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ON THE INVESTIGATIONS OF GALAXY REDSHIFT PERIODICITY

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In this article we present a historical review of study of the redshift periodicity of galaxies, starting from the first works performed in the 1970s until the present day. We discuss the observational data and methods used, showing in which cases the discretization of redshifts was observed. We conclude that galaxy redshift periodization is an effect which can really exist. We also discussed the redshift discretization in two different structures: the Local Group of galaxies and the Hercules Supercluster. Contrary to the previous studies, we consider all galaxies which can be regarded as a structure member disregarding the accuracy of velocity measurements. We applied the power spectrum analysis using the Hann function for weighting, together with the jackknife error estimator. In both structures we found weak effects of redshift periodization.

В этой статье мы представляем исторический обзор изучения периодичности красного смещения галактик, начиная с первых работ, выполненных в семидесятых годах прошлого столетия, и заканчивая сегодняшним днем. Обсуждаются данные наблюдений и используемые методы, при этом показывается, в каких случаях наблюдалась дискретизация красного смещения галактик. Делается вывод, что периодизация красного смещения галактик есть реально наблюдаемый эффект. Мы также обсуждаем дискретизацию красного смещения в двух различных структурах: локальной группе галактик и сверхскоплении Геркулеса. В отличие от предыдущих исследований изучаются все галактики, в т. ч. и те, которые могут быть рассмотрены как элементы структуры, не учитывающие точность измерений скорости. Мы применяем анализ степенного спектра, используя для взвешивания функцию Ханна и оценивая ошибки т. н. методом «складного ножа». В обеих структурах мы находим слабые эффекты периодичности красного смещения галактик.

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INTRODUCTION

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

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

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

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

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

These velocities can have an arbitrary value or they can be grouped around some particular values. Any distribution of galaxy velocities can be described using a continuous or discrete 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 a distribution is called, not very correctly, redshift discretization. The second case is the exact discrete distribution. Radial velocities of galaxies can have only a discrete value. This is a strict quantization of radial velocities. If an object with redshift, which is not a strict multiplication of a periodization value, is sometimes observed, this is due to observational errors. Both the above-mentioned possibilities are called periodization or discretization. The discretization of redshift for astronomical objects can be discussed independently for three cases, namely, galaxies, quasars and large-scale periodicity (about 120 Mpc). In our previous paper [1], the quest for quasar redshift periodicity is described, while the latter studies have been discussed in [2].

In the present paper, we present the investigations of radial velocities of galaxies.

The subject of redshift periodization is not very popular, sometimes even regarded as scientifically suspicious. However, we share the opinion expressed by Hawkins et al. [13] 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 tended to be rather small and were selected in a heterogeneous manner, which makes it hard to assess their significance». 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, respond by pointing out that adherents to the conventional cosmological paradigm have at least a strong prejudice towards denying such results.

We have attempted to carry out this analysis without prejudice. Indeed, we would be 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.

We think that for better understanding of the subject it is necessary to give a review of the obtained results, together with the manner of their receiving. Therefore, in this paper we present this story.

1. THE RELATION BETWEEN GALAXY REDSHIFT AND MAGNITUDE

First studies on relation between redshift, morphological type and magnitude of the galaxy core were carried out by Tifft in 1972 [28, 29] in the Coma cluster of galaxies. They showed that galaxies lie in narrow bands in the magnitude redshift diagram, which slope down in the direction of smaller magnitudes at higher redshifts. A year later Tifft [30] analyzed a sample of about 100 galaxies situated in the center of the Coma cluster. He divided this sample into two smaller ones: first contained elliptical galaxies only, while the second, nonelliptical ones. The redshift-magnitude diagram was reanalyzed showing a strong band structure. In this diagram there were 70 points from which 57 were located within the range of first three bands in the ratio of: $21 : 18 : 18$. The observed effect was compared with another, more distant group of galaxies situated in the Coma cluster. In the group, almost identical properties but a bit shifted in redshift were observed. A 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 was known, so the attitude to the problem was completely empirical.

