Spatial-Temporal Distribution of Superclusters of Galaxies for z < 0.5

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Abstract

Is the universe discrete or continuous? Did superclusters of galaxies come into existence at approximately the same epoch in time or have they been and are constantly generated at random in space and time? In this article we apply statistical methods to a database of 2719 superclusters. We found that for z < 0.5 superclusters are distributed in space in accordance with a Poisson distribution. Their density appears to be declining over time and senescence is not the explanation. This result rules in favor of a discrete universe in which superclusters are produced at a rate less than the rate of expansion.

Keywords: superclusters, cosmology, inflationary universe, Poisson distribution

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1. Introduction

One would expect to observe a Poisson distribution of the superclusters of galaxies only if their origins took place independently in non-overlapping intervals of space and/or time. We would expect their density to decrease with time, that is with decreasing reshift z, if they were all created at approximately the epoch.

A Poisson distribution of the superclusters of galaxies was first reported by Neyman & Scott (1952) utilizing the limited data then available from ground-based telescopes. In the next section, we use the data from the SDSS survey main and Luminous Red Galaxy (LRG) samples collected by Liivamagi, Tempel & Saar (2010) to confirm that superclusters do have a Poisson distribution. In subsequent sections, we use the same data to derive the density of superclusters as a function of space-time.

Two possibilities suggest themselves. First, that the superclusters of galaxies formed at more or less the same point in time (give or take a billion years). Alternatively, superclusters arise and continue to arise independently of one another at different points in both space and time.

Both models presuppose that the superclusters will have Poisson distribution in space. But as will be seen in a third section, the competing models predict quite different spatial-temporal distributions.

2. Observed Number of Superclusters

Suppose we were to count all the superclusters of galaxies located in an arc of constant width and height at various distances $R_o < R_1 < \ldots < R_n$ from the observer so that the volumes V_i, i =0,1,…n of the resulting regions were the same. Note that Vo is a segment of a sphere, while the remaining volumes are ring segments, chosen so that

$$kR_o^3 = kR_1^3 - kR_o^3$$

or

$$R_1^3 = 2R_0^3$$

$$kR_o^3 = kR_n^3 - kR_{n-1}^3$$

$$R_n^3 = nR_0^3;$$

that is, $R_n = \sqrt[3]{n}\ \mathrm{R}_0$.

A list of superclusters, their luminosity distances R, and their redshifts z may be found at http://atmos.physic.ut.ee/~juhan/super/super_lrg/ in the catalog scl_cat_ls00180_e.dat for $z<0.5$. Ordering the catalog by the redshift, we find that $R \approx 3021.33z - 706.89z^2 + 27.54z^3$. See Figure 1. In what follows, we employ the smoothed values of R given by this equation, rather than the less-accurate luminosity distances to be found in the table.

