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SPACE DISTRIBUTION OF QUASI-STELLAR OBJECTS (QSOs)

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SPACE DISTRIBUTION OF QUASI-STELLAR OBJECTS (QSOs)

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The results of an analysis of the distribution of QSOs in a space of various cosmological models by the spectral and correlation methods are presented. In the Fourier expansion of the QSO distribution in the comoving radial coordinate of the Friedmann space with deceleration parameter $q = 1/2$ the perturbation with period $L = 560$ Mpc has been detected. The probability of detecting such a perturbation at a random distribution is $P \sim 10^{-6}$. In the three-dimensional Fourier expansion of the distribution of QSOs over plane waves the peak which corresponds to the perturbation with $L = 510$ Mpc, has been revealed; $P = 5 \cdot 10^{-3}$. The wave vector of the perturbation is directed approximately to the side of a minimum quadrupole mode of the cosmic background radiation.

Subject headings: cosmology - quasars

It is known that the distribution of QSOs in the magnitude of redshift z is not uniform and, apparently, not random (Burbidge, O'Dell 1972; Bell, Fort 1973; Khodyachikh 1979). It is interesting to find out how the QSO distribution looks not in z but in natural (comoving) coordinates of some cosmological models. In the present work the results of an analysis of the distribution of 635 QSOs (listed in the catalog of Burbidge, Grown and Smith 1977) in a space of the cosmological models of Friedmann, de Sitter and Milne are given. By the space the space-like hypersurface of a constant intrinsic (cosmic) time is meant throughout in the text. The statistical methods of the Fourier analysis and the correlation analysis have been used. The nature of the redshift of QSOs is assumed to be completely cosmological. The work has been initiated by Zel'dovich and Novikov's discussion (Zel'dovich, Novikov 1975) of the results of Burbidge and O'Dell (1972) concerning the specific features of the distribution of QSOs in the redshift and by the works of Sokolov and Swartsman (1974) and Sokolov and Starobinsky (1975) which discuss a possible non-triviality of the topology of space and its observational manifestations.

For our analysis of the space distribution of QSOs we use the spectral method. Let us represent the QSO distribution as follows:

$$\rho(R) = \sum^{N} \delta(R - R_j)$$

here R_j is the radial coordinate of the j-th quasi-stellar object, N is the number of QSOs. In the Friedmann model with $q = 1/2$, $R = 2C/H\cdot(1 - 1/\sqrt{z+1})$; in the de Sitter model $R = Cz/H$, in the Milne one $R = C/H\cdot \ln(1+z)$; here $H = 75$ km/sec/Mpc is the Hubble constant, C is the speed of light.

For the Fourier amplitudes we have

$$A(K) = \int \rho(r)\cdot \exp(2\pi i K r)\, dr = \sum_{j=1}^{N} \exp(2\pi i K r_j)$$

here $r = R/R_o$, R_o is the scaling unit.

In what follows, for the spectral power S, we shall take advantage of the fact that at a random distribution of QSOs the following relation

$$S(K) = |A(K)|^2/N = \chi_2^2/2$$

holds where χ_2^2 is the distribution χ^2 with two degrees of freedom.

The probability of finding $S > S_o$ in the sample from n independent modes is as follows:

$$P_n(S > S_o) = 1 - (1 - \exp(-S_o))^n \xrightarrow[S_o \gg 1]{} 1 - \exp(-n\cdot\exp(-S_o))$$

(For details see Burbidge, O'Dell 1972; Yu, Peebles 1969)

The Fourier spectrum of the distribution of QSOs, listed in the catalog of Burbidge et al. 1977, in R in the space of the plane Friedmann model is shown by curve S_R in Fig.1. Attention is concentrated on a large peak $S = 17.2$, which corresponds to a perturbation with wavelength $L = 560$ Mpc and phase $\varphi \approx 0$, i.e. the perturbation is representable in the form

$$\delta\rho/\rho \approx 0.4\cdot \cos(2\pi K_o R/R_o); \quad K_o = 18, \; R_o = 10^4 \text{ Mpc}$$

The probability of appearing such a peak in the spectrum of randomly distributed sources, which contains 100 independent modes,

is $P_{100} = 3\cdot 10^{-6}$ (the dotted line shows the dependence $S = N/K^2$ with which the spectral form of the QSO distribution as a whole is well consistent).

The analysis of the distribution of QSOs in z (Burbidge, O'Dell 1972) corresponds to that in R in space of the de Sitter model.

The analysis for $\ln(1+z)$ by Khodyachikh (1979) corresponds to that in R in space of the Milne model.

