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REDSHIFT PERIODICITY

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Abstract

In this article we present the detailed history of the galaxy, quasar and large-scale (120 Mpc) redshift periodicity, starting from the first works performed in the seventies of the last century until present day. We discuss the observational data and methods used, showing in which cases the discretization of redshifts has been observed. We discussed also the distribution of radial velocities of galaxies belonging to two different structures: the Local Group of Galaxies and the Hercules Supercluster. We applied the power spectrum analysis using the Hann function for weighting, together with the jackknife error estimator. We found weak effects of redshift periodisation in both structures.

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1 Introduction

In the large scale Universe, the search of regulations is connected by testing the radial velocities of galaxies and quasars. We can describe redshift as:

$$z = \frac{\lambda - \lambda_1}{\lambda_1} = \frac{R(t_0)}{R(t_1)} - 1 \simeq \frac{v_r}{c}$$

where: λ is observed wavelength, λ_1 is emitted wavelength and $R(t)$ is scale factor. Redshift depends on:

1. General expansion of the Universe (Hubble flow)
2. Local peculiarities due to matter distribution
3. Small scale motion of matter inside a galaxy

It is commonly accepted that radial velocity of object does not depend on its position on celestial sphere, magnitude and other properties of an object.

These velocities can have arbitrary value or they can be grouped around some particular values. Any distribution of galaxy velocities can be described using continuous or discreet function. In the first case it means that redshift can have arbitrary value. It is possible to find maxima and minima, which means that some redshift values are more probable than others. There are maxima in the distribution of object redshifts, which are separated by a constant value. Such distribution is called, not very correctly, redshift discretization. The second case is the exact discreet distribution. Radial velocities of galaxies can have only discreet values. This is a strict quantization of radial velocities, which means that only multiplication of period value are possible. If sometimes an object with redshift which is not strict multiplication of a periodization value is observed, this is due to observational errors. Both above mentioned possibilities are called periodisation or discretization. In our paper [3] the quest for quasar redshift periodicity is described, while the latter studies have been discussed [2], too.

The subject of redshift periodisation is not very popular, sometimes even regarded as scientifically suspicious. However, we share the opinion expressed by Hawkins et al. [43] that all these effects should be carefully checked. They wrote: "The criticism usually leveled at this kind of study is that the samples of redshifts have tended to be rather small and selected in a heterogeneous manner, which makes it hard to assess their significance. The more cynical critics also point out that the results tend to come from a relatively small group of astronomers who have a strong prejudice in favour of detecting such unconventional phenomena. This small group of astronomers, not unreasonably, responds by pointing out that adherents to the conventional cosmological paradigm have at least as strong a prejudice towards denying such results.

We have attempted to carry out this analysis without prejudice. Indeed, we would have been happy with either outcome: if the periodicity were detected, then there would be some fascinating new astrophysics for us to explore; if it were not detected, then we would have the reassurance that our existing work on redshift surveys, ect, has not been based on false premises."

2 The history of redshift periodicity

2.1 Quasar redshift periodicity

Detection of quasars is not simple because they are dim point-like objects. Usually they are detected through sky survey at several wavelengths. This allows one to discriminate between objects with non-stellar colour. Further spectral observations are decisive to classify them as quasar or non-quasar objects. The basic feature is the UV excess for objects brighter than $M = -24^m$. The QSO spectrum is characterized by several prominent emission lines. These are, among others: $Ly\ \alpha$ ($\lambda_{rest} = 1216$Å), $Si\ IV$ ($\lambda_{rest} = 1400$Å), $C\ IV$ ($\lambda_{rest} = 1549$Å), $C\ III$ ($\lambda_{rest} = 1909$Å), $Mg\ II$ ($\lambda_{rest} = 2798$Å), H_δ ($\lambda_{rest} = 4101$Å), H_γ ($\lambda_{rest} = 4340$Å), H_β ($\lambda_{rest} = 4861$Å) and $[O\ III]$ ($\lambda_{rest} = 4959$Å and 5007Å). However, high-redshift quasars cannot be detected by this method. At $z = 2.1$ the strong emission line $Ly\alpha$ is shifted from ultraviolet to blue filter B (of the UBV photometric system).

Thus, this approach, so characteristic for quasar UV excess and photometry, is no longer a good method to search for quasar candidates, because the sample becomes incomplete. The other method of quasar detection is low-dispersion spectrometry using an objective prism. This method is not as sensitive as the previous one, but can be applied to objects with greater redshift. The main difficulty in quasar detection is the problem of sample completeness. X-rays and radio surveys are also involved in finding quasar candidates. But only optical observations allow one to discover strong emission lines characteristic for quasars. The redshifts of quasars and quasar-like objects are determined from measurements of both absorption and emission lines in their spectra. Moreover, it should be stressed that due to the lack of knowledge of quasar nature and the sources of quasar energy, the overwhelming majority of authors tried to find a correlation between the values of observational parameters. This is very characteristic for each branch of science at the early stages of its development.

The search for possible periodicity in quasar redshift distribution has been an important question from both observational and statistical points of view. The main interest in this matter concerned possible interpretation of the effect. The existence of such periodicity combined with the lack of a known underlying mechanism, constituted an observational basis for claims invoking new physics at work.

The first peculiarity which striked cosmologists looking for an explanation of quasar redshift distribution was the excess of quasars with value of z close to 2. The nature of quasar redshifts was the main subject of early quasar investigations. There have been three interpretations of quasar redshifts:

1. The redshifts are strictly Dopplerian,
2. A part of the redshift is Dopplerian but there is also a non-Dopplerian term,
3. The non-Dopplerian intrpretation, (i.e. the "tired-light hypothesis").

So the main question was whether redshifts are cosmological, (like those of galaxies), which means that they are connected with distances, or not.

This phenomenon is probably the eldest one, because it started in the late sixties of the previous century. Then Burbidges [17, 19] found the existence of sharp peaks in the redshift distribution, grouped around the values of $z = 0.01$ and $z = 1.95$. They also found periodicity in redshift distribution, which can be described by the formula $z_{obs} = 0,061 \cdot n$.

After analyzing the way of redshifts measuring for the objects from the Burbidge's list, Roeder [76] found that some of measurements are incorrect. They are dubious due to the problematical identification of lines in the quasar spectra, as well as the inaccuracy of doublets and blend measurements. The heterogeneous treatment of spectral lines gives five bins with widths of $\Delta z = 0.1$, in which only 6 objects are observed. In these bins the mean values cannot be calculated, so the application of some statistical tests is impossible. Some lines are measured more easily than others, which led to the lack of quasars within particular redshift intervals. This observational effect causes an artificial selection which, together with incorrectly applied statistics gives spurious periodisation of quasar distances to the observer. Roeder noted that the spectral line $Mg\ II$ (usually used for redshift determination for nearby quasars) is shifted for $z = 1.25$ beyond the observed spectral range, thus causing the local minimum in redshift distribution. At $z = 1.8$, the shifted $Ly\ \alpha$ line enters the blue region of the visual spectrum. These two effects considered together yield the minima and maxima observed in the redshift distribution. Essentially the same conclusion was reached by Semeniuk and Kruszewski [82], who independently analyzed the sample of 178 QSO with emission lines. Later on, this was confirmed by Basu [5].

Based on sample contained 116 objects, Cowan [27] found a strong peak with a period $0.1666 \cdot z$ (or $z/6$). One year later he extended his sample to 178 objects and concluded [28] that the periodicity is $z/6$ and $z/16$. In both papers power spectrum analysis (PSA) was applied. After analysing the same sample, Deeming [31] found no statistical significant departure from the expected, random distribution. He wrote, "Of course, like any statistical test of significance, this is one-way; it allows us to accept the hypothesis that the original data were random, but does not necessarily reject the hypothesis that the data were non-random. If the original data were random, then probably seven or so more points could be discovered in the power spectrum at still higher power levels."

Karitskaya and Komberg [54] have explained qualitatively existence of maxima and minima existing in the quasar emission line redshift distribution. They considered the position of four strong emission line in quasar spectrum: Mg II, C III, C IV and $Ly\alpha$. They were first, which have called attention on observational effect with slip related this line to the B filter.

The next person who has noticed existence of redshift periodicity was Karlsson [55] He received that in the $\log(1+z)$ variable the period is 0.089, which gives the observed maxima at $z = 0.3$, 0.6, 0.96, 1.41, 1.96, and two other ones predicted at $z = 2.63$ and 3.46. Similarly, Barnothy and Barnothy [4] found the period of 0.085 in the $\log(1+z)$ variable.

