Observational Tests of the Standard Model: Status and Perspectives

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To check the standard model we have used classic (m,z), (θ,z) tests and the combined (m,θ) test, as well as a new dθ/dt–z test of the quasar expansion dependence on z. As distinct from the usual sampling methods of testing the theory, we use global regression dependencies $\overline{m(z)}$, $\overline{\theta(z)}$, and $\overline{m(\theta)}$ of the observed values determining corresponding statistical patterns.

Based on measured values of (m,θ) and z for approximately 70,000 galaxies and 4,000 quasars it is shown that the dependence of redshift on distance to galaxies and quasars is quadratic $R = R_0\sqrt{z}$ within all redshift intervals investigated $10^{-3} \le z \le 5$. The same dependence is obtained with the quasar expansion test. The quadratic dependence does not confirm the relation resulting from the theory of relativistic cosmology. It is found that the mean values of galaxy and quasar luminosity and dispersion are equal, and independent of z. Nor do the mean galaxy size, mean surface brightness and dispersions in size and brightness depend on redshift within the investigated interval $z \le 0.2$–0.5.

The distribution laws of these values are strictly lognormal. These experimental results lead to the conclusion that the Metagalaxy is a stationary nonexpanding system of galaxies with unobservable origin and bounds within the redshift interval investigated, which corresponds to a time interval of about 5 billion years. It is shown that the quadratic redshift-distance dependence corresponds to a gravitational redshift. However, to explain the shift observed at a given R_o, matter density must be two to three orders greater than visible matter. If all the mass corresponds to visible mass, then the Metagalaxy's horizon is 40-50 thousand Mpc, which makes it possible to explain the microwave background radiation as the optical radiation of stars in the Metagalaxy in a distance interval up to 40,000 Mpc. In this case, the redshift is produced in the process of wave propagation in space, though the mechanism producing it is still unknown.

Is the Majority Right?

For majority opinion to change on the correctness of the hot big bang cosmology, it is clear that one or more of the arguments given above [the redshift-distance relation, the microwave background radiation, the abundance of the light isotopes D, ^{3}He, ^{4}He, and ^{7}Li] must be seen to fail. To most cosmologists, this appears, at present, to be very unlikely. However, if a change does occur, it will probably come from one of three directions:

a. A demonstration that the redshifts are not (all) Doppler shifts associated with the expansion of the universe.

b. A demonstration that there is another plausible mechanism which could be responsible for the MBR, probably related to the idea that it does not have a perfect blackbody spectrum and/or that it could not have been coupled to the matter at an earlier epoch.

c. Revised abundance determinations for the light isotopes which lead to the conclusion that they could not have been made in early nucleosynthesis.

(Burbidge 1989, p.988)

1. Introduction

Nearly half a century ago it was proposed to test the cosmological theory by comparing its predictions with the observable dependence on the redshift z for galaxies of apparent luminosity $E(z)$ and angular size $\theta(z)$. In the big-bang cosmology these theoretical relations are (Lang 1974)

$$E(z) = \frac{L(z)}{R_o^2\Psi^2(z,q_o)(z+1)^2},\quad \theta(z) = \frac{l(z)}{R_o\Psi(z,q_o)(z+1)^{-1}} \qquad (1)$$

Here $R_o(z,q_o)$ is the galaxy's metric distance at the time of observation, which follows from the solution of the Einstein gravitational equation, $R_o = c_o H_o^{-1}$ is the universe radius, H_o is the Hubble constant, $L(z)$ is the spectral power density of galaxy radiation, and $l(z)$ is the galaxy linear size. The function $(z+1)^2$ determines the radiation decay along its path due to the redshift and $(z+1)^{-1}$ takes into account a smaller size of the universe at the moment of radiation in the past. The value of q_o characterizes the spatial deceleration, and has practically no affect on the character of the metric distance dependence on z [$R(z) = R_o\Psi(z,q_o)$]. The

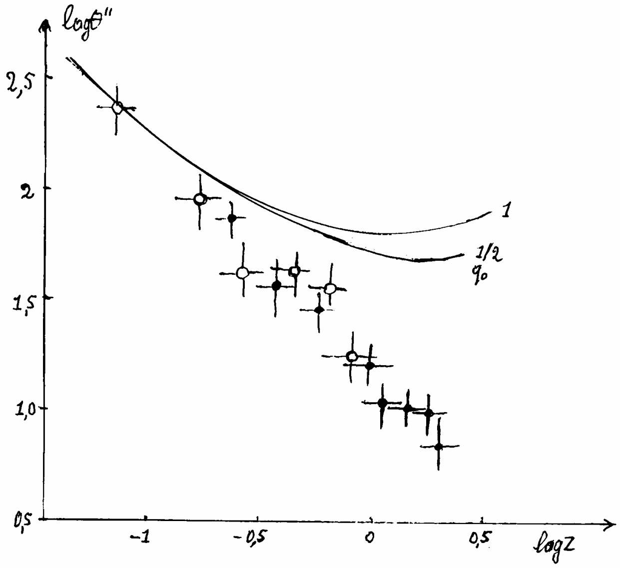

Figure 3. Theoretical curve of the apparent angular size (solid line) compared with measurements of galaxies (empty circles) and quasars (solid circles).

apparent luminosity is usually expressed in magnitudes and $q(z)$ in logarithmic values. The corresponding theoretical expressions are equal to

$$
\begin{aligned}
m(z) &= -2.5\log E(z) = 5\log R_o \Psi(z, q_o) + M(z) - 5 \\
\log q''(z) &= \log l(z) - \log R_o \Psi(z, q_o)(z+1)^{-1} + 5.3
\end{aligned}
\tag{2}
$$

Here $M(z) - 5 = -2.5 \log L(z)$, where $M(z)$ is the absolute galaxy magnitude. Expressions (2) are greatly simplified for concrete models defined by the value of q_o. So, for the closed model $q_o = 1$ and for $q_o = 0$ the distance function $R(z) = R_o z/(z+1)$, and according to (2)

$$
\begin{aligned}
m(z) &= 5\log z + 5\log R_o + M(z) - 5 \\
\log q'' &= -\log z + 2\log(z+1) - \log l(z) + 5.3
\end{aligned}
\tag{3}
$$

A decisive way to test the theory is the experimental determination of the distance function $R(z) = R_o \Psi(z, q_o)$ by measuring values for $m(z)$ and/or $q(z)$. For this it is necessary either to know evolution functions $L(z)$ and $l(z)$ or to eliminate their influence. The first is, in principal, impossible due to the large scatter in galaxy luminosity values and size values. Owing to this fact, in the fifties the "standard candle" and "standard rod" methods were proposed; these consisted in using $m(z)$ and $q(z)$ data for a special sample of galaxies having different redshifts z but strictly the same absolute magnitude $M(z)$ or the same linear size $l(z)$. It only remained to find a way to implement the idea under conditions where galaxy magnitudes and sizes can differ by an order or more from the mean value at the same redshift z. To perform $m(z)$ tests under these conditions, Sandage (1961) proposed to use the brightest cluster galaxies which have different z. It was supposed that in rich clusters all the brightest galaxies have the same luminosities $M(z)$ and, hence, give the solution of the problem.

As a standard size for the $q(z)$ test it was proposed to use the distance between centers of double radio galaxies and radio quasars. It was supposed that this distance is more stable than the size of normal galaxies. Here we summarize the results of these long-standing investigations.

II. Tests using standard source sampling

The $m(z)$ test results are given in the Hubble diagram in Figure 1, which plots apparent magnitudes $m(z)$ of the brightest galaxies whose absolute magnitudes $M(z)$ are presumed the same, *i.e.* $M(z)$ = const. The values of $m(z)$ are in a good agreement with the theoretical curve having the slope $dm/d\log z = 5$ both for closed and open models of the universe. As can be seen, to discriminate the models experimentally it is necessary to measure $m(z)$ at $z > 1$. For this purpose, quasars having redshifts up to $z = 4$–5 were used. The result is given in Figure 2, from which it is seen that the position of quasars on the $m(z)$-diagram does not agree with either the theory or the notion of a "standard" ensemble of galaxies. This discrepancy in the standard cosmology theory is explained by the high luminosity of quasars, which exceeds galaxy luminosities by two to three orders (5–8 magnitudes), making them inappropriate for the "standard candle" test. As a result, quasars are not used in $m(z)$ tests at all. Thus, although it was impossible to discriminate between models (closed or open), it was thought that the $m(z)$ test with so-called "uniform galaxies" showed a $R(z) = R_o z/(z+1)$ dependence, which gives the observable slope of the diagram $dm/d\log z = 5$. The case with the $q(z)$ test suggested by Hoyle turned out to be quite different. The Hoyle diagram (Figure 3) gives the experimental $\log q''(z)$ dependence obtained by Kapahi (1987) for 225 double radio galaxies and 250 double quasars, as compared with the theoretical one for $q_o = 1$ and $q_o = ½$. From Figure 3 it is seen that the $q(z)$ test is in sharp contrast to the theory. However, it was soon explained by the suggested evolution of the galaxy sizes at a rate of $l(z) = l_o/(z+1)^{2\text{–}3}$. This explanation gave rise to a large number of studies using this test to examine the peculiarities of galaxy size evolution. Therefore, the methods proposed to test the theory led to conflicting conclusions, and the problem of verifying the theory by astrophysical observations of $m(z)$ and $q(z)$ has been in a deadlock, which has been detailed in excellent reviews by Burbidge (1989) and Baryshev (1992).