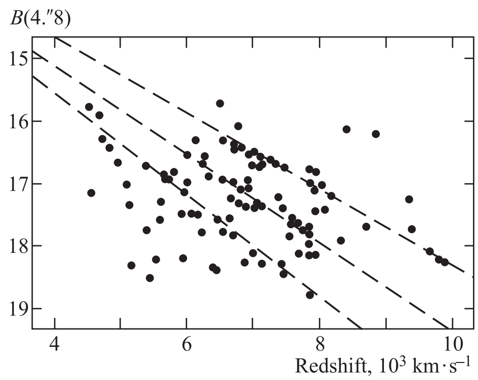

Fig. 1. Nuclear blue magnitudes $B(4.''8)$ versus redshift. Taken from Nanni et al. [22], with a kind permission of authors

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

The existence of the band structure has been shown in the following clusters of galaxies: Coma (contained 108 objects), A2199 cluster of galaxies (33 objects) and Perseus (90 objects) [28, 30]. However, the idea about convergent bands has been considered only for the Coma cluster of galaxies [31].

Nanni et al. [22] reanalyzed the centre of the Coma cluster of galaxies. Redshifts were taken from Tifft's article [30], magnitude — from their own observations. They confirmed the existence of the effect, if seen from the point of convergence of the bands. But there was no effect in a direction transversal to the bands. 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.

The above-mentioned investigations gave evidence that galaxy redshift is not an independent observable, it depends on some previously discarded factors.

2. FIRST OBSERVATIONAL EVIDENCE OF REDSHIFT DISCRETIZATION

A simple model of rotating galaxy is disturbed through noncircular motions and other phenomena. Tifft [32,33] discussed the influence of these effects on the observed radial velocities of galaxies. The precision was the main problem in the early observations of radial velocities of galaxies, because it was too small for testing the effects postulated by Tifft. He [32] analyzed the spiral galaxies NGC 2903, M51 = NGC 5194 and M31, noticing the existence of the areas with a difference of about 75 $\text{km}\cdot\text{s}^{-1}$. Moreover, the redshift differences between the neighbouring galaxies seemed to be the multiplication of 70–75 $\text{km}\cdot\text{s}^{-1}$. Therefore, the difference in redshift among pair galaxies started to be the main target of studies.

There are many articles which studied the redshift difference in the double galaxies. The authors considered newer and better catalogues of galaxies. Fundamental progress was connected with both the accuracy of velocity measurement and an increasing number of considered pairs.

In 1976 Turner [40] published a new catalogue with data obtained in an optical way. On its base, Tifft [33] carried a new analysis of all pairs with the accuracy of redshifts determinations < 100 $\text{km}\cdot\text{s}^{-1}$. The result is statistically significant: he obtained periodicity in redshift distribution with a period 72, 144 and 216 $\text{km}\cdot\text{s}^{-1}$. In 1979 the new data appeared: Peterson's catalogue [26]. Almost all of the data received in radio way had uncertainties of measurement about 20 $\text{km}\cdot\text{s}^{-1}$. Tifft [34] considered pairs of galaxies with redshift difference < 250 $\text{km}\cdot\text{s}^{-1}$ and uncertainty < 50 $\text{km}\cdot\text{s}^{-1}$. He obtained strong periodicity with a period $72n$ (where $n = 1, 2, 3$) for the whole sample.

In 1982 Tifft [35] working with double galaxies introduced a few new criteria which led to a sample containing 40 galaxies out of 48 objects. He concluded that in the region around (72 ± 18) $\text{km}\cdot\text{s}^{-1}$ there were three times more pairs than outside it. The statistical significance of this result is 99.8% using the χ^2 test. There were also populations of small peaks around 36 $\text{km}\cdot\text{s}^{-1}$ and the «zero» peak was shifted to 12 $\text{km}\cdot\text{s}^{-1}$. Unfortunately, grouping was tested in 36 $\text{km}\cdot\text{s}^{-1}$ width ranges which was half the searched periodicity.