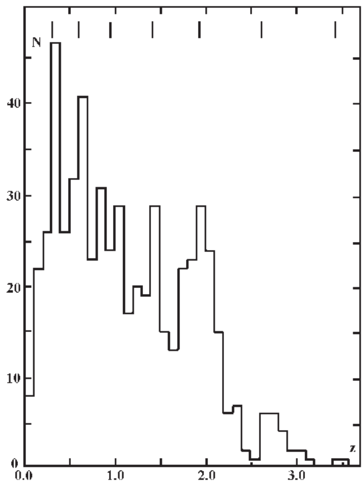

Figure 1: Distribution of QSO redshifts based on Karlsson sample. Bars indicate positions of peaks (reproduced with kind permission of Dr Per Kjaergaard).

The observed redshift distribution similar to that given in Fig 1 was compared by Roeder and Dyer [77] with two theoretical ones, namely the uniform distribution and the smoothly decreasing one for $z > 0.4$. They concluded that global redshift distribution cannot be used because of the selection effects.

It was shown by Karlsson [56] that the observed distribution of quasars cannot be explained by the selection effects pointed out by Roeder [76], Roeder and Dyer [77] and Basu [5]. These effects depend on the assumption that quasar redshift distribution is uniform. Increasing examined sample to 574 objects Karlsson [57] obtained periodicity which can be described by a geometrical sequence with a quotient equal to 1.227.

Lake and Roeder [60], using 1-dimensional PSA, found periodicity in $z = 0.007$, as well as a possible period of 0.0264. Their sample contained not only quasars but objects with emission lines, too. After reducing sample to quasars, only a few distinct maxima were observed. Each particular maximum was not significant statistically, but a comparison with numerical simulations clearly showed a non-random redshift distribution. The probability of the existence of three such clear peaks in random distribution was only $6 \cdot 10^{-4}$.

The periodicity existence was tested also from the point of view of capability of existence of two population of quasars. It seemed that this hypothesis was very interesting for scientists then. Plagemann et al. [73] improved the application of the PSA method used by Cowan [27]. They didn't find any periodicity after analysing sample containing 186 objects.

Burbidge and O'Dell [20] performed the similar analysis like Lake and Roeder [60] using three samples: redshift obtained from emission line only, obtained from absorption lines and mixed with two abovementioned redshift determination. Burbidge and O'Dell found the peak around $z = 0.03$, but there were no peaks around $z = 0.06$ and $z = 1.95$. They pointed out that periodicity depends on data binning. The analysis performed with bin widths of $\Delta z = 0.01$ showed random distributions. Thus, Burbidge and O'Dell concluded, "Of course, one such example proves nothing; however, it does demonstrate the difficulty in determining the reality or nonreality of small-scale features when small numbers are involved."

In 1973 Bell and Fort [9] assumed that observed quasar redshift consist of two components and can be described as:

$$1 + z = (1 + z_c) \cdot (1 + z_x).$$

where z_c - is the cosmological term, while z_x - is a redshift of unknown origin in the source. They showed that the z_x distribution for radioquasars is correlated with their absolute magnitude. They notified quantized absolute magnitude as:

$$M_v = -20.4 + 1.06 \cdot z_x.$$

Using sample of 540 strong-emission-line redshifts, Wills and Ricklefs [100] did not reveal any periodicity. Corso and Barnothy [25] obtained the similar conclusion analysing the sample of 400 objects using PSA method.

When discussing the conclusions of previous investigations that periodicity, found at a great significance level, is not a result of selection effects, Kjaergaard [59] pointed out that the appropriate statistical model has to incorporate the selection effect in order to ensure correctly determined statistical significance. He created the diagram $U - B$ vs z for typical quasars and showed that it is quite similar to the redshift histogram for quasars detected using UV excess. Moreover, he was able to show that methods of quasar selection, such as coincidence between radio and optical positions, as well as spectroscopic selection, exhibit several maxima which can be responsible for the claimed redshift periodisation.

Fang et al [36] used the PSA method and based on 1491 quasars and 58 BL Lac objects distributed in the redshift range $[1.17, 5]$ confirmed Karlsson's result. The analysis of the same sample by Box and Roeder [14] allowed them to detect the period of 0.85 in z at the significance level of 97%. However, the result could be due to the selection effect because they compared various subsamples. The periodicity of 0.205 in $\log(1 + z)$ is due to the sample cutoff for high z and to its incompleteness. The additional analysis of subsamples displayed a low level of significance, i.e. only 81%.

Depaquit et al. [33] pointed out that periodicity in the quasar redshift distribution could be the result of one of the effects described below or of their combination. These effects are:

- presence of selection effects during data sampling,
- non-randomness of quasar distribution in space,
- existence of Dopplerian and non-Dopplerian terms in redshifts.

They noted that the effects of spectroscopic selection can influence the observed discretization, but only for an optically selected sample of quasars and not for radioquasars, in which redshift discsretization is also observed.

Arp et al. [1] tested the periodicity for nine, various samples of quasars and checked if selection effects can influence on observed periodicity. They assumed that redshifts are periodic if z can be written as:

$$\Delta \ln(1+z) = 0.206.$$

This equation describes correctly the major peaks observed at $z =$ 0.30, 0.60, 0.96, 1.41 and 1.96. Their analysis showed that the formula is correct, and the periodicity is not due to selection effects during sample construction. This conclusion is based on totally different methods of subsample construction. Arp et al. [1] wrote: "If the quasar redshifts are caused by the expansion of space and large distances, then the periodicity would violate the cosmological principle that the universe must look the same from all points within it."

There were several opinions that periodicity in the quasar redshift distribution can be explained only by non-Dopplerian effects, i.e. quasar redshifts are not cosmological. Holba et al. [49] showed that effects of periodicity can be obtained also in the standard Friedmann-Lemaître-Robertson-Walker (FLRW) cosmology. The necessary condition is that the periodicity should be much smaller than the considered distance scale.

Burbidge and Napier [21] considered small redshift objects located close to each other on the celestial sphere. They constructed two samples of pairs:

- single galaxy with one close quasar,
- single galaxy with several quasars around.

At the early stage of their investigation, the search for association between bright low redshift galaxies and quasars was made in order to check non-cosmological origin of QSO redshifts. Presently, this method is used to study gravitational lensing. The existence of periodicity in $\log(1+z)$ was confirmed, yielding both previously detected maxima as well as some additional ones at $z = 2.63$, 3.45 and 4.47.

2dF QSO Redshift Survey containing over 10000 objects and 2dF Galaxy Redshift Survey with over 100000 galaxies served as an objective basis of periodicity search for quasar-galaxy pairs. The study

(Hawkin et al. [43]), being a continuation of the above-mentioned paper, was undertaken at Napier's request. Altogether 1647 objects located close ($< 200kpc$) to the low redshift galaxies with $z \in (0.1; 0.3)$ were found. Their redshift distributions is presented in Fig. 2.

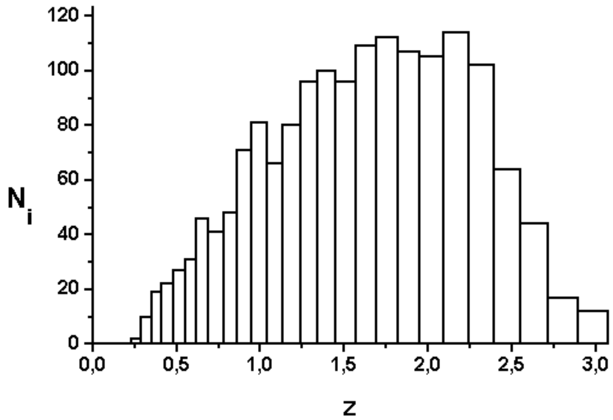

Figure 2: Distribution of QSO redshifts in Hawkins, Maddox and Merryfield's sample.

Some maxima can be observed but according to PSA they are statistically insignificant, which allows one to conclude the lack of statistically significant periodicity in quasar redshift distribution. The result concerns the investigated sample only, i.e. quasars located close, (on the celestial sphere), to low-redshift galaxies. It should be stressed here that the statistical significance of periodicity was detected for a sample of quasars selected in such a manner, but the sample was small. Therefore, it is highly probable that all previously detected periodicities are of the same origin; namely, they are due to the smallness of the samples considered. On the other hand, claims that the detected periodicity is due to selection effects were quite correct but probably we have their very complex interactions.

In conclusions, the lack of periodicity in quasar redshift distribution leaves no room for new physics.

Bell [10] considered two samples of quasars: small redshift quasars $(0.02 - 0.2)$ and high redshifts ones $(2.4 - 4.8)$ (Fig 3). The redshift distribution is non random so the priodicity exist.