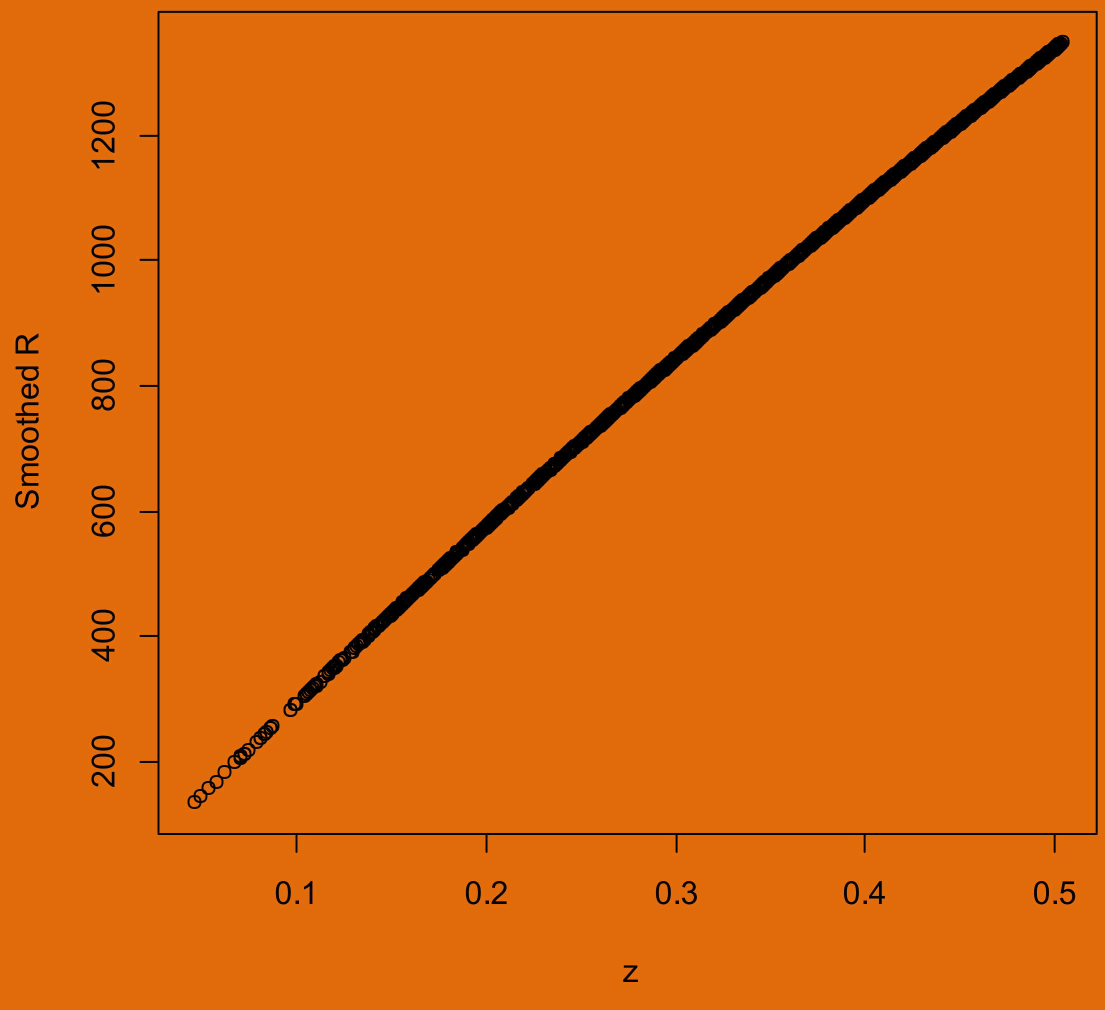
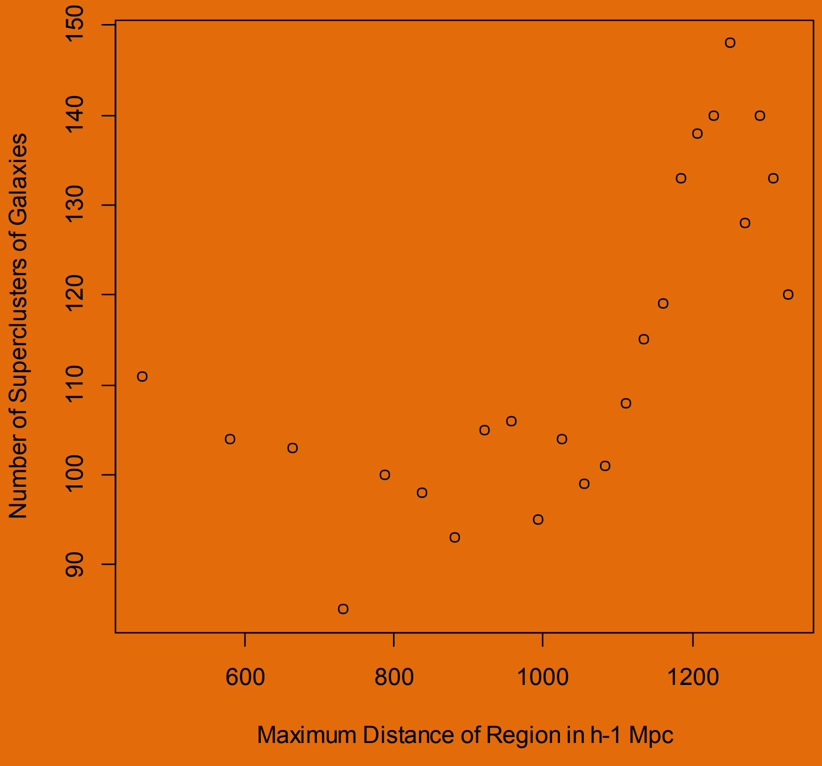