In 1982 Tifft [36] finished his catalogue of pairs of galaxies. He discovered periodicity for 200 pairs at the significance level of 99% or higher.

3. THE ESTABLISHMENT OF THE REDSHIFT DISTRIBUTION

In the 1980s the dynamical development of observational technique was noted. The number of galaxies with known radial velocities increased as well as the precision of determining this value. From the point of view of data analysis it was not an interesting time, because the PSA method was established as the best method used for studying redshift periodicity. Objections that were put against the method by Newman, Haynes and Terzian [25] found an answer in Cocke and Tifft's [6] work. The second method used for testing periodicity was the Bernoulli test. So, it started to be clear that possible discovering of periodicity is not a result of method applied; therefore, the majority of studies were concentrated on data analysis.

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 [9], we applied 11 different corrections taken from different authors. For example:

1. The galactocentric reduction: $v = 232$ $\text{km}\cdot\text{s}^{-1}$, $l = 88°$, $b = 2°$ [11].
2. The galactocentric reduction: $v = (213 \pm 10)$ $\text{km}\cdot\text{s}^{-1}$, $l = (93 \pm 3)°$, $b = (2 \pm 5)°$ [12].
3. The pure heliocentric reduction: $v = 0$ $\text{km}\cdot\text{s}^{-1}$, $l = 0°$, $b = 0°$.
4. The velocity obtained from the Sun's motion relative to the LG center: $v = (306 \pm 18)$ $\text{km}\cdot\text{s}^{-1}$, $l = (99 \pm 5)°$, $b = (-3.5 \pm 4)°$ [7].
5. The cosmocentric reduction: $v = 369$ $\text{km}\cdot\text{s}^{-1}$, $l = 264.7°$, $b = 48.2°$.

Moreover, it was discovered that the effect of redshift discretization appeared not only in the galactocentric frame of reference but also in CMB (correction number 5).

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

In this period, researchers had an access to a few data catalogues: Peterson's catalogue [26], Hayne's data [14], Helou, Salpeter and Terzian's data [15]. They began using corrections to the Sun's motion [8,37]. The Monte Carlo simulations and Kolmogorov–Smirnov test [27] joined to PSA method. The periodicity was searched in the whole samples [5] or in the subsamples [8]. The periodicy around values: $24.15\ \mathrm{km\cdot s^{-1}}$ [37,38], $36.3\ \mathrm{km\cdot s^{-1}}$ [5,8,38], $72\ \mathrm{km\cdot s^{-1}}$ [5], $144\ \mathrm{km\cdot s^{-1}}$ [5] and $90\ \mathrm{km\cdot s^{-1}}$ [5] were stated.

In the 1990s the search for periodicity in galaxies belonging to structures was started. Guthrie and Napier [10,24] considered 2 samples of galaxies: the first contained 112 spiral galaxies with redshift $< 3000\ \mathrm{km\cdot s^{-1}}$ and the second contained 77 dwarf galaxies. They took into account the galaxies lying near the center of the Virgo cluster. The existence of redshift periodicity for dwarf galaxies was not confirmed. However, for the whole sample of spiral galaxies they found possible periodicity around $71.1\ \mathrm{km\cdot s^{-1}}$. Tifft hypothesis was confirmed at 0.99 significance level under the assumption that Local Group velocity towards the Virgo cluster is $100{-}400\ \mathrm{km\cdot s^{-1}}$. Then, the sample of spiral galaxies was divided due to its location in high or low density regions. They found strong periodicity near $71\ \mathrm{km\cdot s^{-1}}$ in a subsample of galaxies lying in the regions of low density. There was no quantization in the spirals in high density regions.

Next sample contained 89 spiral galaxies lying on the Virgo cluster periphery [11,24]. The strong redshift periodicity around $37.2\ \mathrm{km\cdot s^{-1}}$ was found. But this periodicity appeared only if galactocentric redshifts were considered.