The reason for failure lies in a dynamic approach to the solution of a typically statistical problem in which the measured $m(z)$ and $\log q(z)$ values are random, with a considerable dispersion. Moreover, the concept of sampling galaxies with a standard luminosity has no theoretical or experimental foundation, and it leaves much room for subjective sampling that cannot be eliminated.

The use of double radio galaxies and quasars for a $q(z)$ test is less appropriate since there is a stronger evolution of luminosities

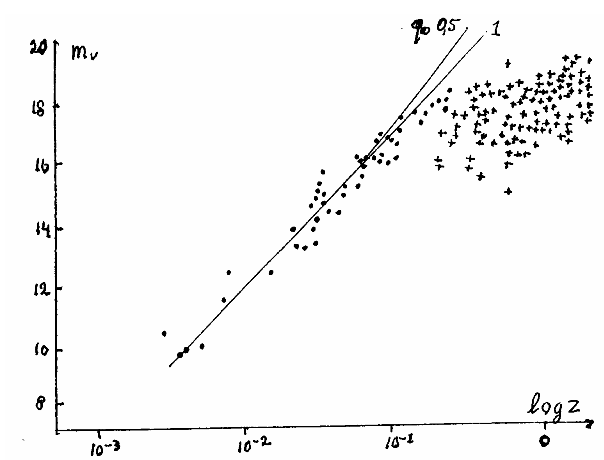

Figure 2. The same as Figure 1, plus the data for sampling of quasars (crosses).

and sizes in the radio waveband than in the optical, and, hence, their stronger dependence on z.

III. Statistical approach to experimental testing (Troitskij 1994, 1995)

As measurements show, the observable parameters of galaxies $m(z)$ and $\log q(z)$ are random values taking the definite field in space m, z, $\log q$. According to (1), (2) the randomness of these values follows from the randomness of the absolute luminosity $M(z)$ and linear sizes $l(z)$ of the galaxies. Thus, a regular part of $m(z)$ and $\log q''(z)$ dependences on $R(z)$ is hidden by random functions $M(z)$ and $l(z)$. They can be treated as a noise with a nonzero mean value which is superimposed on the desired dependence $R(z)$. To reveal $R(z)$ from the measurements of $m(z)$ and $\log q(z)$ it is necessary to eliminate noise components $M(z)$ and $\log l(z)$. For this purpose there exists the regression analysis or averaging method widely used in physics. We must therefore find experimentally the regression dependences $\overline{m(z)}$ and $\overline{\log q(z)}$, which are the averaged random functions of $m(z)$ and $\log q(z)$. The theoretical expressions to be measured take the following form

$$
\begin{aligned}
&\overline{M(z)} = 5\log R_0 \Psi(z, q_0)(z+1) - 2.5\,\overline{\log L}, \\
&\overline{E(z)} = \frac{\overline{L(z)}}{R_0^2 \Psi^2 (z+1)^2} \\
&\overline{\log q''(z)} = \overline{\log l(z)} - \log R_0 \Psi(z, q_0)(z+1)^{-1} + 5.3, \\
&\overline{q''(z)} = \frac{2\cdot 10^5\, \overline{l(z)}}{R_0 \Psi(z, q_0)(z+1)^{-1}}
\end{aligned}
\tag{4}
$$

where a bar over a random function defines the regression function.

As a result of averaging, the functions $M(z)$ and $l(z)$ are transformed into regular functions $\overline{M(z)}$ and $\overline{l(z)}$. They determine the mean dependence of random parameters on z or, in a sense, the mean evolution, since coordinate z is proportional to time in the past. It is apparent that averaging does not obviate the need to know these functions for the determination of $R(z)$. In this case, two equations (4) relate three regular functions: two regression functions $\overline{\log L}$, $\overline{\log l}$ and one dynamic function $R(z)$, the experimental determination of which solves the problem of an agreement between theory and reality. In fact, this has brought us back to the standard candle and standard rod methods. The difference is that we now use a “statistical standard candle” and a “statistical standard size”. This, however, makes it possible to find $R(z)$ invoking additional information to define regular functions $\overline{M(z)}$ and $\overline{\log l(z)}$ from the start. To anticipate, we may say that the problem is solved due to a demonstration that $\overline{M(z)}$ and $\overline{\log l(z)}$ are constant values independent of z!

To test the theory by the statistical method proposed we must use as large and as global a dataset as possible, checked for statistical uniformity, absence of observation sampling influence, Malmquist effect, and the like.

IV. Initial observational data: Hubble and Hoyle global *m(z)* and log *q“(z)* diagrams

For initial data we have used the most complete and up-to-date catalogue of galaxies, the Principal Galaxy Catalogue 1988 (PGC) (Paturel *et al.* 1989) containing 73,197 galaxies. We added to it nearly 3 thousand entries from more recent surveys (Sandage & Perelmutter 1991; Karachentsev & Kopylov 1990). To secure the maximum uniformity of the date we have used galaxies of only one morphological type, *viz.*, spirals of all subtypes, which amount to nearly 80 per cent of all the galaxies given in the PGC catalogue of galaxies. We have also used $m(z)$ data for all known quasars published in catalogues to date (Hewitt & Burbidge 1987; Veron-Cetti & Veron 1989; Hewlett *et al.* 1991).

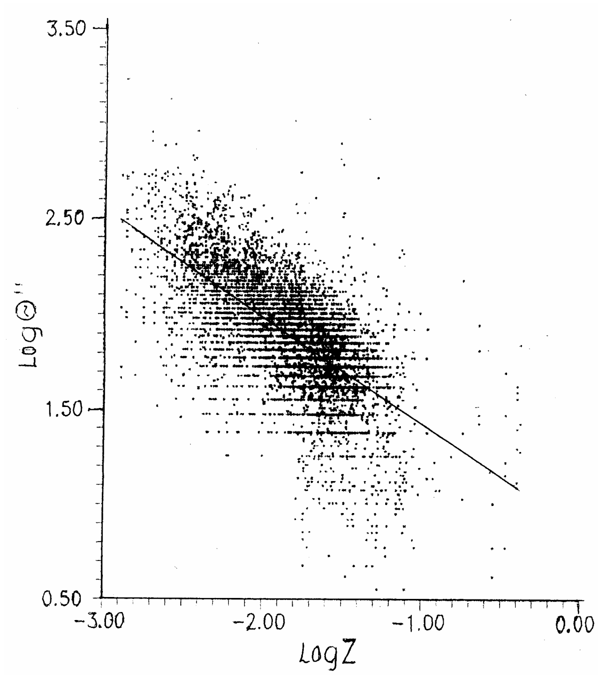

Figure 5. Hoyle diagram for 12,600 spiral galaxies. Solid line is the regression function.

