Towards a self-organizing Universe

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Towards a self-organizing Universe

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Abstract. In this work we show that the large scale structure of the Universe is naturally linked to the E-infinity theory and to the concept of a self-structured Universe. The key idea is that the nonlinear evolution of the Universe towards a fixed point located at \(4 + \Phi^3\) (where \(\Phi\) is the golden mean) must be reflected by the evolution of matter structures. Using data from 2dFGRS we show that the fractal dimension of the large scale galaxy distribution seems to depend on the redshift. This dependence suggests that the Universe has started to form structures about thirteen billions years ago and is evolving towards a Cantorian structure.

1. Introduction

An outstanding problem in modern cosmology is to understand how the formation of large scale structures, such as galaxies and clusters of galaxies can be described within the framework of the standard cosmology. The term “large scale structure” is referred here to a distribution of galaxies on the scales roughly from 40 Mpc to 800 Mpc.

The study of this problem has raised some major questions:

What is the topology of the galaxy distribution on various scales? The cosmological principle states that the universe is homogeneous and isotropic on the largest scale. Is this supposition in agreement with the observational cosmology?

How did the galaxy structures form? How might we constrain the expanding universe and models for structure formation with the observations?

How does the inhomogeneous structure relate to the early evolution of the universe?

What are the connections among the large scale structure, cosmic background radiation, the expansion of the universe and nonlinear dynamics?

Until the middle of 1970’s, the idea that the galaxies are almost uniformly distributed with only a small percent in clusters was widely accepted. But in the late 1970’s, the improvements in spectrographic technology allowed redshift measurements for a large numbers of galaxies. These early

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redshift surveys showed huge voids (as large as 100 Mpc) in galaxy distribution, surrounded by “walls” and spanned by “filaments”.

The next 25 years have witnessed an explosive evolution of our understanding of the motion of galaxies and their distribution. A complete review of these years [1] shows how the field has moved from a morphological, qualitative description of this distribution to a rigorous description which allows us to approach the cosmological implications of the observed large scale structures.

As the interest for nonlinear phenomena and fractal structures has grown in the last two decades, the old hierarchical universe model proposed by Charlier and Fournier in the early 1900’s, has reborn and is to receive new valences.

There have already been several proposals about how the self-organizing systems theory may be applied on scales comparable to the size of a star: the spectra coming from accretion disks suggest that the formation of stars and galaxies is driven by a feedback process which usually characterizes self-organizing systems [2].

But what about the large scale structure? The evidences we have presently for the large scale self-organization of the universe [3] come from different sources: catalogues of galaxy redshifts; absorption lines in quasar spectra; the cosmic background radiation; studies of the distribution of hot ionized gas in clusters of galaxies; measurements of large scale peculiar velocities.

El Naschie’s E-infinity theory emphasized the idea that the Universe has born as the result of a self-organizing process in Cantorian space-time and is moving towards the fixed point [4-7]. It has been shown that the large scale structure is linked to the self-organizing systems and E-infinity theory [8] and the formation of hierarchical structures naturally emerges from the behavior of the space-time within the Torus Universe model [9]. If so, then we should be able to find the reflection of the evolution of the Universe in the evolution of galaxy distribution with cosmic time. In this paper we shall track back the evolution of the large scale structure by studying the dependence of its fractal features with the redshift \( z \). If we accept the redshift as a consequence of the expansion, then the greater redshift the further in the past we look. Through this study we shall take a look into the past until \( z = 6.5 \) (that means almost thirteen billion years ago) when the first star structures were born. We shall show that the fractal dimension of the galaxy distribution is a function of redshift and that this dependence allows us to set another link between the observational cosmology and the self-organizing hierarchical Universe model.