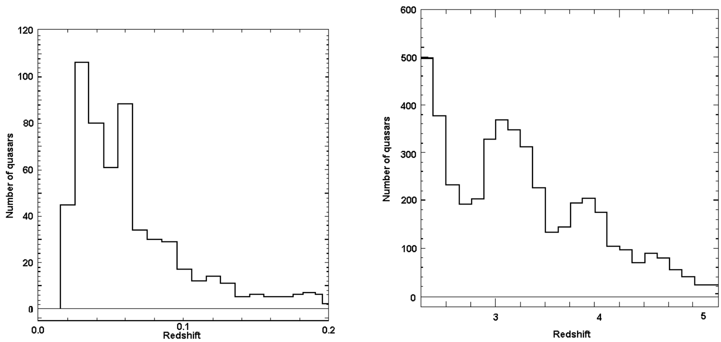

Figure 3: The quasar redshift distribution for low redshift (left panel) and high redshift (right panel) samples (after Bell [2004]).

In 2005 Basu [6] investigated sample cantaining quasars and gamma-ray bursts (GRB). GRB are objects with high redshifts. This sample was composed of 23 GRB, 9 quasars and 1 active galaxy. For these objects Burbidge [18] stated periodicity. But Basu showed that peaks and holes were the selection effects.

2.2 Galaxy redshift periodicity

2.2.1 The relation between galaxy redshift and magnitude

First studies on relations between redshift, morphological type and magnitude of the galaxy core were carried out by Tifft in 1972 [86, 87] in the Coma cluster of galaxies. It showes that galaxies lie in narrow bands on the magnitude redshift diagram, which slope down to the direction of smaller magnitudes at higher redshifts. Afterwards Tifft [88] analyzed sample contained 100 galaxies situated in the center of the Coma cluster and had been divided into two smaller ones: first contained elliptical galaxies only while second - non elliptical ones. The redshift - magnitude diagram was reanalyzed showing strong band structure. There were 70 points on the diagram from which 57 were located within the range of first three bands in the ratio of: 21 : 18 : 18. Observed effect was compared with other, more distant group of galaxies situated in the Coma cluster. In the group almost identical properties, but a bit shifted in redshift were observed. The similar effect occurs in the $(m, \log z)$ diagram for field galaxies. The statistical significance of the band structure was checked using the χ^2 test. In 1972 no physical mechanism responsible for relationship between redshift and magnitude or redshift and morphology were known, so the attitude to the problem was completely empirical.

Tifft added to his sample dimmed objects lying on the bigger area on the sky, so he obtained new sample of galaxies in Coma cluster having 108 objects. After constructed diagram he observed the band structure; there were 89 objects situated on the first three bands. This diagram suggests that galaxies are situated in subgroups along lines. In this paper the first time the power spectrum analysis was applied.

In the follwing clusters of galaxies: Coma (contained 108 objects), A2199 cluster of galaxies (33 objects) and Perseus (90 objects) [86, 88], the existence of band structure has been noted. But the idea about convergent bands has been considered only for the Coma cluster of galaxies [89].

The centre of Coma cluster of galaxies was reanalysed by Nanni et al. [67]. Redshifts were taken from Tifft's paper [88], magnitude from their own observations. They confirmed the existence of the effect, when seen from the point of convergence of the bands. But there were no effect in a direction transversal to the bands (Fig. 4). They stated the statistical significance of these bands. They claimed that this effect could be connected with the systematical errors in the redshift determinations or with some dynamical reasons.

Mentioned above investigations gave evidences that galaxy redshift is not an independent observable, it depends on some previously

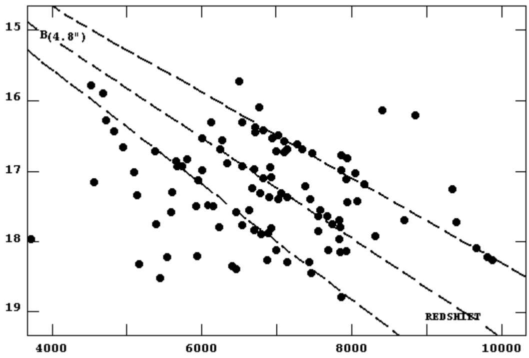

Figure 4: Nuclear blue magnitudes $B(4.''8)$ versus redshift in $km{\cdot}s^{-1}$. Taken from Nanni et al. [67]. With kind permission of Authors.

discarded factors.

2.2.2 First observational evidences of redshift discretization

The simple model of rotating galaxy is disturbed through the noncircular motions and another phenomena. Tifft [90, 91] discussed the influence of these effects on observed radial velocities of galaxies. The main problem in the early observations of radial velocities of galaxies were their precision. It was too small for testing fine effects postulated by Tifft. Tifft [90] analyzed the spiral galaxies NGC 2903, M51 = NGC 5194 and M31, noticing the existence of the areas with a difference about 75 $km \cdot s^{-1}$. Moreover, the redshift differences between neighbouring galaxies seemed to be the multiplication of $70 - 75\ km \cdot s^{-1}$. Therefore the difference in redshift among pair galaxies started to be the main target of studies.

A lot of papers studied the redshift difference in the paired galaxies. Fundamental progress was connected both with accuracy of velocity measurement and increasing number of considered double galaxies.

In 1976 Turner [98] published new catalogue with data obtained in optical way. On its base, Tifft [91] carried new analysis of all pairs with accuracy of redshifts determinations $< 100\ km \cdot s^{-1}$. The result is statistically significant: he obtained periodicity in redshift distribution with a period $72\ km \cdot s^{-1}$, $144\ km \cdot s^{-1}$ and $216\ km \cdot s^{-1}$. The next catalogue appeared in 1979 and was named the Peterson's catalogue [72]. Almost all of data received in radio way had uncertainties of measurement about $20\ km \cdot s^{-1}$. Tifft [92] considered pairs of galaxies with redshift difference $< 250\ km \cdot s^{-1}$ and uncertainty $< 50\ km \cdot s^{-1}$. He obtained strong periodicity with a period $72 \cdot n$ (where $n = 1, 2, 3$) for the whole sample.

One of fundamental case was selection of the best observational data. For example, Tifft [93] discussing 48 pairs from Peterson's catalogue [72] assumed the following criteria:

- high accuracy of velocity difference measurements ($\sigma_v < 25 km \cdot s^{-1}$),
- pairs should lie close to each other,
- one of the pair component can be double,
- redshifts measurements taken from different sources should be similar.

The application of these criteria gave the sample containing 40 pairs. He concluded that in the region around $72 \pm 18\ km \cdot s^{-1}$ were three times pairs more than outside it. Using the χ^2 test the statistical significance of this result was 99.8%. There were also populations of small peaks around $36\ km \cdot s^{-1}$ and the "zero" peak was shifted to $12\ km \cdot s^{-1}$. Unfortunately, grouping was tested in $36\ km \cdot s^{-1}$ width bins what was half of searched periodicity. In 1982, Rood [78] claimed that the "zero" peak could caused the incorrectly strong periodicity. However, obtained periodicity didn't depend on it.

In 1982 Tifft [94] finished his catalogue of pairs of galaxies. He has discovered periodicity for 200 pairs at the significance level of 99% or higher.

2.2.3 The establishment of the redshift distribution

In the eighties of the twenty century the dynamical development of observational technique was noted. The number of galaxies with known radial velocities increased as well as the precision of these values determinations. From the point of view of data analysis it was not interesting time, because the PSA method has been established as the best method using for studying redshift periodicity. Objections that have been put against the method by Newman, Haynes and Terzian [70] have found answer in Cocke and Tifft [24] work. The second method using for testing periodicity was the Bernoulli test. So, it started to be clear that possible discovering of periodicity existence is not result of applicable method. Therefore the majority of studies were concentrated on data analysis.

Researchers had access to few data catalogues in this period: Peterson's catalogue [72], Haynes data's [44] and Helou, Salpeter and Terzian [46] data's. They began using corrections for the Sun's motion (Tifft and Cocke [95], Croasdale croasdale). The Monte Carlo simulations and Kolmogorov - Smirnov (Sharp [83]) test were incorporated into PSA method. The periodicity was searched in the whole samples (Cocke [23]) or in the subsamples (Croasdale [30]). The periodicy around values: $24,15\ km \cdot s^{-1}$ (Tifft and Cocke [95], Tifft [96]), $36,3\ km \cdot s^{-1}$ (Cocke [23], Croasdale [30], Tifft [96]), $72\ km \cdot s^{-1}$ (Cocke [23]), $144\ km \cdot s^{-1}$ (Cocke [23]) and $90\ km \cdot s^{-1}$ (Cocke [23]) has been stated.

The periodicity has been observed only in the case of galactocentric radial velocities or using CMB reference frame, not in the case of heliocentric radial velocity.

