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Quasi-periodicity nature of the redshift distribution of active galactic nuclei

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Abstract. From the data available in 'A Catalogue of Quasars and Active Nuclei' (7th Edition, 1996), of M.P. Veron-Cetty and P. Veron it is found that the redshift distribution of 2360 active galaxies ($0 < z < 0.3$) are quasi-periodical in nature. Peaks appear at $z = 0.032, 0.0605, 0.090, 0.120, 0.15, 0.185$ and 0.24 (The peak at 0.060 was found by Burbidge in 1968 and is observed till date). Direct power spectrum analysis to redshift data show that the quasi-period of the peaks is $D\ z = 0.027 \pm 0.004$. The spatial distance indicated by neighbouring two peaks is $81 \pm 12h^{-1}$ Mpc, which possibly is the 'cell' characteristics size of the large scale structure of the universe ($H = 100h^{-1}\ \mathrm{km}^{-1}\ \mathrm{Mpc}^{-1}$). The present results are supporting the multiply connected models such as T-3 universe and anisotropy's of Cosmic Microwave Background Radiation (CMBR) as established by the recent COBE Differential Microwave Radiometer (DMR) experiment results.

Key words : galaxies : - active galaxies : redshifts of

1. Introduction

From the time of discovery of the high redshift active galaxies or quasars, there have been claims from time to time on the possible periodic structure in the distribution of redshifts of extra-galactic objects. Active galaxies are at intermediate distance between very low redshift galaxies and high redshift quasars. They are more readily and easily detected at large distance than galaxies in general. We believe that active galaxies, including Seyfert galaxies, galaxies with other types of narrow-emission line, and very nearby quasars, can trace the distribution of matter on a large scale than a cluster of galaxies. More and more observations show that the universe is inhomogeneous at larger scale than that the clusters of galaxies have. A lot of efforts have been made to map the structure of the nearby (here we mean distance less than several hundred mega parsecs from us) or deep universe.

In a homogeneous and isotropic universe we expect a redshift distribution of extra-galactic objects to approximately follow a continuous and a periodic distribution. In a Friedmann universe, the coordinate volume of the shell between radial coordinates r and r+dr is given by Narlikar (1989) as

$$dv \sim \frac{r^2\, dr}{\sqrt{1-kr^2}} \tag{1}$$

where k is the curvature in space.

As given by Das Gupta et al. (1988), the Hubble's relation $v = H_0 r$ translates to

$$dv \sim \frac{[q_0 z + (q_0 - 1)\,(\sqrt{1+2q_0 z} - 1)^2]}{(1+z)^3 \sqrt{1 + 2\, q_0 z}} \tag{2}$$

where q_0 is the deceleration parameter.

Without any redshift dependent evolution, the observed redshift distribution of discrete sources will follow equation (2) and will be continuous and uniform. Various observers, however, have reported results that suggest discreteness or periodicity in the redshift distribution contrary to the above expectation. Burbidge (1968) first noticed the apparent periodicity in the redshift distribution of quasars. Evidence for redshift periodicity in nearby galaxies is also found by Gourgoulhon et al. (1992) and Guthrie B.N.G. and Napier W.M. (1991). On the other hand, some large groups of quasars have also been reported by Clowes and Campusano (1991) and Crampton et al. (1989). More recently, Broadhurst et al. (1990) have found a periodic structure in the pencil-beam redshift surveys of galaxies towards north and south galactic pole. They found that, the galaxies appear to have clumped distributions at distances that are multiples of $128h_0^{-1}$ Mpc [$h_0 = \dfrac{H_0}{100 kms^{-1}\ Mpc^{-1}}$]. Redshift periodicity of active galaxies reflect the large scale cellular structure in deep universe. Active galaxies could be good probes of the structure at a scale. Fang (1990) while investigating the periodicity in the redshift distribution of quasars in small-scale three dimensional torus T-3 universe pointed out that periodicities in quasars can significantly be confirmed by means of the power spectrum analysis of the redshift distribution. He concludes that the periodicity of the redshift distribution in a T-3 universe will certainly be detectable as long as the number density of the considered objects is large so that

$$N/L^3 > N_o/L^3 = \frac{3}{4\pi}\,\sigma^{-6}\,(c/H_o)^{-3}$$

where N is the total number of objects distributed randomly among the basic cell with uniform probability,

N_o is the number of observed objects,

L^3 is the volume of the universe.