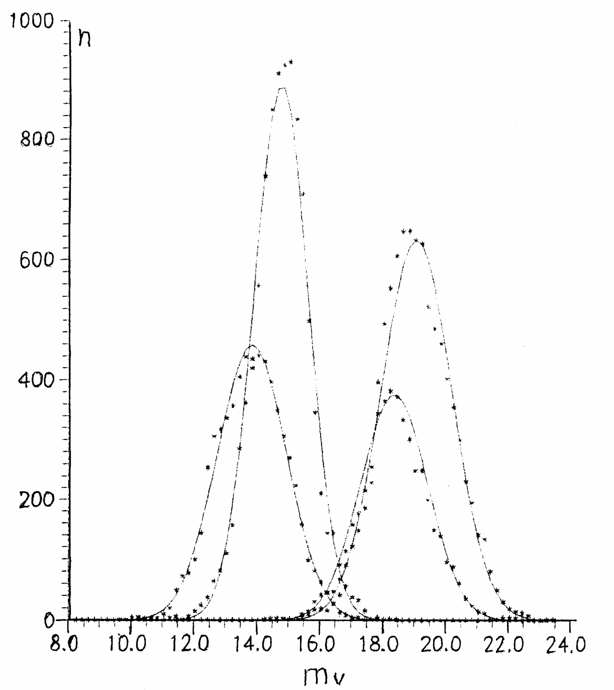

Figure 6: Distribution law $p(m/z)$ for dataset of Figure 4 at log $z_1 = -2 \pm 0.15$, log $z_2 = -1.5 \pm 0.15$ for galaxies and at log $z_3 = 0 \pm 0.5$, log $z_4 = 0.4 \pm 0.15$ for quasars. Solid curves are the Gaussian law; points are the experimental distribution when averaging in intervals $\Delta m = 0.4$. Corresponding standard deviations are $s_1 = 1.06$, $s_2 = 1.0$, $s_3 = 1.1$, $s_4 = 1.1$.

Figure 4. Hubble diagram for 12,600 spiral galaxies and 4,000 quasars (crosses); the central solid curve is the regression function. The two parallel lines are envelopes of the brightest and weakest galaxies and quasars at level $\overline{m(z)} \pm 3$. Dashed line is a theoretical curve at a constant (standard) absolute luminosity equal to $m(z) = 5 \log z + 22.4$.

Figure 4 is the global Hubble $m(z)$ diagram in V-band for all 12,600 spirals and 4,000 quasars. A similar diagram by Hoyle for $\log q''(z)$ is shown in Figure 5 for galaxies only, since corresponding QSO data is lacking. According to Figure 4 the random field of $m(z)$ data for quasars smoothly extends the random field of $m(z)$ data for galaxies, making a uniform global field of $m(z)$ parameters, a single global statistical dependence. This field of random values is fairly sharply bounded from both sides of strong and weak luminosities. Both boundaries are formed by equal parallel lines which restrict the band of $m(z)$ values by a width of 6^m for all z. Within limits, we can regard the global dependence as a random process, since z is also the coordinate of time. To make sure that the random field of $m(z)$ values is not a result of conscious limitations during observations or a sampling process, we need only define its statistical characteristics. Figure 6 gives the result of calculations of m distribution for a given z, *i.e.* $p(m/z)$, for the field of Figure 4 at $\log z_1 = -2 \pm 0.15$, $\log z_2 = -1.5 \pm 0.15$ for galaxies and at $\log z_3 = 0 \pm 0.15$, $\log z_4 = 0.4 \pm 0.15$ for quasars. It also gives the corresponding Gaussian comparison curves, demonstrating that the distribution of random $m(z)$ at each z is sufficiently Gaussian, *i.e.* symmetrical. This unequivocally testifies to the absence of noticeable observational limitations of $m(z)$ both from below and above the $m(z)$ band in Figure 4. Very important is the equal dispersion $s(m) = 1.1^m$ independent of z both for galaxies and quasars, which we have noted before (Troitskij *et al.* 1992; 1994). Hence, the boundedness of the $m(z)$ field from both strong and weak luminosities is defined by the nature of the random field itself. As is known, the total width of the noise band for a Gaussian distribution of a random value is $\pm 3s$; *i.e.* for $m(z)$ it is 6.5^m, as seen in Figure 4. Inside this band there are 99.7 per cent of all existing objects. The unified dependence $m(z)$ for galaxies and quasars is an experimental fact which must be taken into account in discussing the problem of QSO origin. As can be seen, the difference between quasars and galaxies is not the tremendous absolute luminosity, which has led to the hitherto unsolved problem of how the power is generated, but only their different spectra and, apparently, different sizes. If mean radiation energy is equal for galaxies and quasars, it follows that they must share a common nature. Thus, attributing an inexplicable super-radiation to quasars is a delusion caused, as we will show, by an error in determining quasar distances in the cosmological theory and an arbitrary sampling approach when comparing objects.

It is easy to see from (2), that the conditional distribution law $p(m/z)$ of magnitude m at a given z is the conditional distribution law of absolute luminosity $p(M/z)$. In this way the dispersions $s(m)$ obtained are equal to $s(M)$. The same holds for the distribution $p(\log q/z)$.

For the random field $\log q''(z)$ of Figure 5 we have made the same detailed statistical analysis as for $m(z)$. The distribution function $p(\log q''/z)$ is given in Figure 7. It is also a Gaussian function with dispersion $s(\log q) = s(\log l) = 0.22$ for all z.

V. Determination of regression functions of random fields *m(z)*, log *q"(z)*

To determine regression functions $\overline{M(z)}$ and $\overline{\log q(z)}$ from statistical sets $m(z)$ and $\log q''(z)$ given in Figures 4 and 5 the diagram is divided into n intervals $\Delta \log z \approx 0.1$–$0.2$ and in each interval the mean value $\overline{m(z_k)}$ or $\overline{\log q''(z_k)}$ is found resulting in discretization of all $\overline{m(z_k)}$ or $\overline{\log q''(z)}$ functions. Then, taking all points as equivalent, these data were used to determine a continuous regression function. In the process, it turned out that in all cases a linear regression emerged.

This procedure makes it possible to solve two problems: first, to

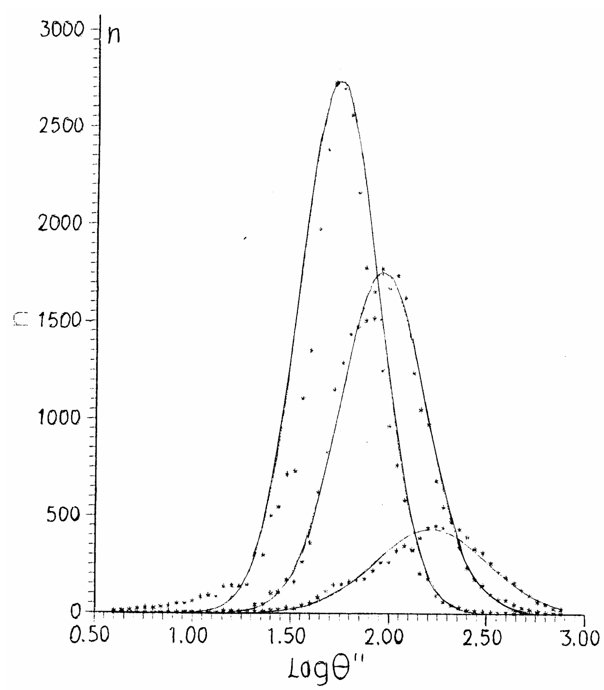

Figure 7. Distribution law $p(\log q''(z)/z)$ for dataset of Figure 5 at log $z_1 = -2.5 \pm 0.25$, log $z_2 = -2.00 \pm 0.25$, log $z_3 = -1.5 \pm 0.25$. Solid lines are the Gaussian law. Points are the experimental distribution in the intervals $\Delta \log q = 0.1$; standard deviations are equal to $s_1 = 0.28$, $s_2 = 0.22$, $s_3 = 0.22$.

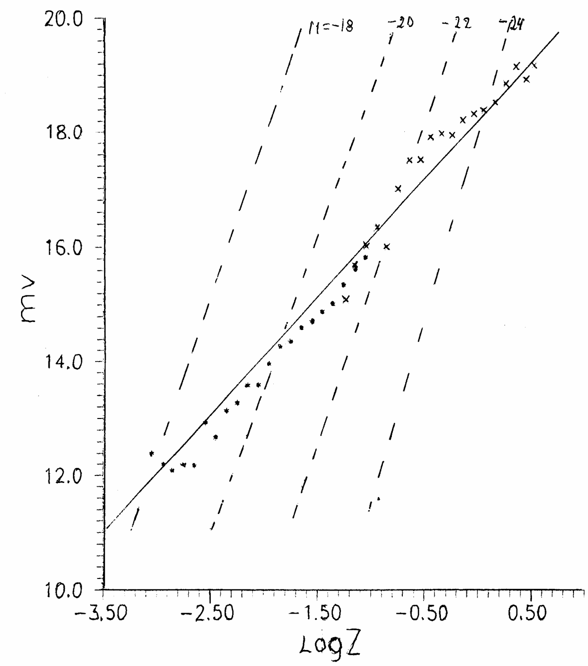

Figure 8. Regression function for $m(z)$ set of galaxies and quasars of Figure 4 calculated by intervals $\Delta\log = 0.1$. Points are galaxies. Crosses are quasars. General dependence $\overline{m(z)} = 2.26 \log z + 18.36$. Dashed lines are theoretical curves at different M.

determine the regression function in any form, linear or nonlinear, and, second, to eliminate the influence of inevitable non-uniform filling with measurements of the parameter field $m(z)$ or $\overline{\log q''(z)}$ along coordinate z. This manifests itself, particularly, for example, for galaxies near boundary values $z = 10^{-3}$–$10^{-2.5}$ and $z \geq 0.2$. It is easy to understand that the usual procedure for finding a linear regression over all galaxy sets using the LMS method causes suppression of a boundary value contribution, with the result that the linear regression is determined by the data of the parameter field central parts, where there are many more measurements. Clearly, when averaging over intervals we do not count boundary intervals containing less than 10–100 data points per interval. In this way the difference between the linear regression over all data points and the regression over the intervals does not exceed 2–5 per cent in slopes of regression lines for $m(z)$ and $\log q''(z)$ sets in Figures 4 and 5. This testifies to a statistically sufficient uniformity of data fields $m(z)$ and $\log q''(z)$. The regression function $\overline{m(z)}$ obtained in this way was then corrected for the Malmquist effect.