In the nineties of the last century started search of periodicity in galaxies belong to structures. Guthrie and Napier [40, 69] took into account galaxies lying near to the centre of the Virgo cluster. They chose spiral and dwarf galaxies with accuracy of radial velocity about $10\ km \cdot s^{-1}$ or better. First sample contained 112 spiral galaxies with redshift $< 3000\ km \cdot s^{-1}$ and second contained 77 dwarf galaxies. For dwarf galaxies there was no periodicity. But for the whole sample of spiral galaxies they found possible periodicity around $71,1\ km \cdot s^{-1}$. Tifft hypothesis was confirmed on 0.99 significance level in assumption that Local Group velocity towards Virgo cluster is $100 - 400\ km \cdot s^{-1}$. Then sample of spiral galaxies has been divided due to its location in high or low density regions. They found strong periodicity near $71\ km \cdot s^{-1}$ in subsample of galaxies lying in regions of low density but there were no quantization in the spirals in high density regions.

89 spiral galaxies lying on the Virgo cluster periphery (Guthrie and Napier [41, 69]) constitute next sample. The strong redshift periodicity around 37.2 $km \cdot s^{-1}$ was found. But this periodicity appeared only if galactocentric redshifts were considered.

The similar study have been performed for galaxies lying at the edge of the Local Supercluster (Napier and Guthrie [68]). They used the database compiled by Bottinelli et al. [13]. They obtained sample contained 247 objects after eliminating these belonging to the Virgo cluster and non spirals. They found that redshifts of spiral galaxies were strongly periodic around 37.5 $km \cdot s^{-1}$. It should be pointed out that in all these investigations from database containing thousands of galaxies only small number of them, namely those with very accurate measurements were taken into account.

Few hypothesis about new physics were considered by them (Napier and Guthrie [68]). The redshift periodicity can be explained by the regularity of the LSC structure or applying the model of oscillation of physical parameters.

If redshifts were taken as radial velocity, one can suppose that galaxies are situated in the regular structure and galaxies have small or negligible peculiar motions, and that this structure take part in the global expansion of the Universe. This model predicts correctly the quantization ranges. If the quantization range Q is given as $Q = H_0 \cdot d$ where H_0 is the local Hubble constant, d is provided scale of the cell, then $Q = 37.5\ km \cdot s^{-1}$. In the large scale structure of the Universe the periodisation has been detected by pencil beam observation. This periodisation can be due to walls and voids between them. It is possible that within walls some aggregation of galaxies exist. So, the small scale periodisation is due to substructures. From that the size of cells can be estimated, comparing this value with light velocity c. We obtain the value 3/8 Mpc, i.e. almost 400 kpc, which corresponds to the size of compact galaxy groups. It is not clear if this hypothesis can explain the observed streaming motions, and due to accidental projection is unable to explain the periodicity around the value of 72 $km \cdot s^{-1}$ observed by Tifft for double galaxies.

Let us list other possibilities:

1. Periodic oscillation of physical constants. The gravitational constant (Morikawa [65]) and the Hubble parameter (Morikawa [66])

were considered, but the required amplitude of changes was greater than observed limits. Also the changes of fine structure constant (Hill et al. [47]) and the variability of the electron mass (Hill et al. [47]) were considered. But there is a problem in this model because periodicity can be smeared out by peculiar motion of galaxies.

2. The Holmlid [50] explanation is quite natural. Because the periodicity is observed only after applying the proper corrections to the Sun's motion, so redshifts can be quantized before they arrived to Earth. According to Holmlid, the quantization process have to occur in the intergalactic space relatively close to observed galaxy, or in the space between our Galaxy and observed galaxy. The galactic space is not empty but is filled by the 'dark matter'. This Rydberg matter is not ΛCDM considered in cosmology. This mass is named the Rydberg matter by Holmlid. In the laboratory after inducing the Rydberg matter through the laser radiation the blushift was observed. This shift became redshift due to Stokes dispersion in the cold Rydberg matter filling interstellar space. So, the galaxy redshift is a result of interaction between the radiation and the cold Rydberg matter. Holmlid claimed that observed values of redshift periodisation ($36\ km \cdot s^{-1}$, $72\ km \cdot s^{-1}$, $144\ km \cdot s^{-1}$) are the natural consequence of the structure of clouds composed from Rydberg matter.

3. In 1996 Tifft [97] considered few galaxy samples taken from the Virgo cluster, the Perseus and Cancer Supercluster regions. He examined these samples for periodicities as viewed from the cosmic background rest frame. He found strong periodicities around $72\ km \cdot s^{-1}$ and $36\ km \cdot s^{-1}$. He thought that this is global feature. As previously only objects with very accurate measurements were considered, which drastically diminished the number of galaxies in the analyzed sample.

4. Lehto [63] developed theoretical model which could predict periods of redshifts. He described basic properties of matter using 3-dimensional quantized time. The time unit is Planck time, it was named (by him) "chronon" and is given as:

$$t_0 = \frac{1}{\nu_0} = \sqrt{\frac{hG}{c^5}} = 1.3506 \cdot 10^{-43}\ s$$

where: h is Planck constant, ν_0 is frequency, which define the maxi-

mum mass and maximum energy.
The redshift quantization can be obtained in assumption that distances are quantized in Planck's units:

$$r_0 = ct_0 = 4.049 \cdot 10^{-33}\ cm.$$

Then the velocity can be written as $v_0 = \frac{r_0}{t_0} = c$. Introducing fundamental time unit and values connected with it, Lehto proposed the scheme of period doubling. The observed value of each physical parameter depends on the above mentioned units through the factor $2^{\pm D}$, where D is number of doubling. Lehto found experimentally that D could be grouped around the value $\frac{1}{3}n$, where n is an integer. On this basis, Lehto concluded that time is 3-dimensional. In connection with this redshift can be described as:

$$v = P = c \cdot 2^{-\frac{9D+T}{9}}.$$

where $T = 0, 1...8$. Because for different D and T there are different velocities, the above equation showed possible redshift periods P.

The fourth possibility is important because Tifft stressed that Lehto consideration gave him theoretical explanation of all obtained periodicity.

2.3 Large scale periodicity

In astronomy two types of surveys can be distinguished. There are either shallow surveys covering large part of the sky or very deep surveys dealing with narrow investigated area. Broadhurst et al [15] published the result of the redshift analysis of their pencil beam survey in the area of a few arc minutes around galactic poles. Surprisingly regular maxima in the redshift distribution were noticed. Fig. 5 shows the number of galaxies with a given redshift. It appeared that the peak distribution is periodic with a period of 128 $h^{-1}Mpc$ ($q_0 = 0.5$). As usually the result has been criticised due to possible observational errors and incorrectly applied statistics (Kaiser and Peacock [53], Dekel et al [32]. The additional observations quickly confirmed the reality of the effect. Broadhurst et al [15] pointed out that they result as not well established yet is uninteresting for cosmologists. The observed effect can be due to the cellular large scale structures in the Universe. The first huge region without galaxies was discovered by Kirshner et al. [58]. Latter on the regions with and without galaxies have been seen in CfA data (de Lapparent et al. [62]) and Perseus supercluster [45]. Galaxies can be distributed along the walls, encompassing depopulated regions. Such picture of matter distribution in the Universe was advocated by Einasto et al [34], who showed that the galaxy clusters, superclusters and voids constitute three dimensional supercluster - void network with characteristic size of a cell about 120 h^{-1} Mpc. Also the analysis of the redshift survey performed in Las Campanas shows the existence of periodicity in redshift distribution in the scale about 100 h^{-1} Mpc. (Landy et al. [61]). Now, due to several independent observations the existence of such network is generally accepted.

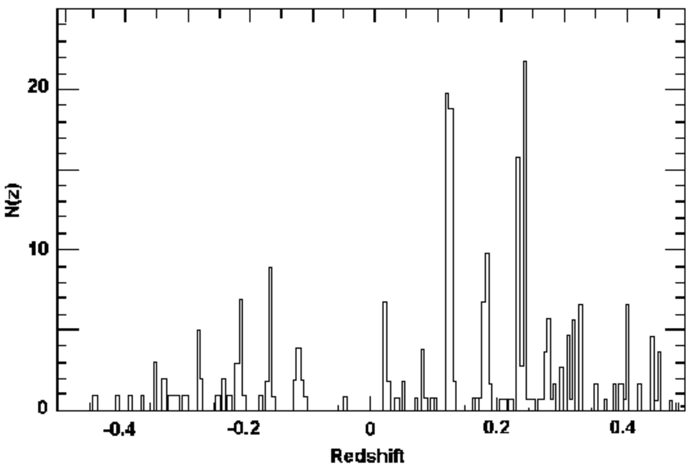

Figure 5: The redshift distribution of galaxies (after Broadhurst et al. [15]).