$\sigma = \frac{d}{R(t_o)}$ where d is the length scales of the size of clumps and/or peculiar motion and t_o the present time.

Or the mean distance D of the considered objects is not as large as

$$D < (4\pi / 3)^{1/3} \sigma^2 (c / H_o)$$

Arp et al. (1990) interpreted the redshift periodicities in terms of density maxima at various large redshift distances in the universe as the obvious one - given the usual assumption of universe expanding from a single origin. However, the cosmological principle requires, each point in space to expand from all others in such a way that no point is identifiable as the center of expansion. If we have shells or 'cells' of active galaxies, we can mark the center from which the universe expands. On the other hand if the active galaxies or quasars are at their redshift distance, then the general accepted cosmological principle may not be applicable or rather violated!

In this paper, we study the quasi-periodical peaks in the redshift distribution of active galactic nuclei (AGN). The distance indicated by neighboring two peaks possibly is the typical size of large 'cell' structures in the universe.

2. Analysis

All AGN data used in this paper is extracted from table 3 of 'A catalogue of Quasars and Active Nuclei' (7th Edition) of M.P. Veron-Cetty & P. Veron (1996) by limiting the redshifts to 0.3. Of the total 2833 objects, the number of AGN with a limiting magnitude of 0.3 are 2360. An active galaxy is defined as a starlike object, or object with a starlike nucleus, fainter than the absolute magnitude $M_B = -23$. These include Seyfert 1, Seyfert 2, or 'LINERS' fainter than the above absolute magnitude. A number of galaxies with nuclear H II region denoting a burst of star formation are also included, the reason being that they are called Seyfert in the past and later reclassified. They considered it useful to keep trace of these reclassifications to avoid further confusion. The galaxies with nuclear radio or X-ray sources which may turn out to be Seyfert-like are also included.

3. Results and discussions

Figure 1 shows the n-z histogram of the redshift distributions of 2360 active galaxies in the sample. At Z = 0.030, 0.0605, 0.090, 0.120, 0.15, 0.185, 0.24 are the local utmost peaks in the redshift distribution. Some of the peaks are very outstanding. Excluding one or two kinds of objects which are thought to have different intrinsic properties from Seyfert 1 galaxies or quasars for example, nuclear H II region galaxies-does not depress these peaks to the general tendency of the distribution.