The Malmquist effect is an understatement of the mean value $\overline{m_{mes}(z)}$ due to observational sampling leading to a primary fixation of strong sources. In other words, weak galaxies are often missed in observations, and this reduces the slope of a regression function. In our case, as can be seen from the distribution laws in Figures 6 and 7, this effect, if it arises, is quite insignificant; otherwise we would have some asymmetry in the distribution curves. Overestimating, we can assume that at $z \cong 3$ "the tail" of the weak source distribution is cut off, beginning above $\overline{m} + s$ and at $z \cong 10^{-2}$, above $\overline{m} + 2s$. Then, as calculation shows (Troitskij *et al.* 1992a,b) the error in determination of a mean value at $z \cong 3$ is $\overline{m_{true}} - \overline{m_{mes}} = 0.3$ and at $z = 10^{-2}$, $\overline{m_{true}} - \overline{m_{mes}} = 0.06$. Hence, the slope of a regression curve should be increased by $0.24/2.5 = 0.1$. A correction to the K-effect calculation using conventional formulas would be a mistake, since this calculation uses the expression for $E(z)$ (1) based on the erroneous theory. On the other hand there is no other way to determine the effect from any experimental data independent of the cosmological model. The essence of the K-effect is that with increasing z the measured value $m(z)$ changes due both to distance $R(z)$ and to higher frequency $n = n_o (z + 1)$ radiation from objects in its frame of reference and narrower bandwidth of radiation at the reception point. It is obvious that this effect will be smaller at lower z, and it turns out that in the standard model at $z \leq 0.2$ it is negligible for galaxies. For the steady-state model the K-effect has approximately the same or a lower value, resulting in a negligible decrease in the slope $dm/d\log z$. The K-effect value for quasars in the standard cosmology, based on our earlier studies (Troitskij *et al.* 1992b; Troitskij & Gorbachova 1993) is equal to $K(z) = 0$ for mean spectral index $a = -1$ ($s = l^a$) within the interval $0.1 \leq z \leq 5$. In the static model this raises the slope of the regression function for quasars from 2.35 to 2.40.

VI. Global regression functions $\overline{M(z)}$ and $\overline{\log q(z)}$ and comparison with predictions

Figure 8 presents the regression $\overline{m(z)}$ for galaxies (dots) and quasars (crosses). As can be seen, the regression for the quasars coincides perfectly with the regression for galaxies at $z \cong 0.1$, rising linearly to $z = 4$. We have a unified linear regression function which, after the corrections given above, is adequately described by the equation

$$\overline{m(z)} = (2.36 \pm 0.1) \log z + 18.5 \pm 0.2 . \qquad (5)$$

The regression function $\overline{\log q(z)}$ is given in Figure 9 and described by the function

$$\overline{\log q''(z)} = -(0.49 \pm 0.05) \log z + 0.81 \pm 0.05 . \qquad (6)$$

Since each mean value $\overline{m(z)}$ and $\overline{\log q(z)}$ in the diagrams in Figures 8 and 9 is determined by averaging n-data points running into the thousands and at boundaries in the hundreds, the random error of the mean value obtained in comparison with a true value is equal to $s_m = s/n \leq 0.1^m$. This error corresponds to the size of points in the diagrams. Likewise, due to the large number of galaxies in each averaging interval we have $\overline{m(z)} = -2.5 \log \overline{E(z)}$ and $\overline{\log q(z)} = \log \overline{q(z)}$ with an error, based on calculations, of not more than 1 per cent. Both figures plot the theoretical dependences (4) at different constant values $\overline{M(z)} = \text{const}$ and $\overline{\log l(z)} = \text{const}$, whence we note a large discrepancy between experimental and theoretical statistical dependences. For slopes $\mathrm{d}m/\mathrm{d}\log z$ and $\mathrm{d}\log q/\mathrm{d}\log z$, the dependences disagree by a factor of 2. This cannot be explained by inaccuracy of the measurements of m and q. Two possible causes remain: error in the theory or the influence of evolution of mean statistical luminosity $\overline{M(z)}$ and mean galaxy size $\overline{l(z)}$. The latter assumption saves the theory if evolution for a closed model is

$$\overline{M(z)} = -2.64 \log z - 24.5, \quad \overline{L(z)} = z^{0.956}\, 10^{11.8},$$

$$\overline{\log l(z)} = 0.52 \log z - 2 \log (z+1) + 5.3, \qquad (8)$$

$$\overline{l(z)} = z^{0.51}(z+1)^{-2}\, 10^{5.3}.$$

However, the required rate of mean luminosity evolution is absolutely unreal, and does not agree with any realistic theoretical estimates, while the required galaxy size evolution appears strange indeed: the size first increases with z approximately proportionally to z up to $z = 0.3$, and then drops off sharply as $z^{-1.5}$. Therewith the mean true galaxy surface brightness $L(z)/l^2(z)$ increases as $(z+1)^4$. In spite of the awkwardness of this evolution, we make two suppositions to explain the discrepancy between theory and practice: the existence of the evolution of mean galaxy parameters and the inadequacy of the theoretical dependence of $R(z) = R_o \Psi(z)$ on z.

To identify the actual cause, a test comparing the observable dependence $\overline{\log q}$ on the value $\overline{m(z)}$ was of crucial importance. It might seem that this test cannot yield any new results, since a relation between $\overline{\log q}$ and $\overline{m}$ follows from the dependences $\overline{m(z)}$ and $\overline{\log q''(z)}$ (5), (6). However, this is not true. Eliminating $\log z$ from these expressions we have

$$\overline{\log q''(z)} + (0.21 \pm 5\cdot 10^{-3})\ \overline{m} = 4.71 \pm 0.05\ . \qquad (9)$$

Here we have used approximately 12,000 galaxies with measurements of z, m and q. To prove (9), we present the regression function of m and q obtained with data on m and q from 36,000 spiral galaxies, among which there are clearly 12,000 with measurements of z. As a result, we have

$$\overline{\log q''(z)} + (0.195 \pm 5\cdot 10^{-3})\ \overline{m} = 4.58 \pm 0.05\ . \qquad (11)$$

As can be seen, the coincidence with (9) leaves nothing to be desired. The corresponding theoretical expression is found from (4) by eliminating the distance function $\log R_o \Psi(z, q_o)$. As a result, we have

$$\overline{\log q''(z)} + 0.2\ \overline{m(z)} = -\log \sqrt{\overline{L(z)}/\overline{l^2(z)}} + 2 \log (z+1) + 5.3\ . \qquad (11)$$

As can be seen, the theoretical expression in the main corresponds closely to the experimental result (9) even though the latter was obtained from experimental dependences that were individually in a sharp contradiction with predictions of the theory. Obviously this happens because of absence of $R(z)$ in $\overline{m} - \overline{\log q}$. The only possible conclusion is that the reason for the discordance between the two classical tests and the predictions of the theory is an inconsistency between the theoretical dependence $R(z) = R_o \Psi(z, q_o)$ and the actual dependence. Comparing theoretical (11) and experimental (10) expressions, and neglecting the component $2 \log (z+1)$ as small at $z \leq 0.2$ we obtain the following very important formula for galaxies

$$\sqrt{\overline{L(z)}/\overline{l^2(z)}} = 5.25\ , \quad 10^{-3} \leq z \leq 0.2. \qquad (12)$$

This relation was obtained by us previously for a number of small data sets (Troitskij 1993).