The correlation function and power spectrum analysis are the two

most popular methods of checking regularity in the galaxy cluster distribution. The correlation function describes structure distribution in real space, while power spectrum analysis redetects density waves in Fourier space.
When superclusters form quasi-regular cellular structure with constant cell size then the correlation function oscillates; the distance between secondary maxima and minima is equal to halved oscillation period. The period of three dimensional oscillations is equal to the size of distance in the distribution. The amplitude of the power spectrum for wavelength corresponding to the period is amplified comparing with other wavelength, which causes the existence of maxima observed as peaks. If superclusters are distributed randomly in space the correlation function is approaching to zero at great distances The power spectrum is frequently used for the comparison of observed matter distribution with that following from the theoretical considerations The power spectrum analysis is presented in Fig. 6 (Einasto et al. [34]).

The predicted shape (continuous line) of the power spectrum in the CDM (Cold Dark Matter) model changes smoothly from regions with positive spectral index for long wavelengths (small value of wave number k) to negative ones for short wavelengths. One well defined maximum for the wave number $k_0 = 0.052\ h\ Mpc^{-1}$ is seen, which corresponds to the wave length $0 = \frac{2}{k_0} = 120 \pm 15\ h^{-1}\ Mpc$. Compared with the CDM model this is very distinct excess. The supercluster - void network shows great regularity. The effect is well established to the distances about 350 $h^{-1}\ Mpc$ (Saar et al. [79]). The analysis of the correlation function for the distribution of Abell and detected in X-rays galaxy clusters shows the existence of oscillations with the period about 115 $h^{-1}\ Mpc$, which corresponds to the maximum in the power spectrum at $k = 0.005\ h\ Mpc^{-1}$ (Einasto et al. [35] , Tago et al. [85]). It is obvious that the existence of 120 $h^{-1}\ Mpc$ periodicity needs theoretical explanations. The first one was based on the simple geometrical model having concentric spheres with mutual distance about 128 $h^{-1}\ Mpc$. This model correctly describes the periodicity, but the position of the observer at the center of the Universe is weak point of the model. The acceptance of this model means the existence of the distinguishable point in the Universe, which is against the cosmological principle.

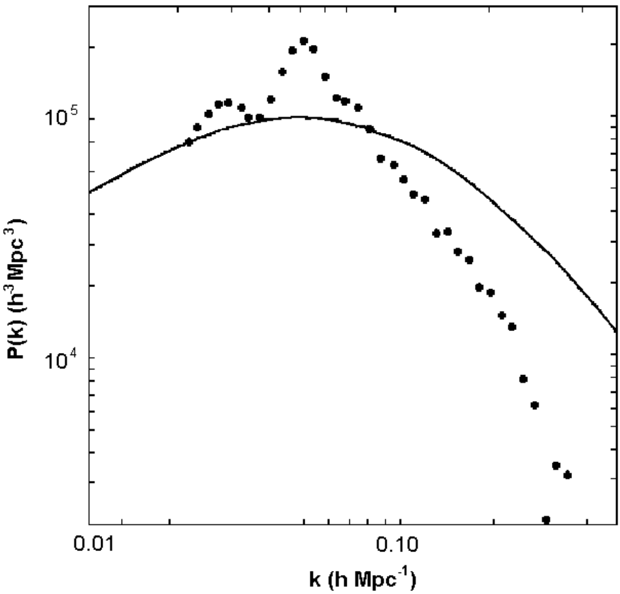

Figure 6: Power spectrum analysis for galaxy structures (after Einasto et al. [34]).

In order to avoid this unacceptable by the scientific community picture a new concept, the "spontaneous breaking of the cosmological principle" (Budinich et al. [16]) was introduced. Also the anharmonic (Crittenden and Steinhardt [29]) oscillations give maxima of galaxy counts on concentric spheres, but allowing for greater asphericity and irregularity.

Some others advocated the necessity of introduction of 'new physics'. The only known manner of elimination of such type of difficulties is assumption that the observed now apparent spatial periodicity is due to the real temporal oscillation of physical "constants" (Hill et al. [47]). Spatially uniform, but oscillating scalar field leads to the oscillations of physical constants. Due to oscillations the modulation of wavelengths or luminosity of distant objects can increase the number of observed objects, at some phase of oscillations. The distribution of number of galaxies with a given luminosity NL with distance r is given by:

$$\frac{dN_L}{dz} = \frac{dN_L}{dr} \cdot \frac{dr}{dz} = \frac{dN}{dr} \cdot \frac{dN_L}{dN} \cdot \frac{dr}{dz}$$

where r is the commoving distance , z - redshift, $\frac{dz}{dr}$ is described by the standard Hubble redshift - distance relation and $\frac{dN}{dr}$ is the distance distribution of all galaxies.

If the relations $\frac{dNL(z)}{dN}$ or $\frac{dz}{dr}$ are periodically modulated then the periodicity in the galaxy distance distribution $\frac{dN}{dr}$ is observed and the isotropy of the effect points out the existence of the regular, spherical layers encircling the observer (Crittenden and Steinhardt [29]).

The temporal periodicity is introduced through oscillation of the interaction coupling constant. This is performed adding the additional contribution of the scalar field, which presently oscillates coherently with cosmic time.

The various specific models chose different physical constant for oscillations. Morikawa [65] proposed the oscillating Universe, in which the Hubble parameter is changing with a period of 10^8 - 10^9 years, which causes the observed density fluctuations without violation of the CMB isotropy. In the considered models the physical constants were substituted by a function of the scalar field $\phi(t)$ and the expected value of this function equals the value of the corresponding physical constant. The function $\phi(t)$ oscillated around the fixed value of the constant in the potential $V\phi(t) = m^2(t)\phi^2(t)$. The oscillation period is determined by a factor $\frac{1}{m}$, which for the wavelength $\lambda = 128\ h^{-1}\ Mpc$ gives mass of the order of $10^{-31}\ eV$. The Morikawa model gives correctly density and the observed quasar redshift periodicity. The scalar field played the role of dark matter. The too small value of the age of the Universe, namely $6.4(\pm 0.2) \cdot 10^9\ h^{-1}$ years, was the main disadvantage of the model. Hill, Steinhardt and Turner [47] considered models with:

- oscillating gravitational constant,
- oscillating atomic lines (due to temporal changes of the constant find structure

- oscillating luminosity of galaxies.

The variability of the constant must be smaller than the accuracy of measurements in order to pass the test of acceptability in the considered model. They show that the oscillations of the Rydberg constant and dark matter density do not fulfill this criterion, while the postulate value of the oscillation of gravitational constant is below the measurements accuracy. The second model was elliminated because contradicted the Braginski - Panow result (Sudarski [84]).
The oscillation of galaxy luminosity is much more complicated. The luminosity of galaxies depends on number and spectral types of stars. In these considerations all astrophysics is involved. In the speed of thermonuclear reactions and the energy transport also standard physical constants occur. Therefore new particles as axions and massive neutrinos are needed for correct explanation of modified transport equations. Moreover, the additional mechanism responsible for oscillation must be introduced. So, the hypothetical particles with the hypothetical cosmological scalar field should be coupled. Moreover, the oscillation of charge and/or electron mass are in conflict with equivalence principle. The other possibility was a peculiar velocity field with small amplitude $\delta_c/c \cong 3 \cdot 10^{-3}$ and period 128 h^{-1} Mpc (Hill et al. [48]). This amplitude is close to the observed in our nearby Universe value of large scale streaming motion of galaxies toward the Great Attractor ($V_r < 10000$ $km \cdot s^{-1}$).

Therefore, the other explanations of the large scale periodicity based mainly on oscillation of the gravitational constant (Salgado et al. [80], Faraoni [37], Quevedo [75]). The weakly interacting massive scalar fields nonminimally coupled with gravitation are introduced, which causes the oscillation of gravitational constant. The different attempt was proposed by Chizhov and Kirilova [22]. They developed the mechanism connected with origin of baryons, proposed by A.D. Dolgov and collaborators based on spontaneous or stochastic symmetry breaking. With some additional assumptions, this mechanism of baryon density perturbations, can lead to the origin of the observed large scale periodicity in the distribution of visible matter.

Apart from papers connected with 'new physics' where are also papers when the large scale periodicity is explained using conventional physics. In introduction to this section there are some classical papers showing how from the analysis of observational data the large scale distribution of matter is reckon. These papers show that in the large scale distribution of galaxies and structures formed from them the characteristic scale of the distribution is somewhat greater than 100 h^{-1} *Mpc*. Numerical simulations also supported this picture of the distribution. The very small probability (10-8) that the observed distribution of matter is random one also suggest the relationship with large scale distribution of galaxies (Gonsales et al. [39]). The other explanation of periodicity is connected with the solution of the equation of motion of the zero mass particle moving in the expanding, isotropic Universe (Bajan et al. [2], Biernacka et al. [12]).