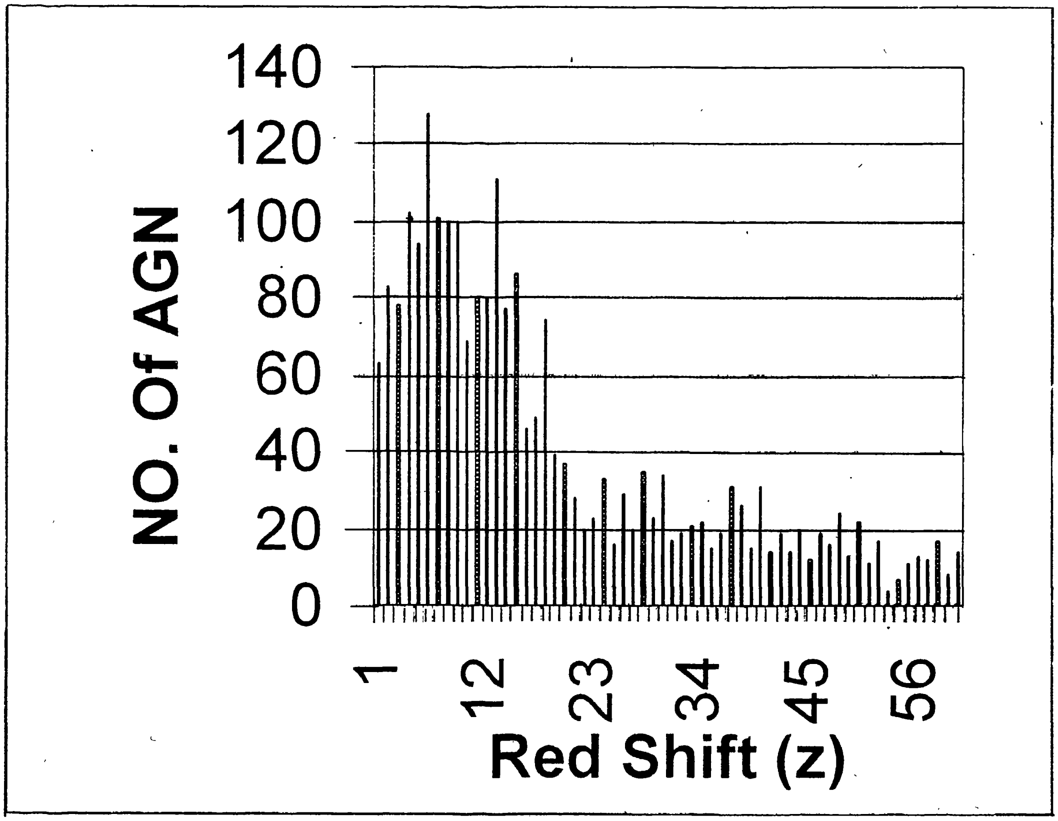

Figure 1. Histogram of the redshift distribution of 2369 active galaxies. Redshift (z) = Bin value (0.005) × Number (1 to 60).

Obviously, there is a period in the redshift distribution, which is shown here by power spectrum analysis. It has been turned out that other methods would show the same periodicity if a strong period reveals itself in a power spectrum analysis done by Duari et al. (1992). Therefore, it is unnecessary for us to analyze the data by many methods if a strong period is really found in the power spectrum. The salient feature of a power spectrum analysis method are as follows. Let z_1, z_2, z_3, ..., z_1, ..., z_N be the redshifts, for n 'waves' in [z_{min}, z_{max}], the spectral power function can be defined as

$$P(n) = \frac{1}{N}\left\{ [\sum_{i=1}^{N} \cos (\frac{2\pi n(z_i - z_{min})}{z_{max} - z_{min}})]^2 + [\sum_{i=1}^{N} \sin (\frac{2\pi n(z_i - z_{min})}{z_{max} - z_{min}})]^2 \right\} \qquad (3)$$

for M independent trails, the probability for a peak in a random spectrum reaching P_n is

$$p(>P_n) = 1-[1-\exp(-P_n)]^M$$

As a matter of experience from a lot of our Monte Carlo tests, M could take a value as large as N.