Thanks to progress in astrophysical measurements, it is possible to carry out a direct measurement of functions (9) and (10) without separate measurements of m and q. The point is that equations (9), (10) and (11) multiplied by 5 give a mean over-disk value of apparent galaxy surface brightness. Therefore, because direct measurements can be made of apparent surface brightness, we have a new cosmological test.

VII. Galaxy surface brightness: the third cosmological test

CCD technology allows a direct measurement of surface brightness distribution over a galaxy disk. Measurements are made of the brightness of an area element visible within a solid angle which is many times smaller than the galaxy angular size. The resulting

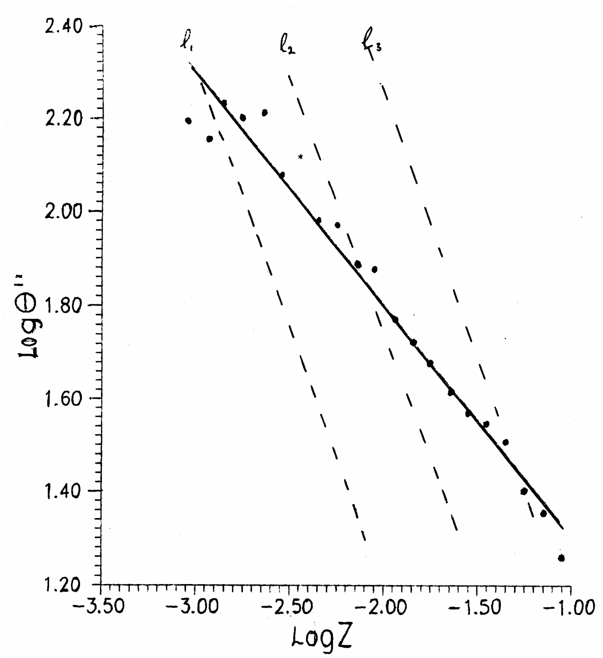

Figure 9. Regression function for $\log q''(z)$ of the dataset of Figure 5 calculated by intervals $\Delta \log z = 0.1$. Solid line is regression $\overline{\log q(z)} = -0.49 \log z - 0.81$. Dashed lines are theoretical curves at different l.

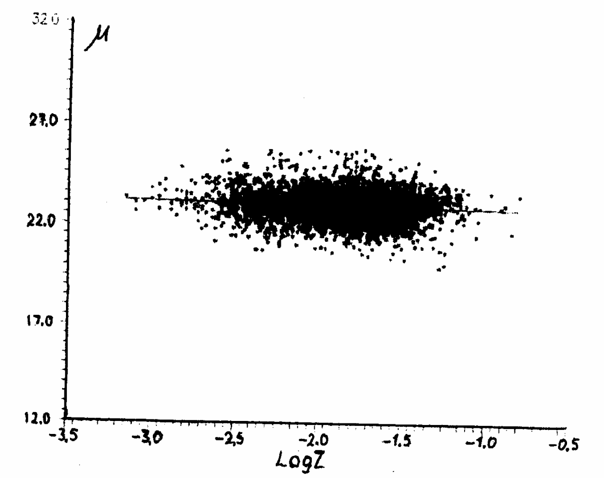

Figure 10. Diagram of dependence of **mean over disk surface brightness** on redshift for 8,550 spirals. Solid line is regression function $\overline{m(z)} = -0.134 \log z + 22.7$.

apparent surface brightness distribution pattern is used to determine the mean surface brightness in magnitudes $m(z)$ averaged over the galaxy disk. According to the theory, this mean surface brightness is expressed in terms of m and q^2 equal in magnitude

$$m(z) = -2.5 \log \left\{E(z)/q''^2(z)\right\}$$
$$= m(z) + 5 \log q''(z). \qquad (13)$$

It is easy to see that $m(z)$ is independent of $R(z)$. It differs from (11) by a factor of 5. Substituting in (13) the values $m(z)$ and $\log q''(z)$ from (4) we obtain a theoretical expression for the regression

$$\overline{m(z)} = -2.5 \log \left[\frac{\overline{L(z)}}{\overline{l^2(z)}}\right] + 10 \log (z+1) + 26.5\,. \qquad (14)$$

The experimental value for regression $\overline{m_{ex}(z)}$ has been determined from the set of random values $m(z)$ for 8,650 galaxies from the (Paturel *et al.* 1989) catalog according to (13). This ensemble of random $m(z)$ is given in Figure 10 together with the regression function equal to

$$\overline{m_{ex}(z)} = -0.13 \log z + 22.67\,, \quad 10^{-3} \leq z \leq 0.2. \qquad (14a)$$

From this it follows that the apparent surface brightness averaged over a galaxy disk is practically independent of z or increases weakly with increasing z, but does not decrease as $10 \log (z+1)$, as predicted by the standard cosmology theory (14). Now we determine the regression $\overline{m(z)}$ according to (13) through the experimental regression functions (5) and (6) and we obtain the expression $\overline{m_{ex}(z)} = -0.1 \log z + 22.55$, close to (14a). Thus, according to our calculations, the apparent surface brightness averaged at each z over a sufficiently large data set is practically independent of z and equal to $\overline{m_{ex}(z)} = \text{const} = 22.6$ stellar magnitudes. According to numerous direct measurements the analogous value is equal to $\overline{m(z)} = 23 \pm 0.5$ (Dresler *et al.* 1990; Hoessel *et al.* 1987; Irwin *et al.* 1990; Peltier *et al.* 1990; Greaham 1992). In line with the above discussion, for comparison with the theory we take the experimental value of $\overline{m_{ex}(z)}$ equal to

$$\overline{m_{ex}(z)} = 22.6 \pm 0.6\,, \quad 10^{-3} \leq z \leq 0.2 \qquad (15)$$

where $s(m) = 0.6$. Comparing (15) with theoretical expression (14) we obtain $\overline{L(z)}/\overline{l^2(z)}\,(z+1)^4 = 36$. Since functions $(z+1)^4$ and $\overline{L(z)}/\overline{l^2(z)}$ are of different nature and, consequently, independent, each is equal to a constant value. It is obvious that $(z+1) = 1$, then

$$\sqrt{\frac{\overline{L(z)}}{\overline{l^2(z)}}} = 6.0\,, \quad 10^{-3} \leq z \leq 0.2 \qquad (16)$$

which coincides with expression (12), obtained from measurements of m and q.

VIII. Determination of *r(z)* and main statistical parameters of galaxies and quasars

For this purpose we must use some definite cosmological model. It is expedient to take the standard cosmology model, although its inadequacy is evident enough from the foregoing analysis. To determine the distance function we use the experimental result (5) and (6) for the regression functions. In physical terms we have

$$\overline{E_{ex}(z)} = z^{-0.945} \cdot 10^{-7.4}, \quad \overline{q''_{ex}(z)} = 6.5'' \, z^{-0.49}. \qquad (17)$$

By comparing with corresponding theoretical expressions (4) we obtain two independent equations for three unknown functions. Due to this fact, the system does not have a unique solution, and this allows us to determine only relations $R(z)/\overline{L(z)}$ and $R(z)/\overline{l(z)}$. Or, in other words, we can express the desired distance function *via* arbitrary regression functions $\overline{L(z)}$ and $\overline{l(z)}$. For distances according to E_{ex} and q''_{ex} we have obtained

$$(R_o\Psi)_m = z^{0.5}(z+1)^{-1} \cdot 10^{3.7} \sqrt{\overline{L(z)}}\,,$$
$$(R_o\Psi)_q = z^{0.5}(z+1) \cdot 3.1 \cdot 10^4 \, \overline{l(z)}.$$

Since $\overline{L(z)}$ and $\overline{l(z)}$ are related by expression (16), both the relations obtained can be expressed in terms of $\overline{L(z)}$. As a result we obtain different dependences on distance z at the expense of terms $(z+1)$ associated with the expanding universe hypothesis. However, both distance functions should naturally be strictly similar, since in both cases they give the metric distance, but not some effective distances adopted in the standard cosmology. So, we seem to arrive at the initial state, because to determine $R(z)$ we must now know the functions $\overline{L(z)}$ and $\overline{l(z)}$. This turns out to be quite possible using additional new statistical tests. However, there exists an apparent opportunity to choose dependences $\overline{L(z)}$ and $\overline{l(z)}$ which, after their substitution in (18), give the theoretical value $R_o\Psi$ and save the theory. For the model, $q_o = 1$ or $q_o = 0$ when $R_o\Psi = R_o z/(z+1)$ it is sufficient to suggest the evolution $\overline{L(z)} = \overline{L_o}\, z$ and $L(z) = \overline{l_o}\, z^{0.5}/(z+1)^2$. But, as noted above, these dependences adjusting observations with the theory are unreal both by the form and value.

