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Possible Discretization of Quasar Redshifts

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A number of new peaks in the distribution of redshifts of quasi-stellar objects have been found. These, together with the well known peaks at $z = 1.956$ and $z = 0.061$, form a geometrical series.

Key words: quasi-stellar objects — redshift

Introduction

The distribution of emission-line redshifts of quasi-stellar objects has been studied on the basis of the list of redshifts compiled by Burbidge and Burbidge (1969). Eleven redshifts measured later have also been included (Burbidge, 1970). The total number of redshifts is 166.

Earlier investigations in this field have indicated the presence of very narrow peaks in the distribution of redshifts of QSOs and related objects (Burbidge, 1968; Cowan, 1969). The existence of such narrow peaks naturally implies that the spread in cosmological redshift and the spread in redshift due to random motions are both small. If they are not, those peaks will be eliminated.

Method of Investigation

In the present investigation the redshifts are collected in bins of 0.1 z, and the resulting distribution is given as a histogram in Fig. 1. As a comparison the distribution from an earlier list (Burbidge and Burbidge, 1967) is represented by the shaded area in Fig. 1. The solid areas represent the most recent measurements.

Five peaks in the distribution can be seen. The effect obviously gets more pronounced as the material grows larger, and there also seems to be a tendency for the latest determinations to fall on or close to the peaks.

It is very remarkable that the quantities $(1 + z_i)$, where $i = 1$ for the peak at $z = 1.956$, can be described as a geometrical series with a ratio

$$(1 + z_i)/(1 + z_{i+1}) = 1.227 \,. \tag{1}$$

This ratio has been derived from the well known peaks at $z = 1.956$ ($i = 1$) and $z = 0.061$ ($i = 6$; not seen in Fig. 1). The z-values obtained by this approach are $z_1 = 1.96$, $z_2 = 1.41$, $z_3 = 0.96$, $z_4 = 0.60$, $z_5 = 0.30$ and ($z_6 = 0.06$).

Statistical Analysis

In order to test the above hypothesis, that is, the reality of relation (1), the z-values are transformed to the new variable $x = \log(1 + z)$. The range in x studied is 0.068–0.518, which has been considered suitable to test the correctness of relation (1). This means the exclusion of seven objects, five of which have redshifts smaller than 0.17 and the two others have redshifts greater than 2.3. These objects are situated far from the peaks (more than 0.5 times the expected period). Furthermore, the inclusion of the QSOs with redshifts smaller than 0.17 in a search for a peak in this redshift range would necessitate the inclusion also of N-galaxies and other probably related objects. This has not been considered necessary, as one (and only one) peak in this range (at $z = 0.061$) has been found significant by others.

The distribution of x is given as a histogram in Fig. 2. The interval width used is 0.01, which means that the total range in x is divided into 45 cells.

The observed distribution is first tested against a random distribution by forming von Neumann's ratio (cf. Hart, 1942). This ratio (S) is given by

$$S = J \sum (n_{j+1} - n_j)^2 / (J - 1) \sum (n_j - \bar{n})^2 \,, \tag{2}$$

where J = total number of cells, j = cell number, and n_j = number of values in cell j. S can be said to

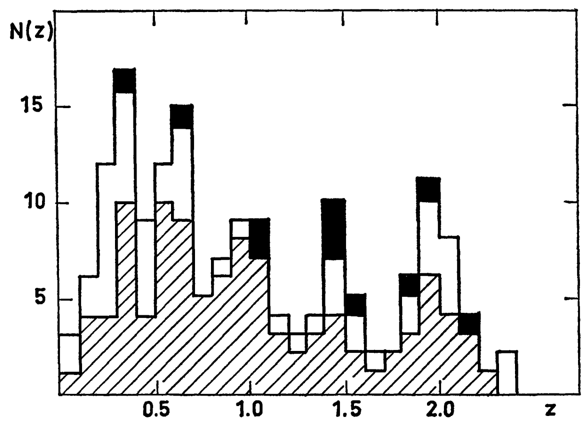

Fig. 1. Histogram of the distribution of quasar redshifts. A bin-size of 0.1 z has been used. The shaded area represents the redshifts known in 1967, and the solid areas represent eleven determinations from 1970

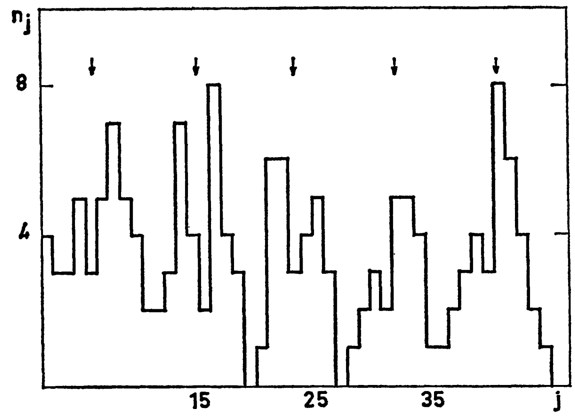

Fig. 2. Distribution of $x = \log(1+z)$ for 159 QSOs with $0.17 < z < 2.3$. j is the cell number. The positions of the expected peaks are marked by arrows

be a measure of how systematically the cell frequencies fluctuate around the mean frequency $\bar{n}$. The value of S for the observed distribution is 1.37, which means that this distribution at a significance level better than 2%, shows more systematical fluctuations than would be expected from a random sample.