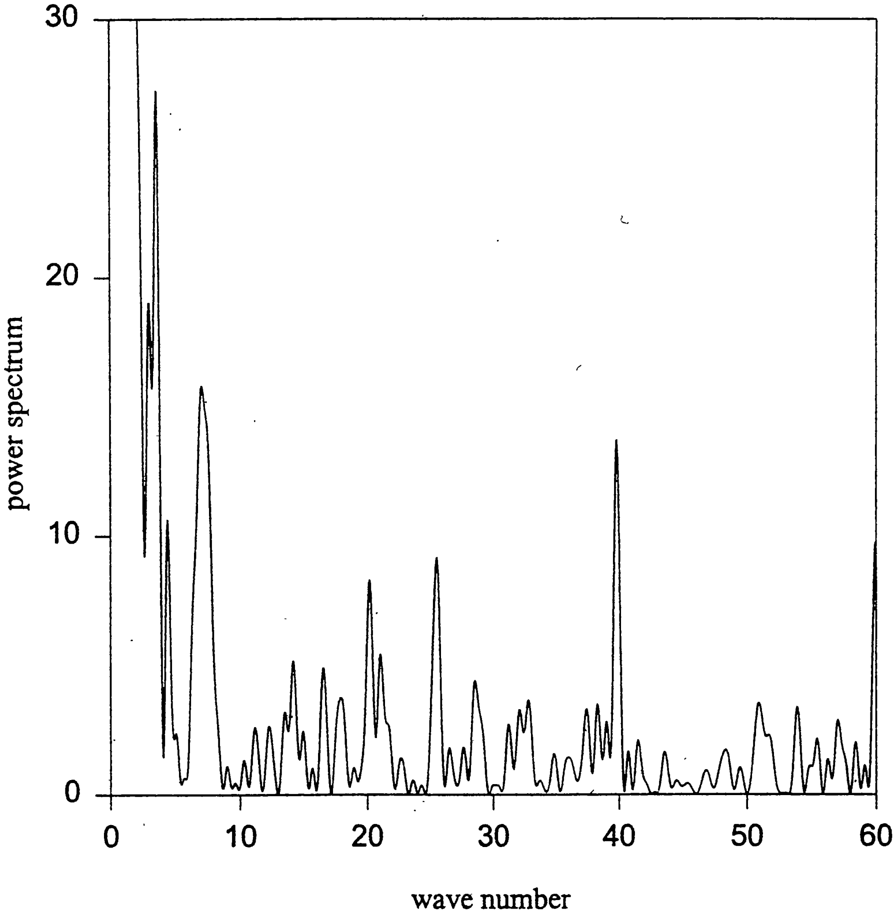

Figure 2. Power spectrum of the redshift distribution of 2360 active galaxies.

The power spectrum is calculated for all the 2360 redshifts of active galaxies with a limiting z of 0.30. The power spectrum graph is shown in figure 2. There is a very strong period at n = 7.1 ± 0.5. The highest peak of spectral power (very wide also) scales 15.8. The probability of such a peak in random spectrum is only 10^{-4}. The "wavelength" of the period, i.e., the separation between neighboring peaks, is $\Delta z = 0.027 \pm 0.004$, corresponding to a distance of 81 ± 12 h^{-1} Mpc (adopting a deceleration parameter $q_0 = 0.5$). The power spectrum analysis confirms the quasi-periodical peaks found in the histogram (figure 1).

The quasi-periodical peaks exist in the redshift distribution of active galaxies despite the fault of sample's completeness. In fact, the redshift distribution of 831 non-quasar AGN from the catalog of Hewitt A. and Burbidge G.R. (1991) shows the same quasi-periodical four peaks in both the histogram and its power spectrum, although the objects in the catalog were selected conservatively by omitting 'LINERS', galaxies with small and weak Seyfert properties (including H II objects). The more objects are included, the more remarkable these peaks appear.

As shown in the figure 1, the number of objects falls off as redshift z increases due to less and less observationally competence. Nevertheless, the peaks are outstanding out of the general tendency. In fact, any observation, if it reaches depth of one redshift peak is impossible to get over objects with lower redshifts. Thus observational incompleteness is not responsible for these peaks above. On the other hand, it is the observational incompleteness that makes the peaks at $z = 0.185$ & 0.24 not as significant as the peaks at $z = 0.030$ & 0.060.

Note that the peak at $z = 0.06$ was found by Burbidge (1968) from 47 quasar and 25 non-quasar emission-line objects, and was confirmed by Burbidge & Hewitt (1990) in the redshift distribution of 560 non-quasar AGN. Out result obtained from more than 2000 active galaxies shown the figure 1 confirm Burbidge's finding again. The peak at $z = 0.030$ has also almost the same significance as the 0.060 peak, while the 0.090 peak is about 3 times and the 0.120 peak about 2.5 times outstanding from nearby number fluctuations in the histogram.