To define functions $\overline{L(z)}$ and $\overline{l(z)}$, we make use of the independence of dispersions $\mathrm{D}M(z)$ and $\mathrm{D}\log l(z)$ of redshift z. From this fact we will show that the mean values $\overline{m(z)}$ and $\overline{\log l(z)} = \log \overline{l(z)}$, and consequently, $\overline{L(z)} = L_o$ and $\overline{l(z)} = l_o$ are independent of the redshift. We now consider the set of galaxies at given $z_k \pm 0.5\ \Delta z$. The luminosity of each galaxy evolves according to its individual law, tht total determining the evolution of the mean value $\overline{M} = M_o\ \varphi(z/z_o)$, where M_o is the mean value at some $z = z_o$. This is equivalent to evolution of each galaxy in the set according to $m(z) = M(z_o)\ \varphi(z/z_o)$ where $m(z)$, $M(z_o)$ are the random values distributed by the normal law and $\varphi(z/z_o)$ is a regular function. The dispersion of the random $m(z)$ is equal to $\mathrm{D}m(z) = \varphi^2(z/z_o)\ \mathrm{D}\,\overline{M(z_o)}$ and the mean value, respectively, to $\overline{m(z)} = \overline{M(z_o)}\ \varphi(z/z_o)$. Due to the absence of a marked drift in the dispersion to either side, $\varphi = 1$ and, hence, $\overline{L_0} = L_o$, $\overline{l_0} = l_o$. We now consider the question: at the expense of which parameters may evolution of galaxy luminosity take place. Galaxy evolution is obviously determined mainly by the number of stars N, their temperature and sizes r, *i.e.*

$$L \cong N \sum r^2 (M_p) F(n, M_p) \varphi(M_r) \Delta M_p$$

where M_p is the absolute luminosity of a star, $\varphi(M_p)$ is the star luminosity distribution function, $F(n, M_p)$ is the Planck emissivity function expressed *via* the absolute emissivity of the stars. The sum value is defined by the immutable laws of the star main sequence formation typical for all galaxies. Thus, luminosity evolution may be related to the evolution of star number in galaxies, *i.e.* $L \approx N = 10^n$; but on the other hand $L = 10^2 \cdot 10^{-0.4M}$ and, therefore, $n = -0.4M + 2$. For $M = -21$, $n = 10.4$, which is close to the known value $10 \le n \le 12$. The fact that $\overline{M}$ is independent of z means that the mean number of stars in galaxies is constant over the space. However, in any given place in space the relation (16) is observed, which shows that on the average the luminosity of each galaxy at given z is connected with its size, *i.e.* with the number n of stars in it, and this connection is independent of z. The same reasoning can be applied to the evolution of $\log l$. Therefore, the random values m and L, as well as $\log l$ and l, have their own invariable values of dispersion and mean values $\overline{M(z)} = M_o$, $\overline{L(z)} = L_o$, $\overline{l(z)} = l_o$ over all the space studied, *i.e.* $10^{-4} \le z \le 5$. Therefore, the field of random values $m(z)$ and $\log l(z)$ is a stationary one.

Another confirmation of the invariance of the mean luminosity is the z-independence of the mean statistical spectral index of quasar optical spectra in all bands of redshift $0.1 \le z \le 4$ and galaxy spectra studied up to $z \le 0.2$ (Troitskij 1993).

We pursue our determination of $R(z)$, and now substitute $\overline{L(z)} = L_o$ and $\overline{l(z)} = l_o$ in (18), which yields, as already mentioned, two different functions $(R_o\Psi)_m$ and $(R_o\Psi)_q$ expressing one and the same metric distance, each being in disagreement with the theoretical expression for the standard model $R_o\Psi = R_o z/(z+1)$. An indispensable requirement of the equality of both expressions for metric distance is fulfilled only on the condition $(z+1) = (z+1)^{-1} = 1$. Finally, we have

$$(z) = R_o\sqrt{z}\ ,\quad R_o = 10^{3.7}\sqrt{L_o} = 3.1\cdot 10^4\, l_o\,,$$

$$\sqrt{L_0}\Big/ l_0 = 6.2\ . \qquad (19)$$

Hence, the astrophysical predictions of the standard cosmology are not experimentally supported. We therefore arrive at new expressions of the z-functions for observable parameters $\overline{E(z)} = L_o/R_o^2\Psi^2(z)$ and $\overline{q(z)} = l_o/R_o\Psi$ where $\Psi = \sqrt{z}$. To find L_o, M_o, l_o and R_o, it is sufficient to use the mean values of galaxy luminosities in the vicinity of our galaxy known from direct measurements within radius $z \le 10^{-4}$. It may be considered that $M_o = -20.5^m \pm 0.5$; then

$$R(z) = 600\ \sqrt{z}\ \text{Mpc}\,,\quad L_o = 10^{10.2} L_\odot,$$

$$l_o = 19\ \text{kpc},\ m_o = 22.7\ . \qquad (20)$$

The accuracy of L_o, l_o and R_o values is determined by the accuracy of estimation of the galaxy mean luminosity M_o. Any inaccuracy of M_o within $\pm\ 0.5^m$ produces a maximum error of no more than $\pm$ 25 per cent in the given data.

The independence of mean luminosity values, sizes, surface brightness, the form of continuum spectra of the galaxies and quasars as well as the dispersion from object locations in Metagalaxy space for the set complies with the well-known perfect cosmological principle, *i.e.*, uniformity and isotropy of the universe in space and time established earlier relative to the mean volume density of the matter. Certainly, the constancy of the mean values mentioned does not exclude evolution of luminosity and size of individual galaxies. Appropriate here is an analogy with a mean strength of a large group of people, which remains unchanged in time, even though each individual experiences an evolution of his strength. The statistical uniformity of galaxy characteristics in universal space testifies to the stationary state of its processes. From this we may conclude that its age must exceed the age of the galaxies, estimated as 15–20 billion years, at least by an order or two.

IX. Discussion of results of measurements

The main point at issue is the discrepancy between our meas-

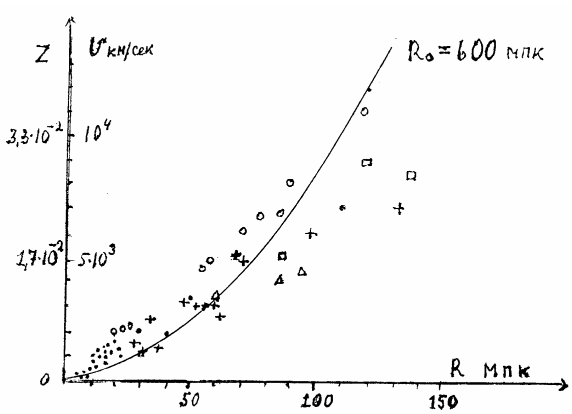

Figure 11. Redshift-distance dependence taken from Rowan-Robinson (1988). Different presentation of experimental points corresponds to different method of distance measurements.

+	Supernovae
○	Tully-Fisher
Δ	Cepheids
	Dispersion of stellar velocities
•	Two or more methods

Solid line is $R = 600\sqrt{z}$ Mpc.

