mpc.

The algorithm we have used separates and contorizes the clusters in terms of magnitude M so we can compute the dependence n = f(M) where n is a frequency-type function who describes the normalized multiplicity of a given magnitude M_i in the sample. We considered appropriate to define this function as

$$n = \frac{N_i}{M_i - M_{i-1}} \tag{1}$$

where N_i is the number of clusters containing M_i galaxies and M_{i-1} is the last magnitude with $N_i \neq 0$.
More interesting is the dependence in linearized coordinates, ln(n)=f(ln(M)).

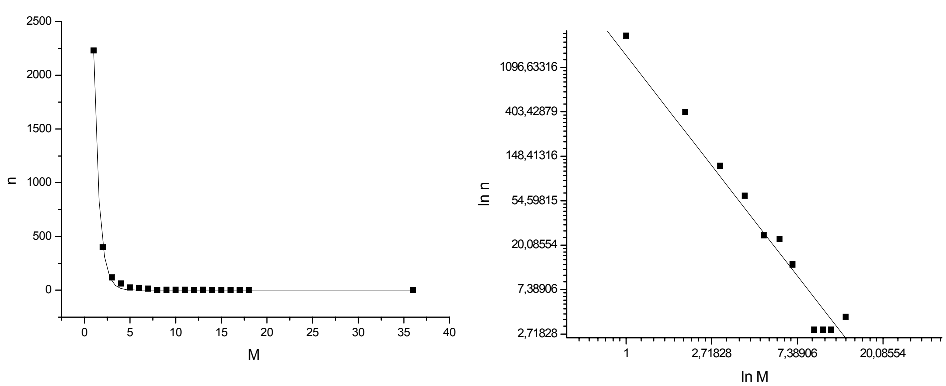
In order to show this dependence, our program randomly selects a galaxy as a reference point in the sample and seeks neighbouring galaxies, separated by a distance $r < r_0$, and counts them as constituents of the same cluster. In the second step these neighbours becomes reference-points and the algorithm is repeated until no new neighbours are found. Taking the above definition for clusters, we do not consider necessary to cut the thin “bridges” which connect greater agglomerations. The calculus was made for two correlation lenghts, with acceptable choice of h, and we compared the results.

3. RESULTS AND DISCUSSION

As we expected, with increasing the magnitude M, the number of clusters is decreasing. Using a correlation-length r_0 =0.005 (in computational units), we found - for example - 401 groups with two galaxies, only 119 with three galaxies, 61 with four galaxies. For groups with M<100 galaxies, the increasing is well described by an exponential decay:

$$n = Ae^{-\frac{x}{t}} \tag{2}$$

with $A \approx 12\ 10^{3}\ (\pm\ 4\ 10^{2})$ and $t \approx 0.6\ (\pm 0.1)$.



a b

Fig. 2. For r_0=0.005 (in computational units); a: for small clusters(M<100), the relation between n and M is a exponential decay. b: on linearized scale, the dependence is a linear decay with slope b=-2.145. The error in the slope determination is about 0.106. As for the following, the graphics are made using Origin 6.0.

Figs. 2.b and 3 show the dependence in linearized scales. One can observe that there is a linear decay with the same slope (in the limits of errors) for both correlation-lenghts. The equality of the slopes obviously is the consequence of the scale-invariance clustering. In respect with this scale-invariance, we can consider other values for correlation length in the cluster's definition. It is expected that for other values of correlation lenght, the slope will be the same. If we will increase this value over a limit r_{max} (expected to be the maximal distance between two neighbours), all the galaxies will be token in one single cluster. Also, if r_0 will be smaller than the minimal value of distance between any two galaxies in the sample, no clusters will be found so we will have just isolated galaxies. We make the assumption that in the range of this two values, with a probability to have great errors near the limits, the self-affinity will assures independence on the value of r_0. This does not means that the correlation length may be of any value in other studies, for example in topological characterization, calculus concerning the mean-density.

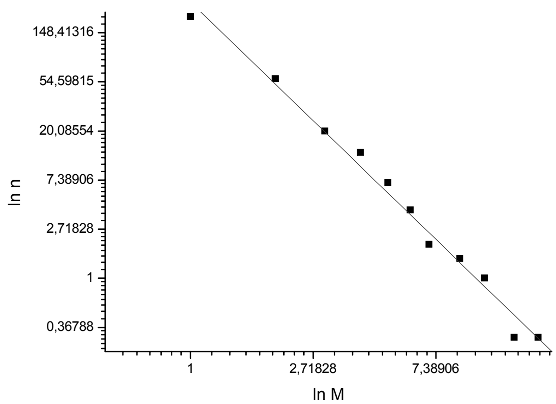


Fig. 3. For r_0 =0.025, the slope is b=-2.4193 with an error of 0.189.

We note that is also expected that the same study done for different samples will provide similar results. To be exact, we talk about the assertion that distribution of matter in the universe follows the same statistical laws independent of the system of reference. In other terms, based on cosmological principle, the universe presents in each part the same features, if the scale of surveys large enough for a good applicability of statistical laws. In conclusion, the cluster's multiplicity decreases with the magnitude of the cluster. Small clusters appear to be more often than smaller ones, with a possible characterization by a 1/f function, in linearized coordinates.

Functions as "1/f" are called by Mandelbrot "Joseph noises" and are correlated – in their original sense – to natural fluctuations with a spectral density proportional to $f^{-\beta}$ where β is a constant and f designates the frequency. Such functions are self-affine with exponent β-1 [6]. Well-known examples are in electronics - the noises generate by the electric contacts (which are also fractal surfaces), in hydrology (in the fluctuations of the river's level) but also they occur in music, in the wobble of Earth's magnetic poles, or concerns the uncertainties in time even as measured with an atomic clock [6].

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