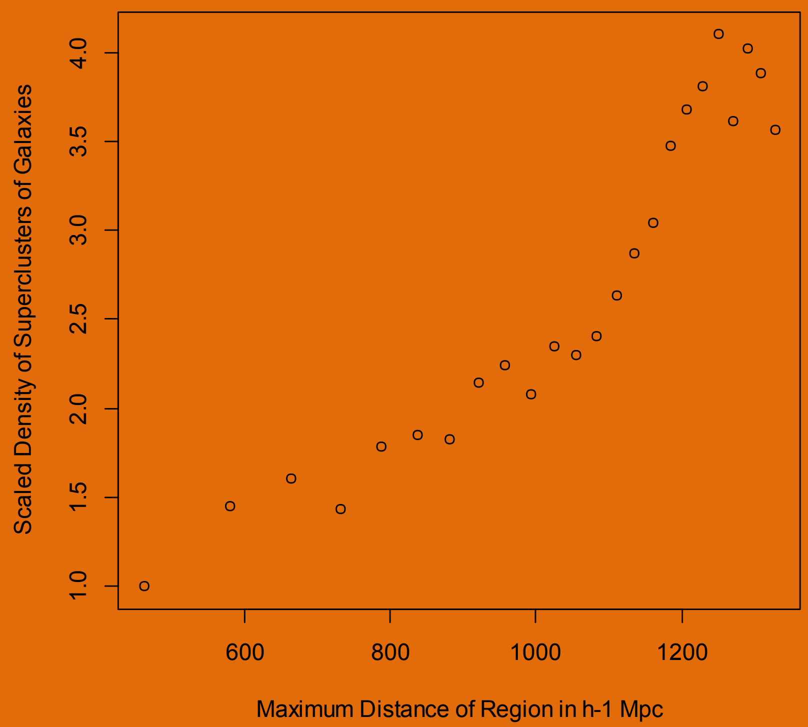
Figure 1

We first set Ro = 460.514 so as to incorporate 110 superclusters of galaxies, yielding Figure 2a.

Denote by N_i, the number of superclusters observed in the region V_i located at a distance R_i from the Earth. The apparent density of superclusters is given by N_i / R_0^3.

But as we observe further and further from Earth, we are going back in time as well as outward in space; at an earlier time, the universe was smaller. Specifically, the redshift z is a function of the expansion of the universe, so that a scale factor proportional to the radius of the universe, a(z), decreases as 1/(1+z); see Schneider (2010, p155). Thus, the actual density $D(z_i)$ of superclusters in a region V_i at redshift z_i is $N_i(1+z_i)^3 / R_0^3$. Rescaling the corrected densities yields Figure 2b.





Figures 2a,b

3. Spatial Distribution of Superclusters of Galaxies

We divided the data from catalogue scl_cat_ls00180_e.dat into 9600 equal-sized regions, based on the 24 distances used to create Figures 2a,b, sixteen equal subdivisions of the right ascension which ranged from 111 to 261, and 25 equal subdivisions of the declination which ranged from -3.7 to 69.6. Our findings, comparing the observed distribution derived from this data set with a theoretical distribution based on the Poisson, are shown in Table 1:

Table I: Spatial Distribution of Superclusters of Galaxies						
Number	0	1	2	3	4	5
Observed	7178	2012	370	38	1	1
Poisson Distribution	7095	2144	324	32	2	0

4. Expected Numbers and Density of Superclusters

The cold dark lamba model (CDλM) assumes that all superclusters formed at approximately the same time and the continuing expansion of our universe merely dilutes their density. Suppose when the superclusters came into existance, the radius of the universe in scaled units was $a(z^*) = 1/(1+z^*)$ and that the total number of superclusters was N*. The density of superclusters at that time was $D^* = kN^*(1+z^*)^3$.