2. Tracking back the history of the Large Scale Structure

The two degree field galaxy redshift survey (2dFGRS) is a survey consisting of 382323 objects which includes spectra for 232155 galaxies in two slices covering a total area of about 1500 squares degree in both the north and the south galactic poles. The limiting apparent magnitude of the survey is \( b = 19.5 \) and the largest redshift, \( z = 0.3 \), is corresponding to a distance of about 1000 Mpc. From the south survey we have selected a sample containing 57266 galaxies, with declinations \( \delta \in [-24^\circ,-30^\circ] \), right ascensions \( \alpha \in [23h,3h] \) and redshifts within \( z = 0 \) and \( z = 0.21 \). We have divided this sample in ten sub-samples, each of them covering an interval as thick as \( \delta \varepsilon = 0.02 \) with an exception for the first sub-sample which is stretching from \( z = 0 \) to \( z = 0.03 \). Using the box-counting method, for each sub-sample we have calculated the capacity dimension. If we consider a set \( N(\varepsilon) \) of points distributed in a three dimensional Euclidian space then we can always cover the set with cubes of edge length equal to \( \varepsilon \). Let \( N(\varepsilon) \) be the minimum number of cubes needed to cover the set. The capacity dimension is then defined by:

\[
D = \lim_{\varepsilon \to 0} \frac{\ln N(\varepsilon)}{\ln \frac{1}{\varepsilon}}
\]  

(1)
For each sub-sample we have transformed the spherical coordinates into Cartesian ones and we have counted \( N(\varepsilon) \) for eleven values of the edge length \( \varepsilon = \frac{1}{9}, \frac{1}{10}, \ldots, \frac{1}{20} \). We have plotted \( \ln N(\varepsilon) \) versus \( \ln \varepsilon \) and then we have found the slope of the regression curve which fits the data. This slope of the regression curve is equal to capacity (Hausdorff) dimension. The results are listed in Table 1.

Table 1: Fractal dimension of the galaxy distribution for the sub-samples selected from the south slice of the 2dFGRS

<table>
<thead>
<tr>
<th>Redshift range</th>
<th>0</th>
<th>0.03</th>
<th>0.05</th>
<th>0.07</th>
<th>0.09</th>
<th>0.11</th>
<th>0.13</th>
<th>0.15</th>
<th>0.17</th>
<th>0.19</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of galaxies</td>
<td>3808</td>
<td>2743</td>
<td>7473</td>
<td>6731</td>
<td>8115</td>
<td>9205</td>
<td>6807</td>
<td>5575</td>
<td>3529</td>
<td>3573</td>
</tr>
<tr>
<td>Fractal dimension (±0.021)</td>
<td>1.91</td>
<td>2.006</td>
<td>2.03</td>
<td>2.04</td>
<td>2.019</td>
<td>2.105</td>
<td>2.099</td>
<td>2.174</td>
<td>2.17</td>
<td>2.26</td>
</tr>
</tbody>
</table>

Figure 1 shows the dependence of the fractal dimension of the galaxy distribution with the redshift, as it results from the data in Table 1.

The linear approximation of the above dependence has the form

\[
D = 1.89901^{+0.13}_{-0.11} + 0.166^{+0.013}_{-0.012} \cdot z
\]

(2)

If we simply extrapolate this dependence then we obtain that the Universe was characterized by a smooth spatial distribution of matter (the fractal dimension \( D = 3 \)) at \( z = 6.5991 \), when it started to become inhomogeneous. In the Lambda-Cold Dark Matter model, this redshift is corresponding to a moment located at about twelve-thirteen billions years ago, after the moment of re-ionization and in the age of the first quasars’ birth. The general opinion is that the re-ionization was probably quite rapid.
and could have taken place between \( z \sim 6 \) and 20. Our result is in agreement with the works of Songaila [10] and Zheng [11] which state that the epoch of re-ionization is not more recent than \( z \sim 5.8 \), since there is no distinctive absorption in the spectra of the highest redshift quasars due to the presence of a neutral intergalactic medium. The value \( z = 6.5991 \) also matches well the observations on the highest redshifted quasars [12].

The dependence (2) shows that, since the apparition of the first structures, the fractal dimension of matter distribution decreases as the Universe becomes more and more structured.

By replacing the corresponding value for the fractal dimension of the Cantor cube \( D = 1.8927 \) in the equation (2), we obtain a redshift \( z = -0.0478 \). This result means that the distribution of galaxies will reach the Cantorian structure after about half billion years from now.

### 3. Concluding remarks
In this work we have shown that the fractal dimension of the galaxy distribution is, as a function of the redshift, a good indicator of the evolution of the large scale structure. This result is in perfect concordance with the theory of hierarchical structure formation and argues for a self-organized universe.

### References