The analysis of the QSO distribution in these models has been repeated for the QSOs of the catalog of Burbidge et al. (1977). No statistically reliable peak ($S < 7$) has been detected in the de Sitter model. In the Milne model the peak with parameters $S = 12.5$, $L = 820$ Mps and $\varphi = 2.39$ has been discovered, this peak being much smaller than that in the Friedmann model.

The analysis of the peak amplitude as a function of the deceleration parameter in the standard Friedmann model with $P = \Lambda = 0$ has shown that S has the maximum near $q = 1/2$, $L = 550$ Mpc, $\varphi \sim 0$, Fig.2. Apparently, periodicity most clearly manifests in the simplest Friedmann model with deceleration parameter $q = 1/2$.

In the Friedmann model with flat space ($q = 1/2$) the expansion of the QSO distribution in plane waves has been carried out. Such a three-dimensional analysis has been made for all independent modes with a wavelength from 10^4 to $2\cdot 10^2$ Mps, that corresponds to $\sim 2\cdot 10^5$ independent modes. Apparently, an analysis of the higher space harmonics has no sense because of possible proper motions and the errors in determining the coordinates. As a result, the single statistically significant peak has been discovered. The spectral power of this peak is $S = 17.25$, $L = 510$ Mps, $\varphi \sim 1.1$. The coordinates of the intersection point of wave vector with celectial sphere are: $\alpha = 6h50'$, $\delta = 6°$, $\Delta\alpha = \Delta\delta = 20°$ (the width in the half power level). The spectrum of the distribution of QSOs along this direction is shown in Fig.1, curve S_X.

At a random distribution the probability of detecting such a peak is $P \sim 10^{-8}$. The probability for $2\cdot 10^5$ independent modes is $P \sim 5\cdot 10^{-3}$. The region near the origin of coordinates in the space of wave numbers, which contains the modes with a wavelength larger than $2\cdot 10^3$ Mpc has been ignored since it contains the information on the global distribution of QSOs. The distribution of the spectral power of the remaining peaks is in accord with the representation concerning their random origin. The tail of the differential distribution of the number of modes as a function of S : $n(S) = N(S) - N(S+1)$ ($N(S_0)$ is the number of modes $S > S_0$), is shown in Fig.3. The solid line shows the dependence to be expected for a random distribution. The dashed line shows the standard deviation.

It is noteworth that the perturbation parameters are surprisingly close to the corresponding parameters obtained in the Fourier analysis of the distribution of QSOs in radial coordinate R from the same catalog: S = 17.2, L = 560 Mps. By now, no convincing mechanism, which could explain such a connection, is found. This property, just as the wavelength of a perturbation, is insensitive to the sample size of QSOs. So, for 200 QSOs of the catalog in Rees et al. (1977) the peak power in the expansion in plane waves is $S = 12.1$, in the expansion in R - $S = 12.6$; the perturbation wavelength $L \simeq 550$ Mpc. The direction of the wave vector of perturbation for these catalogs coincides with an accuracy of 10° and is close to the plane of Galaxy.

The one- and three-dimensional correlation analysis of distribution of relative distances of QSOs has been carried out (in R and in the direction of the wave vector of the perturbation found in the one-dimensional case). In the correlation function there is a periodical component which is associated with the periodic perturbation of density and corresponds to the peak in the Fourier spectrum, i.e. the correlation function may be represented as follows:

$$B(d) = N + 2\cdot\sum S(k)\cos(2\pi kd) \sim N + 2\cdot\sum_{k=1}^{10} S(k)\cos(2\pi kd) + 2\cdot S(k_0)\cos(2\pi k_0 d)$$

$$d = (R_1 - R_2)/R_0\,, \quad R_0 = 10^4\ \text{Mpc}\,, \quad k_0 = 20$$

The correlation function has no other specific features.

There is no doubt in the reality of a peak in the spectrum of the distribution in R . All the irregularities in the distribution of sources in the celectial sphere have been integrated and, hence, have no significant influence. The mechanism, which accounts for the peculiarities of the distribution of QSOs by entering the bright spectral lines of radiation into the range of observation

(Karitskaya, Komberg 1970; Basu 1978), does not explain the observable periodicity in the distribution of QSOs. The distribution of the brightness of sources as a function of R , which is generated by the motion of a series of bright spectral lines through the filter transmission band, is correlated with the distribution of QSOs in the same extent (the correlation coefficient $r \simeq 0.5$) as the Fourier harmonic with period L = 560 Mpc ($r \simeq 0.4$). However, they are not correlated with each other ($r < 0.05$). (It should be noted that the half-width of the spectral window, which is reduced to the corresponding z , always exceeds the period of perturbation.) This indicates that the shift in bright lines into the window of observation accounts for the other peculiarities (of larger scale) in the distribution of QSOs. It is impossible to explain the peak in the expansion in plane waves in such a way at all.