At a later time, the density will have been diluted by the expansion of space so that the true density $D^*(z)$ will be equal to $kN^*(1+z)^3$. If the CDλM holds, $D(z)/D^*(z)$ will be a constant. Figure 3 depicts the observed relationship between D* and D, casting doubts on the near-simultaneous origin of the superclusters.

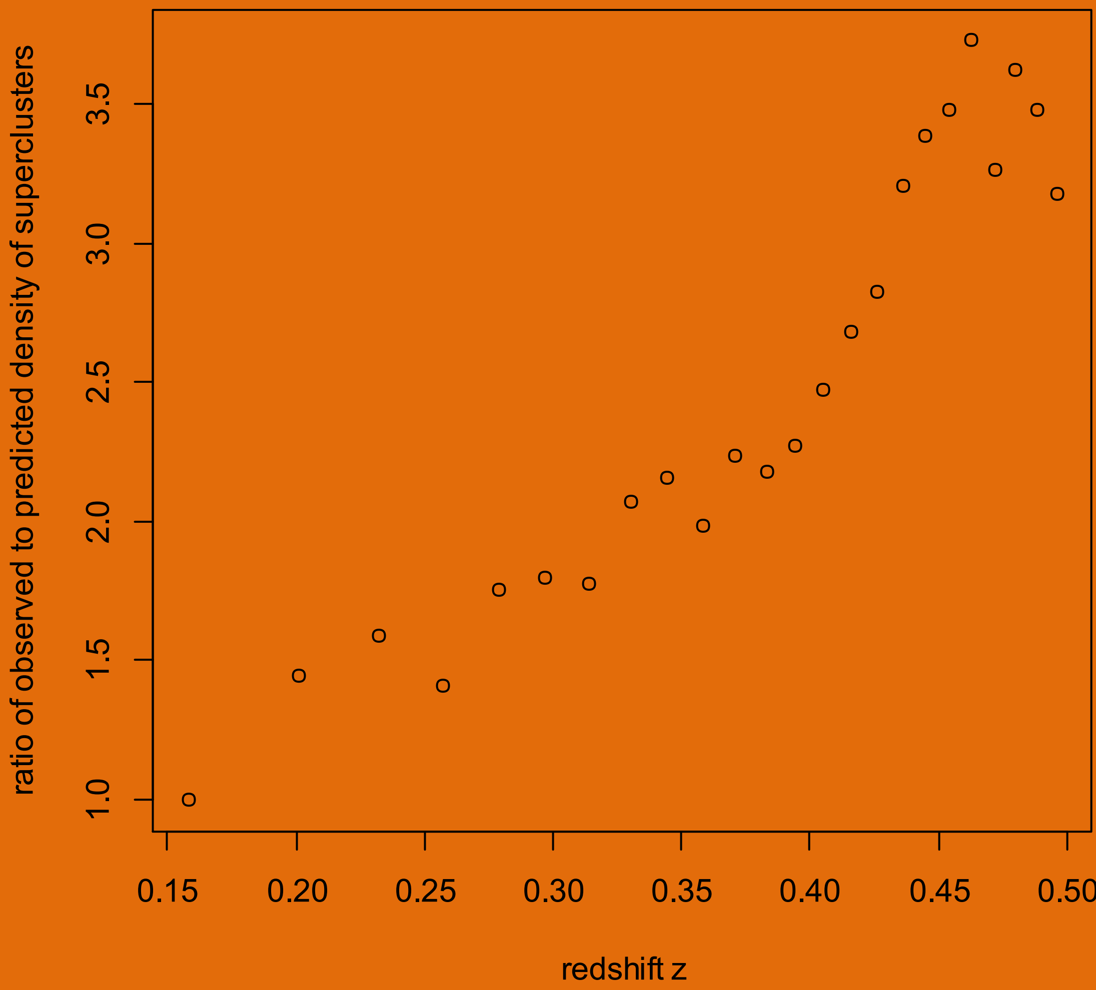


Figure 3

Friedgut (2013) proposed that the superclusters arise at random points in time-space with events in nonoverlapping regions of time-space occuring independently of one another. The total number that are formed in a fixed period of time is proportional to the size of the universe. The change in density with time is thus more or less constant. The change may be be less than, equal to, or greater than the rate of expansion. Were this model true, the observations depicted in Figure 3 would suggest that the rate of creation was less than the rate of expansion.