Then, Guthrie and Napier [23] took into account the galaxies lying at the edge of the Local Supercluster. They used the database compiled by Bottinelli et al. [4]. After eliminating their belonging to the Virgo cluster and nonspirals they obtained a sample containing 247 objects. They found that redshifts of spiral galaxies were strongly periodic around $37.5\ \mathrm{km\cdot s^{-1}}$. It should be pointed out that in all these investigations from database containing thousands of galaxies only a small number of them, namely, those with very accurate measurements, were taken into account.

A few hypothesis about new physics were considered by them [23]. The redshift periodicity can be explained by the regularity of the LSC structure or by the application of the model of oscillation of physical parameters.

If redshifts were taken as radial velocity, one could suppose that galaxies are situated in the regular structure and have small or negligible peculiar motions and that this structure takes 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 a provided scale of the cell, then $Q = 37.5\ \mathrm{km\cdot s^{-1}}$. In the large-scale structure of the Universe the periodization was detected by pencil beam observation. This periodization can be due to the walls and the voids between them. It is possible that within the walls some aggregation of galaxies exists. So, the small-scale periodization is due to substructures. Hence, the size of cells can be estimated, comparing this value with light velocity. 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 it is impossible to explain the periodicity around the value of $72\ \mathrm{km\cdot s^{-1}}$ observed by Tifft for double galaxies.

Let us list other possibilities:

1. Periodic oscillation of physical constants. The gravitational constant [20] and the Hubble parameter [21] were considered, but the required amplitude of changes was greater than the observed limits. The changes of fine structure constant [16] and the variability of the electron mass [16] were also considered. But there is a problem in this model because periodicity can be smeared out by a peculiar motion of galaxies.

2. The Holmlid [17] explanation is quite natural. As the periodicity is observed, only after applying the proper corrections to the Sun's motion, redshifts can be quantized before they arrive to the Earth. According to Holmlid, the quantization process has to occur in the intergalactic space relatively close to the observed galaxy, or in the space between our Galaxy and the 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 the result of interaction between the radiation and the cold Rydberg matter. Holmlid claimed that the observed values of redshift periodization (36, 72, 144 $\mathrm{km \cdot s^{-1}}$) are the natural consequence of the structure of clouds composed from Rydberg matter.

3. In 1996 Tifft [39] considered a 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 and 36 $\mathrm{km \cdot s^{-1}}$. He thought that this is a global feature. As before, only objects with very accurate measurements were considered, which drastically diminished the number of galaxies in the analyzed sample.

4. Lehto [19] developed a theoretical model which could predict periods of redshifts. Lehto described basic properties of matter using 3-dimensional quantized time. The time unit is Planck time and is named (by him) «chronon».

The fourth possibility is important because Tifft stressed that Lehto's consideration gave him a theoretical explanation of periodicity.

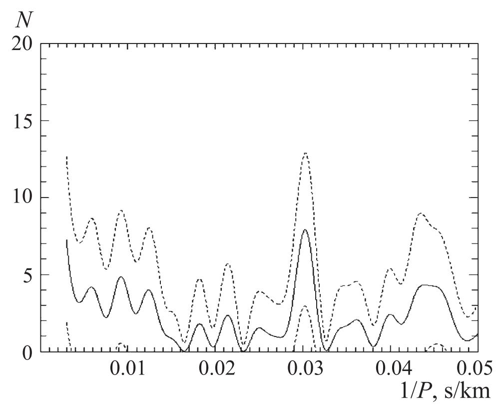

Fig. 2. The result of PSA analysis for Local Group of galaxies (sample: 28 galaxies from the van den Bergh list, correction of the radial velocity: 1) [9]

We investigated the periodicity in two structures: Local Group of Galaxies and Hercules Supercluster. We discuss the distribution of radial velocities of galaxies belonging to the Local Group [9]. The main problem is: to determine which galaxies belong to the Local Group of Galaxies. We discussed 55 objects taken from the Irwin's list [18] together with 7 galaxies from Maffei's group. That was the first sample. The second sample containing 32 objects was taken from the van den Bergh's list [3]. In Irwin's and van den Bergh's lists there were 9 and 7 objects without determined redshifts, respectively. So, we took into consideration samples containing 28 and 46 galaxies. The third sample containing 39 objects is called «pure» Irwin's data (the data without galaxies from Maffei's group and without galaxies with unknown redshifts). The newest data allow us to include redshifts for 6 from 9 galaxies with unknown redshifts. So, for further consideration we took 5 samples containing 46, 28, 39, 45 and 34 galaxies.