2.3.1 The possible explanation of the large scale periodicity

We present an explanation of the large scale periodicity using a toy model (Biernacka et al. [12]). Let us consider the solution of the Kepler problem, this is the equation of motion of a zero energy particle moving in a central gravitational field in the homogeneous and isotropic expanding Universe. The standard Friedman-Lemaitre-Robertson-Walker (FLRW) metrics is used.

The Newtonian motion of a particle in gravitational field with FLRW metrics is:

$$(ds^2) = (dt)^2 - \sum_i a^2(t)(dx^i)^2. \tag{1}$$

The observed coordinates X^i in the expanding Universe are:

$$X^i = a(t)x^i, \; dX^i = a(t)dx^i + x^i da(t), \tag{2}$$

when instead of the differential of the Euclidean space dX^i the co-variance differential of the FLRW space coordinates :

$$a(t)dx^i = d[a(t)x^i] - x^i da(t) = dX^i - X^i \frac{da(t)}{a(t)}$$

was used.
The equation (1) in terms of variables (2) is:

$$(ds^2) - (dt)^2 - \sum_i (dX^i - H(t)X^i dt)^2 \tag{3}$$

where $H(t) = \frac{\dot{a}(t)}{a(t)}$ is the Hubble parameter. The classical Newton action in the space with the interval (3) and the covariant derivative $\dot{X}^i - H(t)X^i$ can be written as:

$$S_A = \int_{t_I}^{t_0} dt[\sum_i (P_i(\dot{X}^i - H(t)X^i) - \frac{P_i^2}{2m_I}) + \frac{\alpha}{\sqrt{X_i X^i}}] \qquad (4)$$

where $\alpha = M_{\bigcirc} m_I G$ is a constant of a Newtonian interaction of a particle having a mass m_I located in a gravitational field with central mass $M_{\bigcirc}$. In the terms of conformal time $d\eta = \frac{dt}{a}$ in effective units $r = \sqrt{x_i x^i} = \frac{R}{a}$, $P_r = P_R a$ the action (4) is:

$$S_A = \int_{\eta_I}^{\eta_0} d\eta[P_r \frac{dr}{d\eta} + P_\theta \frac{d\theta}{d\eta} - \frac{P_r^2 + P_\theta^2/r^2}{2m} - \frac{\alpha}{r}]$$

where $m = a(\eta)m_I$.

Let us consider a particle moving in a plane in the cylindrical coordinates:

$$X^1 = R\cos\Theta,$$
$$X^2 = Rsin\Theta$$

In the gravitational field with Schwartzschild metrics:

$$ds^2 = (1 - \frac{2\alpha}{mr})dt^2 - \frac{dr^2}{1 - 2\alpha/(mr)} - r^2\sin(\theta)^2 d\theta^2$$

In the case of rigid state when energy and pressure densities are equal: $a(\eta) = \sqrt{1 + 2H_I(\eta - \eta_I)}$, where H_I is the initial value of the Hubble velocity (Behnke et al. [8]).

Then, the action is:

$$S_{schw} = \int_{\eta_I}^{\eta_0} d\eta[P_r \frac{dr}{d\eta} + P_\theta \frac{d\theta}{d\eta} - Q_{schw}\sqrt{P_r^2 Q_{schw}^2 + P_\theta^2/r^2 + m^2} + m] \qquad (5)$$

where $Q_{schw} = (1 - \frac{r_g m_I}{rm})^{1/2}$, $r_g = M_\odot G$ and P_r, P_0 are conjugate impulses in corresponded coordinates.

The path of the considered particle is given in Fig. 7 The total energy of a system defined in equation (5) can be written as:

$$E = Q_{schw}\sqrt{P_r^2 Q_{schw}^2 + P_0^2/r^2 + m^2} - m$$

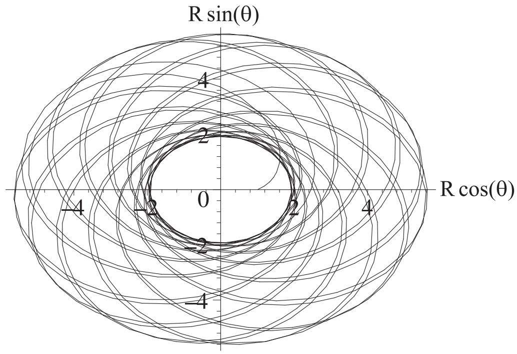

Figure 7: The probable motion of zero energy particle in expanding gravitational field (Biernacka et al. [12]).

and at the initial point $\eta = \eta_I$ ia chosen as equal zero. The trajectories begin at the point (1.0). It is quite easy to see that the probability of finding a particles in some places is greater than in others. It was shown that in the expanding FLRW Universe with the assumed rigid state of matter it is possible to obtain structure formation from the initially uniform distribution of zero mass particles. So, this mechanism can be responsible for the formation of the cellular structures in the Universe. The fine tuning allows to find distribution when high density regions are separated by 130 Mpc.

3 Method of analysis

In our investigations we used the power spectrum analysis (PSA) (Yu and Peebles [101], Webster [99], Guthrie and Napier [40]) together with the Rayleigh test (Mardia [64], Batschelet [7]). Newman et al [71] showed that PSA is very useful for finding periodicity among irregularly distributed points. The second method: the Rayleigh test (Mardia [64], Batschelet [7]) is a simple test of uniformity, which also allows to detect periodicities in the irregularly distributed points. For a given frequency the Rayleigh power spectrum corresponds to the Fourier power spectrum as well as it measures the probability of the existence of a sinusoidal component.

Let us assume that m points are distributed along a finite line with coordinates x_i, where $i = 1, \ldots, m$. We can define the phase with respect to the period P:

$$\Phi_i = 2\pi x_i / P.$$

The phase Φ_i which corresponds to the i-th x coordinate unambiguously describes the radius vector I_i.

The length of the vector R, being the sum of all I_i vectors, can be used for testing isotropy of the distribution of points x_i with respect to the period P:

$$R(P) = \sum_{i=1}^{N} I_i(P).$$

From the formal point of view the vector R describes a random walk in the plane after m steps.

We use the statistic R^2 defined by:

$$R^2(P) = \left(\sum_{i=1}^{N} \cos \Phi_i \right)^2 + \left(\sum_{i=1}^{N} \sin \Phi_i \right)^2 .$$

The probability distribution of R^2 can be calculated from the null hypothesis:

$$p_i d\Phi = \frac{d\Phi}{2\pi} \qquad\qquad \Phi \in (0, 2\pi),$$

where $p_i(\Phi)d\Phi$ is the probability that the phase Φ_i corresponding to the point x_i is located in the interval Φ and $\Phi + d\Phi$. The distribution of R^2 corresponds to the Fourier power spectrum for the function $f(\Phi) = \sum \delta(\Phi - \Phi_i)$.

It is known that the variable:

$$s(P) = \frac{2R^2}{m},$$

has the distribution (Webster [99]):

$$p(s, m)ds = ds(m/4) \int_0^\infty J_o^m(\omega) J_o(\omega \sqrt{ms/2}) \omega d\omega,$$

where J_o is a Bessel function.

The distribution $p(s, m)$ is calculated numerically by integrating approximations of the Bessel function using the Romberg method (Press et al. [74]). For large m it could be also aproximated as a χ^2 distribution with 2 degrees of friedom.

Error bars of $s(P)$ can be estimated using the "jackknife" technique of drawing all possible samples of $N-1$ values from the N data points, repeating the power spectrum analysis on these samplings. Such a procedure allowed us to calculate the standard deviation in the derived values of s $\sigma_j(P)$. The best estimator for the standard errors in the value of s is then just $\sqrt{N-1}\sigma_j$ (Hawkins et al. [43]).

The simulation of the power spectrum for random uniform distributed data is presented on the Figure 1. The diagrams showing values of the s-statistics versus $\frac{1}{P}$ present the result of power spectrum analysis. On each diagram there are several peaks. These peaks allow one to find each possible period, as well as to investigate the significance of each particular peak in the power spectrum. The level of significance of each peak is given by $C = 1 - pn_t$, where p is the probability of obtaining from the theoretical, random distribution, the value of the s-statistic equal to or greater than the observed value of the s-statistic, while n_t is the number of independent peaks within the analyzed frequency range (Guthrie and Napier [41], Lake and Roeder [60]).

The additional test increasing the efficiency of the test for weak clustering, following (Webster [99], Scott [81]) is based on the summation over the whole power spectrum. This sum gives the value $SI = \sum s_i$, having a χ^2 distribution with $2n_t$ degrees of freedom. So, the expected value of the SI statistic is $2n_t$. The SI-test can be used for testing the randomness of the distribution.