It is noteworth that the wave vector of perturbation intersects the celectial sphere approximately in the same direction, α = 6h50'±40', where there is the maximum of the quadrupole-like component of the distribution of cosmic background radiation, α = 5h24'±40' (Fabbri et al. 1980). The direction of the wave vector is probably close to that to the minimum of the quadrupole mode on both coordinates.

Apparently, the analysis of the space distribution of QSOs enables one to affirm that there is no evidence on the deviation of the topology of space from the Euclidean (R^3) on the scale up to $2\cdot10^3$ Mps. At the same time one can assume that periodicity in the distribution of QSOs contains the information on the spectrum of density perturbation in the range of hundreds of Megaparsecs and, possibly, on the space-time geometry. We think that periodicity in the distribution of QSOs in $\dot{R}$ might be a manifestation of the oscillations of a scaling factor, which occurs if the vacuum polarization is taken into account (Gurovich, Starobinsky 1979; Vorobyev 1980).

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Fig.1. Spectral analysis of the distribution of QSOs.

Fig.2. The perturbation parameters of the QSO distribution as a function of the magnitude of deceleration parameter q.

Fig.3. The tail of the differential distribution of the number of modes as a function of ξ.

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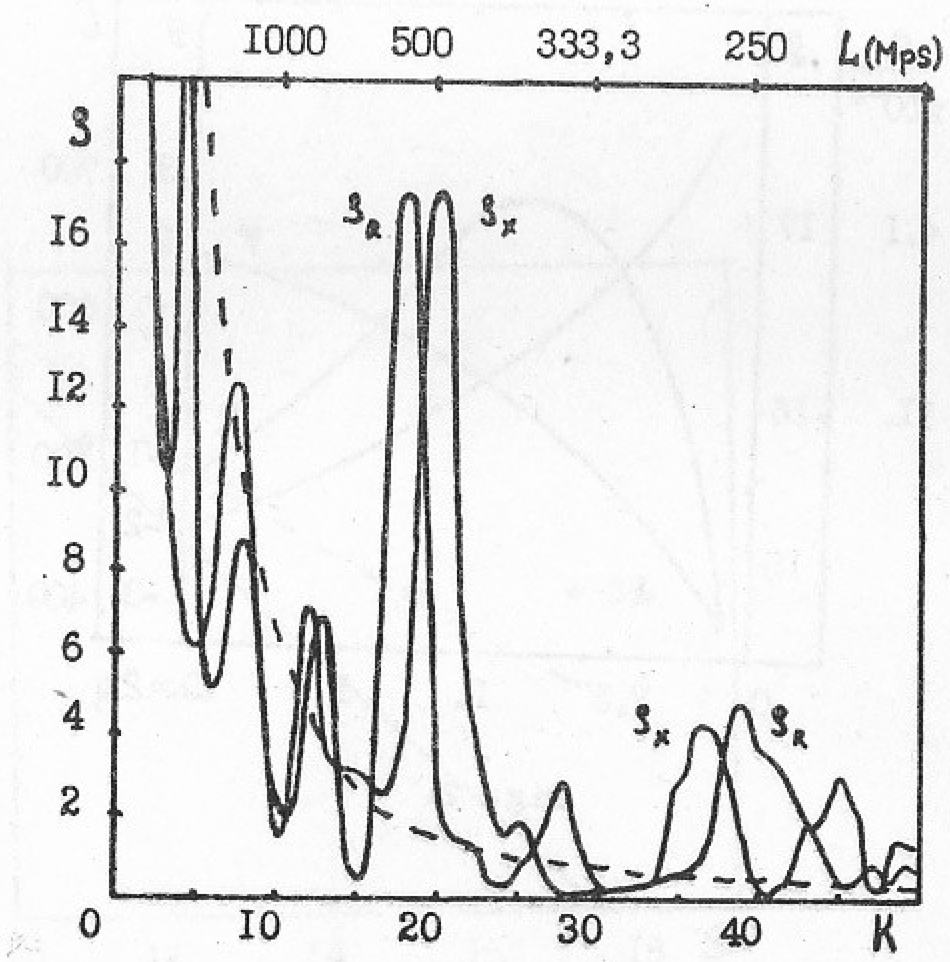

Fig. 1.