In the variable x an arithmetical series will occur if the above hypothesis is correct. The positions of the peaks corresponding to the z-values calculated by means of relation (1) are marked by arrows in Fig. 2. The expected period in x is 0.089.

To test the reality of a period in the distribution the autocorrelation coefficients $R(k)$ were calculated

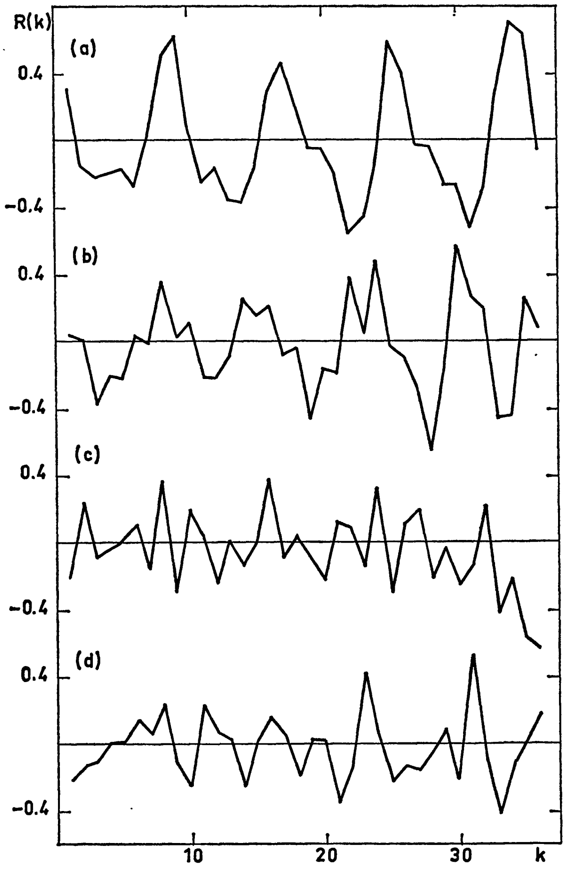

Fig. 3. Plots of the autocorrelation coefficients $R(k)$ for the observed distribution, (a), and for the three best (out of 100) generated random distributions, (b)—(d), for k ranging from 1 to 36

for $k = 1{,}36$. $R(k)$ is defined by

$$R(k) = \sum (n_j - \bar{n})(n_{j+k} - \bar{n}) \cdot \{(\sum (n_j - \bar{n})^2)(\sum (n_{j+k} - \bar{n})^2)\}^{-1/2} . \quad (3)$$

The same calculations were also made for 100 generated random distributions, with the same total population and number of cells.

A maximum of $R(k)$ for $k = k_0$ implies that the distribution studied has a period of k_0 intervals. Maxima should then also occur at $2k_0, 3k_0, 4k_0, \ldots$, representing 2, 3, 4, ..., times the period, respectively.

Plots of $R(k)$ for the observed distribution and for the three best random distributions are given in Fig. 3. The observed distribution seems to have a well defined period close to the expected value. The extreme smoothness and continuity of the observed distribution, compared with the random distributions, are very remarkable. This means that the peaks in the observed distribution are very well defined, and that no secondary peaks occur. It can also be seen that the maxima in the $R(k)$-distribution for the observed values reach values considerably higher than those for the random distributions.

It must be concluded that the probability of a distribution with a period as well defined as this occuring by chance is definitely below 1%, and is probably far smaller than this.

Results and Discussion

It has been shown that there is most probably a real discretization of quasar redshifts, and that this discretization with the present data can quite accurately be described as a geometrical series in $(1 + z)$, that is, by means of relation (1).

The two peaks around $z = 0.30$ and $z = 0.60$ have been discussed by Burbidge (1968), who concluded that they were real. This is certainly in favour of the present hypothesis, but a still stronger argument for the reality of the relation found is that it establishes a connection between the peaks at $z = 1.956$ and $z = 0.061$, which can also be regarded as a connection between QSOs and objects related to them, that is, N-galaxies, Seyfert galaxies, and some compact galaxies.

It seems unavoidable to conclude that redshifts of QSOs, and probably also the redshifts of these related objects, are intrinsic to the objects. The spread around the peak values is in this case most easily explained as being due to random motions.

It is obvious that a quantization of one of the fundamental physical constants (electron mass, for instance) would yield a relation of the form (1), but whatever the reason, it seems extremely difficult to explain the observed effect, if it is assumed that redshifts of QSOs are mainly cosmological in origin.

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