Burbidge G., and O'Dell (1972) noted a periodicity of a 'wavelength' of 0.031 in z and two peaks in the redshift distribution near $z = 0.03$ and 0.06 from a few tens of small redshift objects. Now, these two peaks as well as the period are completely confirmed thirty year later using more than two thousand active galaxies. The power spectrum analysis in the last section strongly supports the existence of the peaks at $z = 0.090$ and 0.120, although they are not as confident as the peaks at $z = 0.030$ and 0.060 due to the sample incompleteness.

In fact, the redshift cone diagram of the Bahcall-Soneira superclusters (1991) in $z = 0° - 40°$ slice shows that there are some high-density regions near $z = 0.03$, 0.06, and probably 0.09. We also note that in a complete sample of galaxies a very strong distribution peak is near $z = 0.12$. This makes the peak of $z = 0.12$ convincing, in spite of its low confidence from the histogram.

One dimensional redshift distribution is the average of three dimensional spatial distribution over all directions. Fortunately due to observational incompleteness, the structure information is not smeared out even for objects farther than tens of mega parsecs distributed in all directions in the sky. One dimensional distribution actually couldn't reveal the real spatial structure, nevertheless, the information on spatial structure must be reflected if the clustering phenomenon is clearly shown in one dimensional redshift distribution.

The quasi-periodical peaks possibly are an indication of the large scale structure in the universe. The characteristic size of clusters of galaxies is about $45h^{-1}$ Mpc, only a half of the distance ($\sim 80h^{-1}$ Mpc) indicated by neighboring peaks in the redshift distribution. The peaks in the redshift galaxies indeed are probably the reflection of some over-dense regions. Thus the separation indicated by neighboring peaks in the redshift distribution possibly represents the characteristic size of the 'cell' in such a structure. If so, the spectrum power peaked at the characteristic scale, which would be comparable to the free path in a random walk, can be easily understood. The above findings are inconsistent with the T-3 model of the universe which has a symmetry of cubic lattice as proposed by Fang (1990). The wavelength and the mean number density of the active galaxies are well fitted with the periodicities given by T-

3 universe with adjustable parameters. Further Fang and Mo (1987) showed that if the size of the universe is smaller than the present horizon, then the multiply connected topology with global anisotropy cannot be ruled out. The recent COBE DMR experimental results of CMBR as stated by Smoot (1994) clearly established the anisotropy's in a multiply connected cosmological model with redshift periodicities as found in our present investigations.

According to the big bang theory, the universe is expanding from an original primeval fire ball - a linear thermal equilibrium state of very high density and temperature. As the universe expanded, it cooled and when it reached the temperature of around 3000° Kelvin, the primeval plasma coalesced to neutral hydrogen and helium. At that time i.e., about 3.10^5 years after the big bang, the CMBR was free to move through the universe with a negligible scattering by the free electrons. As a result, the photons are undisturbed, except for the inflation of the universe (uniformly and isotropically) since that epoch. If the primeval universe was slightly inhomogeneous, the CMBR is also slightly anisotropic, as detected by COBE DMR experimental results. The present results of anisotropy may be of this nature. This puts us on firm footing and allows us to use CMBR isotropy observations to set limits on anisotropy, homogeneity and dynamics of universe.

4. Conclusions

The present results are supporting the multiply connected models such as T-3 universe and anisotropy's of CMBR as established by the recent COBE DMR results. The sample of active galactic nuclei analysed here is intermediate between nearby galaxies and distant quasars. It is widely accepted that quasars are distant active galactic nuclei. The quasi-periodical peaks found in this sample suggest the large scale structure of the universe comprising of prominent 'cells' related to different epochs of 'z'. Thus the inflationary universe (uniformity and isotropy) on one end and quantized redshifts and periodicities on the other end are to be reconciled. We do not wish to draw any deeper conclusions beyond this, stating that the present cosmological models face stiff challenges!

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