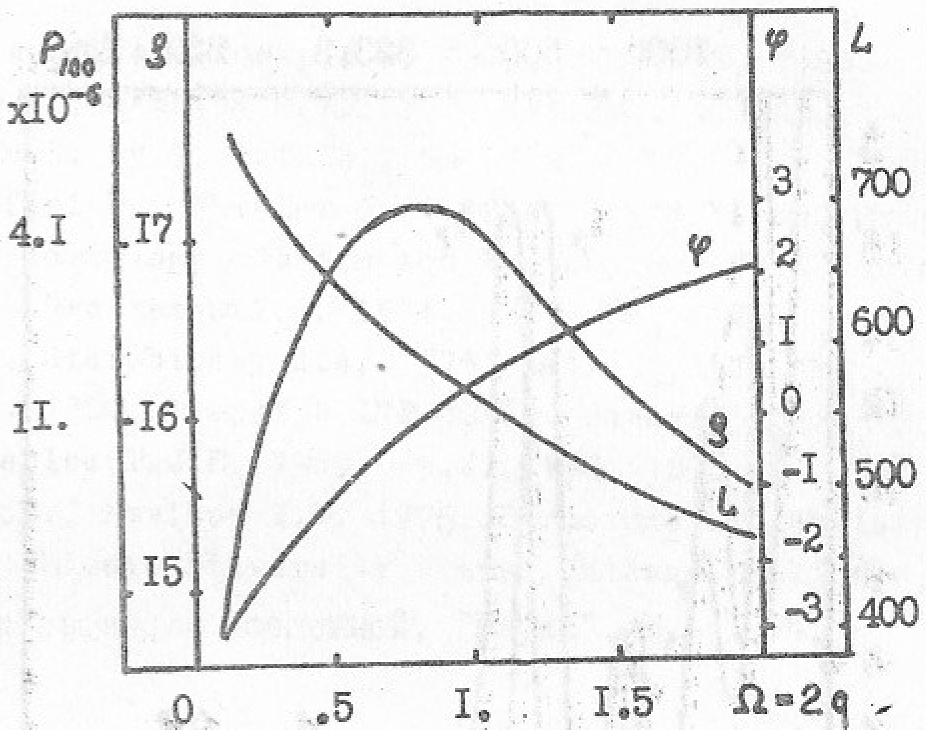

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Fig. 2.

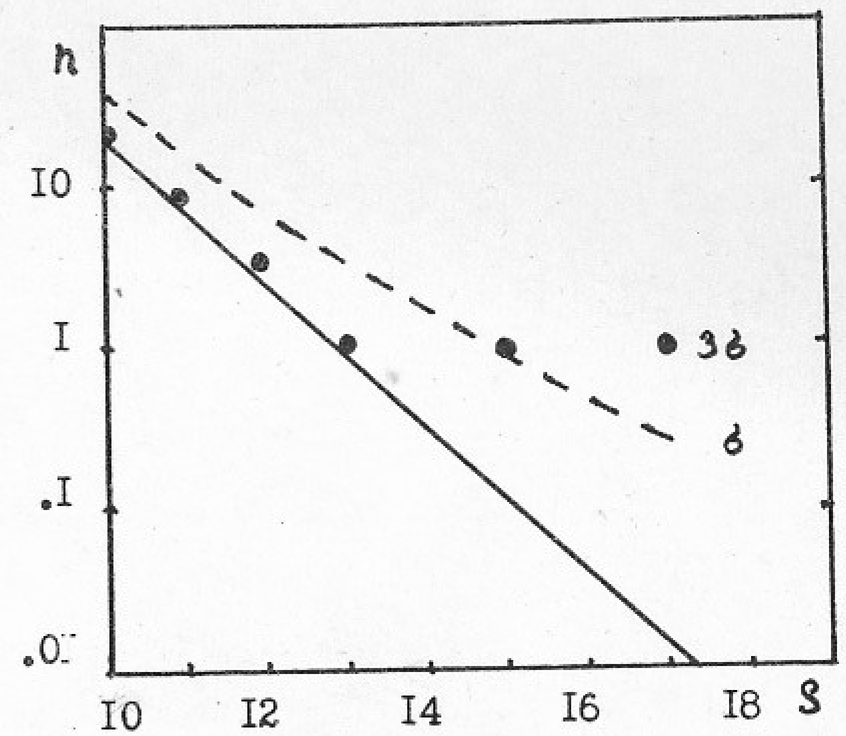

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Fig. 3.

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