The clustering statistic Q is equal to the value of the SI-statistics over its expected value. The expected value of Q statistic in the case of a random walk ($2n_t$) is calculated. For a random distribution the expected value of Q is equal to 1, with an error: $\sigma(Q) = \frac{1}{\sqrt{n_t}}$ (Webster [99]). We tested the hypothesis that the value of Q is greater than unity rather than equal to this value. We decided to consider in our analysis the first 50 peaks. In this case, at the significance level 0.05 the critical value of the SI statistic is 124.3, while 135.8 for significance level 0.01. Please also note that $\sigma(Q) = 0.14$.

Newman et al [71] pointed out that Yu and Peebles' version of PSA can be correctly applied only when a uniform distribution function is tested. As see from Figure 2 such an approximation could be accepted for raw data but not when correction for the solar motion is included.

Hawkins et al. [43] discussed the power spectrum method when the data are not uniformly distributed. They proposed to use the window function, and showed that power spectrum method works well in that case. Now the power of s at the period of P is given via formulae (Hawkins et al. [43]):

$$s(P) = 2R^2 / \sum_{i=1}^{N} w_i^2,$$

where

$$R^2(P) = (\sum_{i=1}^{N} w_i \cos \Phi_i)^2 + (\sum_{i=1}^{N} w_i \sin \Phi_i)^2,$$

Following Hawkins et al. [43] we repeat our analysis using the Hann function as a weighting:

$$w_i = \frac{1}{2}\left[1 - \cos\left(\frac{2\pi x_i}{L}\right)\right]$$

where L is chosen to cover the range over which the data are selected.

It should be pointed that now the expected value of the clustering statistic Q is not necessary equal to 1 especially for the small number of points. We give 1000 simulations for the normal distributed data with variance taken from the real data with correction a. We find that in the case of sample I (46 galaxies) the mean value of Q is equal to 1 but $\sigma(Q) = 0.195$. For sample II (28 galaxies) the mean value of Q decreased and is equal to 0.90 but σ (Q) = 0.177. It mean that noise value of $s = 2$ (see Hawkins et al. [43]) is slightly change. The example of the simulation of the power spectrum for normal distributed data weighted using a Hann function is presented on Figure 3. On can see that when the data are apodized, the expected height of the peak decreased.

4 Our investigations of galaxy redshift periodicity

4.1 Local Group of Galaxies

There is no common agreement which galaxies belong to the dynamical aggregate named the Local Group of Galaxies (LG). To our investigation we took 55 objects in our neighborhood taken from Irwin's list (Irwin [51]) together with 7 galaxies, mostly with Maffei group, which could also *probably* be regarded as the LG members (Iwanowska [52]). But Van den Bergh [11] concluded that only 32 objects can be the LG members while 3 further objects can be regarded as possible the LG members. So, we decided to perform all calculations using these two sets of data.

It should be noted that in the van den Bergh list there are 7 galaxies (not including Phoenix) without redshift while in Irwin's list are 2 more such objects (Cetus and Cam A). So for further analysis we took 28 and 46 galaxies, respectively.

The newest data allow us to find redshifts for 8 of the total 9 galaxies which have unknown redshifts, when the analysis presented here began. We repeated the analysis with these objects considered. However, we decide to exclude Tucana because its radial velocity measurement is uncertain. Moreover, for two galaxies, new version of the Irvin's list replace old redshift (NGC 147 157 $\mathrm{km \cdot s^{-1}}$ and NGC 221 190 $\mathrm{km \cdot s^{-1}}$) by the new one. We do not also include to our analysis Cam A (noted in NED as uncertain, no errors determined). Finally, adding 6 galaxies to Irvin's and van den Bergh's lists we obtain samples of 45 and 34 galaxies respectively. After these changes we took five samples containing 46, 28, 39, 45 and 34 galaxies, into further consideration.

The heliocentric radial velocity of galaxy should be corrected relative to the Sun's motion around the Galaxy center and/or around the center of Local Group. In our paper (Godlowski et al. [38]) we applied 11 different corrections taken from different authors. For example:

1. the galactocentric reduction: $v = 232\ km \cdot s^{-1}$, $l = 88^o$, $b = 2^o$ (Guthrie and Napier [41]),
2. the galactocentric reduction: $v = 213\ km \cdot s^{-1} \pm 10\ km \cdot s^{-1}$, $l = 93^o \pm 3^o$, $b = 2^o \pm 5^o$ (Guthrie and Napier [42]),
3. the pure heliocentric reduction ($v = 0\ km \cdot s^{-1}$, $l = 0^o$, $b = 0^o$),
4. the velocity obtained from the Sun's motion relative to the LG center: $v = 306\ km{\cdot}s^{-1} {\pm} 18\ km{\cdot}s^{-1}$,$l = 99^o{\pm}5^o$, $b = -3.5^o{\pm}4^o$ (Courteau and van den Bergh [26]),

5. the cosmocentric reduction (Cosmic Microwave Background reference frame): $v = 369\ km \cdot s^{-1}$, $l = 264.7^o$, $b = 48.2^o$

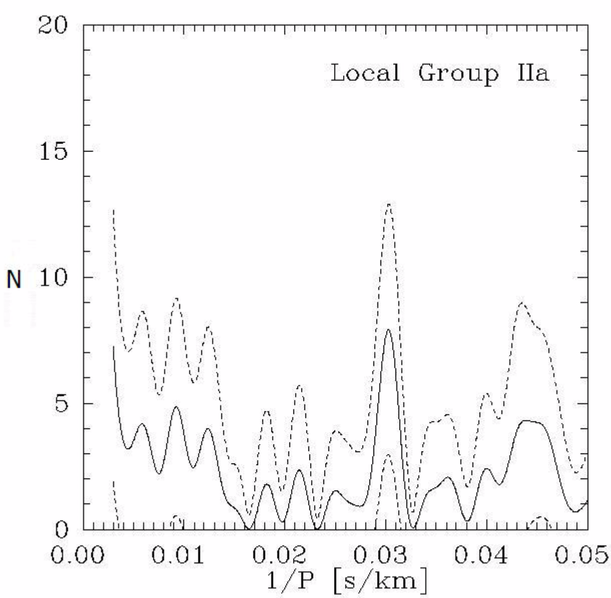

Figure 8: The result of PSA analysis for Local Group of galaxies (sample: 28 galaxies from the van den Bergh list, correction of the radial velocity: 1) (Godlowski et al. [38]).

The distribution of galaxy redshift seem to be non-random when correction for motion of Sun relative to center of our Galaxy is taken to account. An excess of galaxies with radial velocities of 24 $km \cdot s^{-1}$ and 36 $km \cdot s^{-1}$ is detected, but the effect is statistically weak. Only peak for radial velocities 24 $km \cdot s^{-1}$ seem to be confirmed on the confidence level 95%.

With reduction for motion of the Sun relative to LG we obtain no periodisation.

4.2 Hercules Supercluster

We also discussed the distribution of radial velocities of galaxies belonging to the Hercules Supercluster. Our sample contained 2522 galaxies with radial velocities in the range (7500, 15000) $km \cdot s^{-1}$ beeing complete in 80%. As in above case we used PSA to analysis that sample. We used 5 velocity corrections presented above.

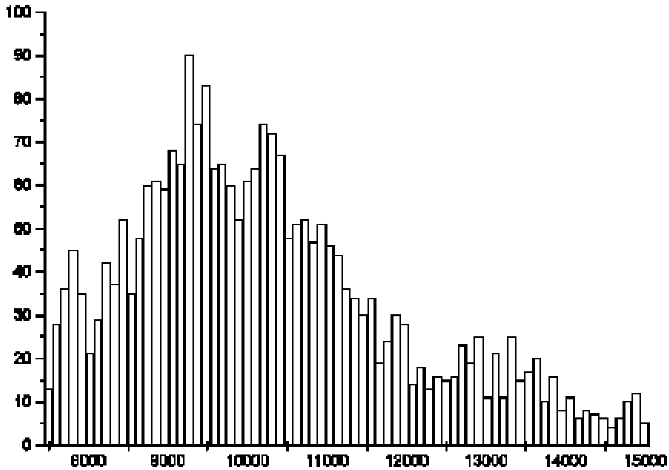

Figure 9: The distribution of radial velocities in the Hercules Supercluster.

Although, it seemed that the maxima occuring in the fig 10 are clear (peaks around 73 $km \cdot s^{-1}$ and 24 $km \cdot s^{-1}$), the probability that they are coming from non - random distribution is 95%, which means that they are at 2σ significance level.