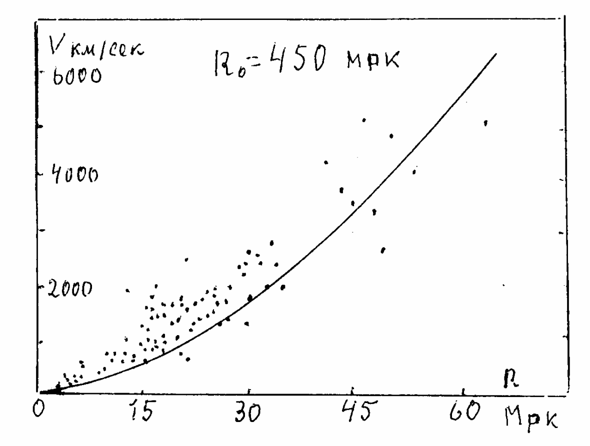

Figure 12. Redshift-distance dependence according to Tully-Fisher. Solid line is $R = 450\sqrt{z}$.

urements of the distance function equal to $R(z) = R_o\sqrt{z}$ and the Hubble law of linear dependence on distance $R(z) = R_H z$. This discrepancy is not a strong argument against our results, since the Hubble law has been established for small values of $z \le 0.02$, at which any smooth function of distance, including $R = R_o\sqrt{z}$ is hardly distinguished from the line. Besides, the galaxy distance scale has been established mainly by Cepheids without taking into account the evolution of the product of absolute luminosity by oscillation period used in conjunction with it. The evolution of this parameter for Cepheids becoming supergiants may be essential even for distances less than 1 Mpc. Finally, the Hubble law was obtained over a small number of measurements, not exceeding a hundred and fifty. Due to a wide scatter of data, this is statistically insufficient to establish a reliable linear connection between R and z. Numerous corrections, for example, for proper motion of the Sun, Galaxy and local group of galaxies, *etc*., detract from the objectiveness of the data. Further details can be found in a thorough review by Rowan-Robinson (1988). A diagram of the final direct measurements of $R(z)$ taken from this work is given in Figure 11. It is plotted by measurements of z and R for 160 objects with data grouped by similar distances and measurement methods. Our nonlinear dependence $R = 600\sqrt{z}$ is also plotted in this diagram. Some departure of the diagram points from this dependence at $R \le 30$ Mpc is likely to be connected with elimination by the sampling of data with zero or even negative velocities, which are bound to occur due to the proper (peculiar) motions of the galaxies. These velocities, with a peak at a level of $3s = 900$ km/s within distances $0 \le R \le 30$ Mpc, exceed Hubble's velocities. This would cause a large spread of data which, however, is not seen in the diagram. It is obvious that direct measurements of $R(z)$ may give unambiguous results if we have a statistically representative dataset.

Arp & Van Flandern (1992) recently proposed new methods for measuring $R(z)$ on the basis of the Tully-Fisher law. The data are given in Figure 12 in comparison with $R = 450\sqrt{z}$. The striking thing is not that these—and the measurements considered above—confirm the quadratic dependence on z, but the fact that they give the same value of $R_o = 500$–600 Mpc which has been found from astrophysical measurements. This is an impressive confirmation of the results. Most dramatic is a new experimental confirmation of the $R = R_o\sqrt{z}$ law from a quite unexpected field of measurements. As is known, there are currently 32 quasar objects which, according to measurements of their structure at radio wavelengths, demonstrate superluminal velocities of expansion if one applies the formulae for standard cosmology to calculate the object distances (Cohen *et al.* 1988). By measuring the rate of change of the source angular dimension and knowing the distance $R(z)$, it is trival to obtain the corresponding linear velocity of the radio-luminous object.

If we consider the existence of superluminal motion of matter impossible, the phenomenon is explained by the light-spot effect (Ginzburg 1985). According to the theory, this effect takes place when there is an acute angle between the directions of moving luminous matter and observation, if the matter moves with light or nearlight velocity of relativistic particles. This theory faces the particular difficulty of explaining why the only matter only moves nearly along the line of sight to the observer. Leaving aside the theory, we choose to approach the problem from the purely experimental viewpoint. The paper mentioned above gives angular rates of change $dq/dt = \dot{q}$ of object dimension in milliseconds of arc per year, as well as z values for the object. Figure 13 plots log $\dot{q}$ as a function of log z for 32 sources. The regression obtained by the least squares method is also given. The equation of this regression function is

$$\log \dot{q} = -0.47 \log z - 1.03 \qquad (21)$$

with a standard deviation $s(\log \dot{q}) = 0.23$. From this, expressing $\dot{q}(z)$ in radians per year, we obtain

$$\dot{q}_{ex}(z) = 0.5\cdot 10^{-9} z^{-0.47} \qquad (22)$$

This relation is easily explained by the steady-state model of the universe and its related experimental parameters. We might legimately suggest that all cases of the matter expansion in quasars entail one and the same physical process, one and the same cause. This process may be the motion of either light or relativistic particles in the source frame of reference. Therefore, the increase of the apparent angular size of the source is $\dot{q}(z) = R_o \sin a / R(z)$, where a is the angle between the direction of the expansion and the line of sight. It is obvious that the motions at $a \cong 0$ or p will not be noted since the object moving in these directions is projected to the source itself. It seems practically to observe the motion in a wide angle interval $a = p/2 \pm p/3$. Averaging the expression for $\dot{q}(z)$ over a in these limits we have the theoretical

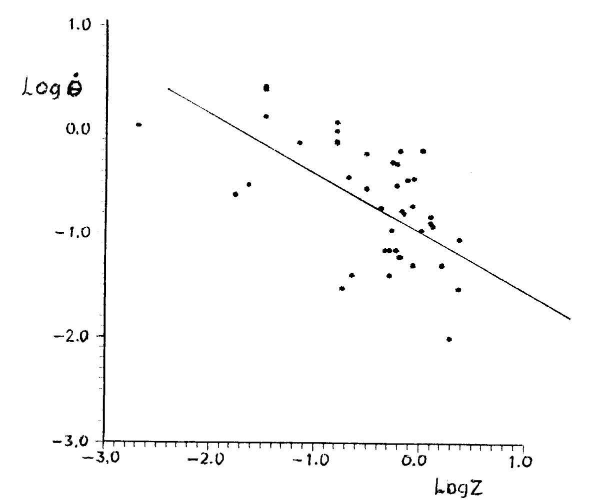

Figure 13. The rate of change of angular size for quasars as dependent on redshift. Straight line is a regression function equal to $\log(dq/dt) = -0.57 \log z - 0.91$.

value $\dot{q}\,(z) = 0.85\ R_o/R(z)$, where in the general case $R(z) = R_o\,\Psi(z)$. Comparing this with the experimental function $\dot{q}_{exp}(z)$ (22), we obtain $\Psi(z) = \sqrt{z}$ and $0.85\ R_o = 0.5\cdot 10^{-9}\,R_o$. The main and unexpected result here is a confirmation of the dependence $R(z) = R_o\sqrt{z}$ obtained above. Of even greater surprise is the fact at $R_o = c = 0.31\text{pc}\cdot\text{year}^{-1}\,R_o = 530$ Mpc. This is a dramatic result. On the basis of this analysis, we believe that measurement of the angular dimension drift in quasar structure features is a remarkable crucial cosmological test since it does not require any special assumptions to determine $R(z)$. We cannot see how to interpret the dependence $R = R_o\sqrt{z}$ derived from the experimental data in any other way, or by what reasoning it might be rejected, save to suggest that R_o depends on z. However, on the contrary, from these observations a very important conclusion seems arguable, *viz.*, that light velocity, and hence, the maximum velocity of the matter, are independent of z—*i.e.* of time—and equal to a constant value.

The quite wide scatter in the data is most probably connected with errors in the complex measurements of extremely small angular shift. A quadratic dependence of redshift, it should be noted, was first proposed theoretically by Segal (1957) on the basis of group theory. The resultant formula is given as the law $z = \tan^2 R/2R_c$ (Segal 1993), where R_c is the universe radius. For small distances $R \ll R_c$, the R,z relation coincides with our experimental result, and is equal to $z = R^2/4\,R_c^2$. This relation was checked by a comparison of the observed dependence $m(z)$ with the theoretical one at $R = 2R_c\sqrt{z}$ using statistical methods (Nicol and Segal 1978).

As a result, satisfactory agreement was shown between the observed data and the theoretical dependence $m(z) = 2.5\ \log z + \text{const}$. From this, it is concluded that $z \sim R^2$. This conclusion is not, however, unique and unambiguous. It is correct if the luminosity evolution is *a priori* absent, *i.e.* $L(z) = \text{const}$. Otherwise the evidence suggests that $m(z) \approx \log L(z) R^{-2}(z)$, from which $R(z)$ cannot be determined, since $L(z)$ is unknown.

Segal (1990) gave the value $R_c = 160 \pm 40$ Mpc, which was obtained from measurements of quasar angular expansion rates similar to those made by us above, independently. Nicol and Segal (1978) found that a very instructive and curious thing happened when they determined the R,z dependence. As early as 1925, Lundmark (1925) had shown that the observed $m(z)$ dependence corresponds to the quadratic law $z \sim R^2$. In the same years, Hubble and Humason carried out $m(z)$ measurements of different galaxies which, as Segal has shown, correspond to the quadratic law, *i.e.* $dm/d\log z = 2.5$. Only a selection of first rank galaxies in clusters followed the linear law, and was used later. Nicol and Segal (1978) offer compelling arguments to show the fallacy of the first rank galaxy selection method, and point out the correct procedure for sampling the brightest galaxies, which was proposed independently and justified in the present paper. In spite of a great number of publications (about 30) by Segal and his coworkers devoted to this problem, they have not convinced the scientific community. This is explained first by the lack of proofs of the uniqueness of the quadratic law, and second, by the use of original, unconventional statistical methods to analyse a relation between the observed and theoretical dependence $m(z)$, instead of the obvious and widely used methods of regression analysis.