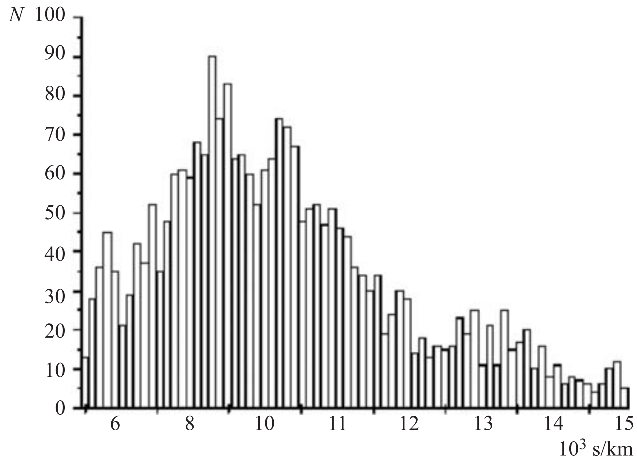

Fig. 3. The distribution of radial velocities in the Hercules Supercluster

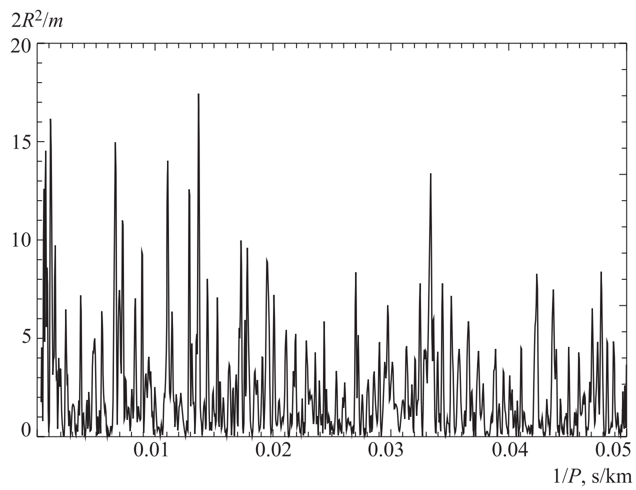

Fig. 4. The result of the PSA analysis for the Hercules Supercluster members

We applied the power spectrum analysis using the Hann function as a weighting together with the jackknife error estimation. We perform the detailed analysis of this approach. The distribution of galaxy redshift seems to be nonrandom. An excess of galaxies with radial velocities of 24 and 36 $\mathrm{km \cdot s^{-1}}$ is detected, but the effect is statistically weak. Only a peak for radial velocities 24 $\mathrm{km \cdot s^{-1}}$ seems to be confirmed at the confidence level of 95%.

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

$7500,\ 15000\ \mathrm{km\cdot s^{-1}}$, and it was complete in 80%. As in the above case, we used PSA to analyse that sample. We used 5 velocity corrections enumerated above.

For galactocentric reduction at the 2σ confidence level the peaks around 73 and $24\ \mathrm{km\cdot s^{-1}}$ are observed. Although it seemed that the maxima shown in Fig. 3 are clear, the probability that they are coming from nonrandom distribution is 95%, i.e. at the 2σ significance level.

CONCLUSIONS

In our opinion, the existence of redshift periodicity among galaxies is not well established. The earlier results are based on a very small fraction of objects extracted from the large databases. At the early stage of investigations such an approach was the correct one, errors of individual measurements 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. As we considered all galaxies, our samples are greater. Measurements with lower accuracy could smear out the regularities, but regularities are not introduced artificially.

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

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