4.3 Conclusions

In our opinion the existence of redshift periodicity among galaxies is not well established. The earlier results are based on a very small

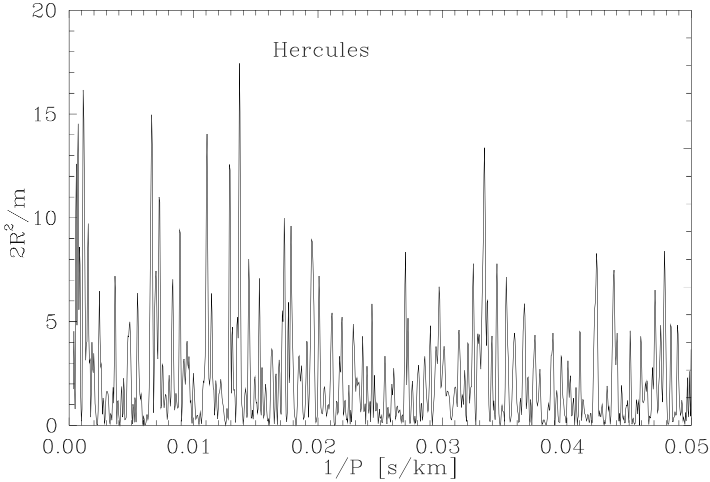

Figure 10: The result of the PSA analysis for the Hercules Supercluster members.

fraction of objects extracted from the large databases. At the early stage of investigations such approach was the correct one because errors of individual measurement were great. Presently, the radial velocities of galaxies are determined in an industrial manner. The accuracy of radial velocity determination is good enough for considering all galaxies. Therefore, we chose this manner of data treatment. Our samples are greater because we considered all galaxies. Measurements with lower accuracy could smear out the regularities, but regularities are not introduced artificially.

Previous result, based on selected samples showed the existence of the periodicity in the galaxy redshift distribution on very high significance level. We found that, at 2σ significance level some effect is observed. We think that the solution of this curious phenomenon can be solved in the nearest future, using large data base, which together with such correct method as PSA will allow one to estimate the significance of the effect as sufficiently convincing level. We expect also that after clear and convincing showing of the existence of the effect, theoretical explanations of this phenomenon can be performed.

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Comment by

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The paper of Bajan and Flin (BF hereafter) is connected with one of the important problem of modern astronomy — the existence or not redshift discretisation. This concept is pretty controversial. Results of the different papers give antagonistic results. Some authors claimed that redshift periodisation hypothesis is strictly confirmed, while other denied this. From the theoretical point of view some authors pointed out that the redshift periodisation force us to accepted the existence of "new physics", while other tried to explain this phenomenon on the ground of "classical physics". From the other hand some scientist claimed there is no "theory" allowing one understanting how quantisation will manifest itself. Such persons usually don't belive in the reality of the redshift periodisation and sugested that all evidences for it are wrong, or at least, missinterpreted. On of the most positive feature of the paper BF paper is that the authors discuss the state of the art and discuss it non-judgementally and objectively.

The story of redshift periodisation or regularities started in 1967 started in 1967 with the paper Burbidge & Burbidge (1967) (not as BF quoted with Burbidge (1968)). Burbidge (1968) noted the existence of sharp peaks in quasar redshift distribution, grouped around the values of $z = 0.01$ and $z = 1.95$. He also found periodicity in the redshift distribution, which can be described by the formula $z = 0.01 \cdot n$.

The investigations tested either strict quantization, that is precise multiplication of the some strict value of redshifts, or (usually with help of the power spectrum analysis) the effect of periodisation, i.e. the grouping of objects radial velocities around some values.

During the next years, the effect of periodisation was either confirmed or denied on the basis of incorrectly applied statistics and/or possible selection effects. The selection effects have been discussed by many authors. Some of them, (e.g. Karlsson 1971), claimed that the observed redshift distribution is not due to the selection effects, while other authors (e.g. Basu 2005) expressed the opposite opinion. For example Burbidge and Napier (2001) took into account a new sample of high redshift quasars located close (in the projection on the celestial sphere) ($\leq 10^{''}$) to the low redshift galaxies. They claimed that existence of periodicity in the $\log(1 + z)$ scale, was confirmed. Opposite result was obtained by Hawkins, Maddox & Merrifield (2002). Investigating 1647 objects, they found no periodicity for quasar-galaxy pairs. Their null result is due to taking into account the window function with "jackknife" technique which should be done for samples with non-uniform density distribution with distance. This is the main reason of such results, contrary to BF statement that this occurs due to large sample. By this way BF also use this technique in their redshift studies. Their weak 2σ periodicity in both investigated structures (Local Group and Hercules Supercluster) can be due to this approach. Other result was resently obtained by Bell (2004). He used two quasar samples, one with high redshifts $2.4 - 4.8$ and the other with low redshifts $0.02 - 0.2$. He showed that all peaks in these two redshift distributions occur at the previously predicted preferred values. One of the latest work on redshift periodicity was done by Basu (2005). He investigated the same 33 objects (GRBs, QSO and active galaxy) as Burbidge (2003) and contrary to Burbidge, claimed that all existing peaks are due to selection effects.

Started with the work of Tifft (1976) there are also many papers discussing galaxy redshift quantization. He analised the redshifts of galaxies in the Coma cluster and claimed that were maxima being preferentially in multiplication of $72.46\,\mathrm{km \cdot s^{-1}}$. A few years later, the existence of global periodicity was reported (Tifft & Cocke 1984); however, the period was not $72\,\mathrm{km \cdot s^{-1}}$, but $36\,\mathrm{km \cdot s^{-1}}$ or possibly $24\,\mathrm{km \cdot s^{-1}}$.

Therefore, it is very important to check if the discretisation does occur. I share the opinion expressed by Hawkins et al. (2002) that all these effects should be carefully checked. They claimed:

"The criticism usually leveled at this kind of study is that the samples of redshifts have tended to be rather small and selected in a heterogeneous manner, which makes it hard to assess their significance. The more cynical critics also point out that the results tend to come from a relatively small group of astronomers who have a strong prejudice in favour of detecting such unconventional phenomena. This small group of astronomers, not unreasonably, responds by pointing out that adherents to the conventional cosmological paradigm have at least as strong a prejudice towards denying such results.

We have attempted to carry out this analysis without prejudice. Indeed, we would have been happy with either outcome: if the periodicity were detected, then there would be some fascinating new astrophysics for us to explore; if it were not detected, then we would have the reassurance that our existing work on redshift surveys, etc, has not been based on false premises." This important quotation is also noticed in the BF paper

BF discuss the problem of the discretisation of redshift for astronomical objects independently for three cases, namely galaxies, quasars and large-scale periodicity ($120h^{-1}$ Mpc). The last problem is connected with the fact that in the large-scale Universe, one aspect of the any regularities in structure appearence is connected with radial velocities of galaxies. These velocities can have arbitrary values. Regular patterns can be regarded as periodisation, discretisation or quantization of galaxy redshifts. BF analised in details sources of possible seclection effect which may influence the results obtained by different authors. Unfortunately BF did not conclude presenting their opinion in this matter.

Another very important question conected with the analised topic is, if there are any theoretical predictions leading to redshift periodisation. This subject is very controversial, not popular and usually very suspicious at first glance. However, on the basis of the claimed results of redshift periodisation, several theoretical papers pointed out the necessity for so-called new physics. BF discuss in their paper possible theoretical explanation of the analised phenomenon.

In the early stage of these studies, association between bright low-redshift galaxies and quasars was used for checking the non-cosmological origin of QSO redshifts, as well as to test the possibility of ejection of QSO from parent galaxies, which is a problem investigated even now (Bell 2004). Usually, the galaxy redshift quantisation is interpreted in favour of origin non-cosmological redshift. Moreover, there are suggestions that clusters of quasars evolved into clusters of galaxies, so the galaxy redshift distribution should reflect this fact.

Tifft (1996) sugested another idea for explaining of the investigated problem. He claimed that galaxy redshift distribution has periodic character, because time is quantized. If this effect is global, it means that it should be observed in all galaxy structures.

The large scale periodicity in the scale $120h^{-1}$ Mpc can be due to the distribution of galaxies in the Universe or oscillation of physical constants. The authors showed also the possibility of obtaining such distribution of objects considering the Kepler problem in the expanding Universe. It should be pointed out that in such approach some elements of the chaotic behaviour are present. Due to this fact the solutions presented on the BF Fig. 7 densely cover the plane. In the natural way maxima in the density distribution are occuring, which causes the periodisation of the object location. More detailed analysis of the problem with estimation of the scale would be very interesting.

Finally, I conclude that the Bajan and Flin paper is very interesting and clearly presents the state of the art of the redshift discretisation problem.

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