5. Death and Mergers of Super-Cluster of Galaxies

Before rejecting the CDλM out of hand, consider that other factors may be at work. If we were to observe a similar decline in numbers in populations of businesses or nations, we would attribute it to mergers. We know that galaxies merge, but current observations suggest that the superclusters continue to fly apart rendering mergers impossible, particularly if they all came into existence at about the same time. The Friedgut model also is ruled out for it views superclusters as entirely separate entities, separated by an expanding scalar field, incapable of merging

If we were to observe the population density of a mature population of cells or organisms decreasing with time, we would attribute it to deaths. We know that individual stars are extinguished over time, perhaps so too are entire galaxies, clusters of galaxies and superclusters.

If all the superclusters were created at approximately the same epoch, their population would pass through three phases each lasting billions of years, a phase in which the density increases, a phase in which the numbers remain more or less constant, and a phase in which the sky empties of stars.

Under the Friedgut model, the population of superclusters would pass through two phases, a period before senescence is observed in which the density of superclusters increases and a period in which the numbers of superclusters remain more or less constant.

The catalog data suggest we are currently in the transition between the first and second phases in either case.

If the death of superclusters is the explantion for the decrease in super-cluster density with time, we would expect the median number of galaxies per super-cluster and the median sum of galaxy luminosities to be an inceasing function of z. Figure 4 shows that just the opposite is true.

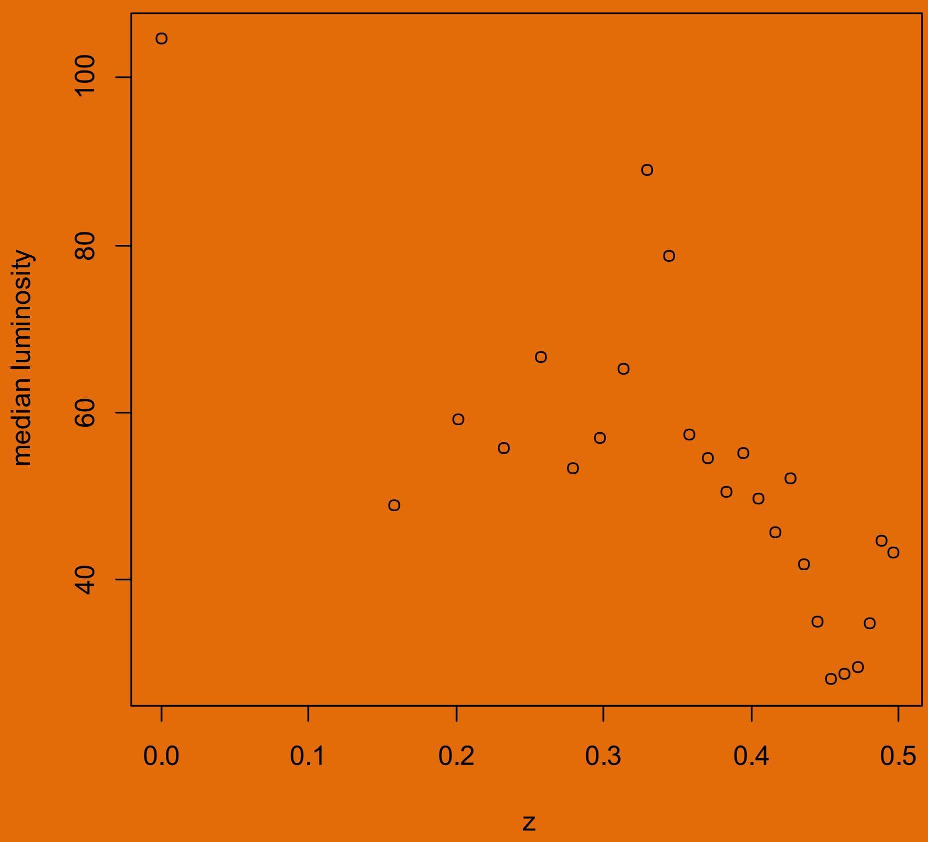


Figure 4

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