Unfortunately, few of Segal's works were published in the astronomical literature and, therefore, were not known up to 1994; but on the other hand this makes the coincidence of methods and results all the more valuable and objective. Where there are differences, they are by no means serious. For example, according to Segal R_c is at once the radius of the universe and the horizon, since at $R = R_c$, $z = \infty$ and the quadratic dependence of the redshift takes place only at $R \ll R_c = 160$~Mpc. In our case, the quadratic relation $R = R_o\sqrt{z}$ is unlimited at least up to $z = 5$, and R_o has a meaning of distance at $z = 1$. The size of the universe does not follow directly from observations.

The work of the prominent researcher Toivo Jaakkola closely parallels the approach in the present paper. The style of his investigations is a combination of ideas based on principles of universe structure with a search for observational confirmation of these principles. This includes the Perfect Cosmological Principle, *i.e.* the idea that the mean values of matter and radiation parameters in the universe are invariable and uniform in space and time (Jaakkola 1989). In the cosmology based on this principle, called in Jaakkola's work "Equilibrium Cosmology," the redshift is formed in the process of light propagation in a stationary non-expanding space. This is a fundamental statement which transforms the redshift problem into the field of the relationship between electromagnetic radiation and the properties of the physical vacuum. As a concrete manifistation of this relation, Jaakkola considered an electrogravitational interaction resulting in an exponentional dependence of the redshift on distance in the form $(z + 1) = \exp\,a\ r$, where $a = 1/H_o^{-1}\,c$. This corresponds to the well-known "tired light" hypothesis. in which the frequency changes proportionally to the time $t = v/c$ taken by the light on its way from the source to the observer. However, in practice this relation leads to the linear Hubble dependence $r \cong cH_o^{-1}$ (z-0.52^2) up to $z = 0.5$–0.7, which, as we have shown, does not correspond to reality. In general, Jaakkola had to resort to the Hubble law in his calculations, since he had no other authentic alternative at the time. Now, there is practically no doubt that the redshift mechanism must be sought taking into account the quadratic dependence of redshift on distance. This of course does not rule out the general concept of "Equilibrium Cosmology". This idea made it possible for T. Jaakkola to see the possibility of MBR formation due to thermal radiation of stars in the universe, and to suggest a solution to the puzzle of the observed equality between MBR energy and the energy of optical radiation from stars in our Galaxy (Jaakkola 1993). Our findings are, in essence, a crucial experimental verification of the view that the universe adheres to the Perfect Cosmological Principle, but not to the gravitational equations of Newton or Einstein.

Another result requiring discussion is an unexpected coincidence of $m(z)$ dependences for galaxies and quasars. We are told that quasars cannot be used together with galaxies to plot a general dependence $m(z)$ since they are of a different nature. Galaxies have thermal radiation and quasars have synchrotron radiation, so how can they be combined in a Hubble diagram? And so on? First, we do not combine them by force; they combine themselves, without asking astronomers for a single $m(z)$ dependence, apparently because they have the same luminosity as galaxies. The unification can be seen only in an unbiased usage of all $m(z)$ data for a large number of galaxies and quasars, not for an arbitrary selection, as in Figure 3. Second, quasars and galaxies occupy one and the same space, and their optical radiation is subjected to the same action by this space, resulting in the observed redshift. By virtue of this fact, quasar apparent luminosity $m(z)$ is determined by one and the same dependence $R(z)$ as for galaxies. This is why they have the same slope $d\overline{m}/d\log z$ of the dependence $\overline{m(z)}$ as galaxies.

Sometimes it is assumed that quasars have an additional initial redshift that is not connected with distance. However, this redshift cannot be identical for all quasars; otherwise excluding this effect would cause a displacement of the quasar $m(z)$ dependence in the Hubble diagram and destroy the fit with the galaxy $m(z)$ dependence. Since this is not the case, the additional redshift must be dependent on distance, much like the main shift; *i.e.* there is no need for it. So, instead of heaping up new assumptions, one should start with the most obvious idea that galaxy and quasar redshift is determined only by distance from the observer. Needless to say, this assumption does not contradict the quasar synchrotron radiation mechanism and their other parameters, such as small dimensions *etc*. Therefore, quasars are quite suitable for determining $R(z)$ dependence using our methods. However, one cannot ignore the phenomenon, discovered by Arp, of close associations between some quasars with large redshifts and galaxies with significantly lower redshift which seem to show signs of physical connection. There is no reasonable explanation of this phenomenon so far.

Lastly, we must return to a detailed consideration of how and to what extent the selection method of first rank (the brightest) galaxies can continue. For this purpose we return to Figure 4, giving the distribution of galaxies in m,z space and the theoretical dependence $m(z) = 5\log z + 21.5$ at a constant luminosity of $M = 21.5$ and $q_o = 1$ which was used to plot experimental $m(z)$-data of the galaxies which were allegedly uniform in absolute luminosity given in Figure 1. As can be seen, selection of the brightest galaxies at small $z = 10^{-3}$ proceeds from the left corner of the $m(z)$ field where galaxy luminosity m is $3s = 3.3^m$ greater than the mean value $\overline{M}$ corresponding to the maximum of the Gaussian distribution curve. At $z = 0.1$–0.5 the theoretical curve goes through the field of the galaxies and quasars of luminosity (3–4)s less than in the maximum of the distribution curve. In this field there may be (this is easily calculated by integrating the distribution function from $m + 3$ to $m = \infty$) about $3\cdot10^{-3}N$ galaxies, where N is the total number within redshift interval $z = 0.1$–0.5. From these low luminosity galaxies, sometimes grouped in clusters, we can always select the brightest ones which, by definition, turn out to be within the limits of the theoretical curve. Thus, the method of selecting the brightest galaxies from clusters leads to the formation of an $m(z)$ dependence in which galaxy absolute luminosity is not constant, but changes from $\overline{M} - 3s$ to $\overline{M}$ +(3–4)s. This explains the high value of slope $dm/d\log z = 5$. In reality, galaxies and quasars with the same standard luminosity lie on lines parallel to the regression curve, which corresponds to galaxies lying in the maximum of the luminosity distribution curve and having luminosity equal to $\overline{M}$. This very dependence should be used for comparison with the theory. It is clear from the above that the brightest galaxy method can be modernized if we select the brightest galaxies, not from clusters, but from all objects in the given interval Δz at different redshifts $10^{-3} \le z \le 4$ by observing representative samples. The work of Sandage and Perelmutter (1991) is closely related to the galaxy selection method described here. It gives a comparison of galaxy surface brightness as dependent on redshift with predictions of standard model of cosmology (14)

$$m(z) = -2.5\log L(z)l^{-2}(z) + 10\log(z+1) + \text{const}.$$

Here, as mentioned earlier, the second term is determined by the expanding universe hypothesis, and is called the Tolman signal. A total of 19 galaxies were used to obtain the experimental dependence within the redshift interval $0.03 \le z \le 0.59$ on the basis of $m(z)$ and $q(z)$ data which, according to (13) yield surface brightness $m_{exp}(z)$. In this way, it is obviously necessary to select galaxies with the same ratio $L(z)/l^2(z)$. An attempt was made in this work to avoid the influence of sampling, so only those galaxies were selected which were on the theoretical Hubble line $m(z) = 5\log z + \text{const}$, where according to the standard model $L = \text{const}$. Then, from the galaxies selected in this way, individuals were chosen for which the theory gave one and the same value l. This selection method is not correct, since galaxies are chosen using the theory, which is what is being tested. As shown above, this sampling yields galaxies with an absolute luminosity that is strongly dependent on z. In this example, we see once again the need to use statistical methods of analysis and, consequently, large datasets that neglect the influence of large dispersions. The Tolman signal can be extracted only from the regression dependence $\overline{m(z)}$ determined from large datasets that are uniform over visible and easily stated features such as, for example, galaxy morphology type. It follows from the above that selecting of galaxies by features of their parameters m and l is impossible if m and l are measured by indirect procedures using these or other hypothetical theoretical dependences. Until now, no reliable direct methods had been developed, since the methods of Tully-Fisher and Faber-Jackson are statistical. The criteria for selecting sets of galaxies and quasars may only be parameters that are defined unambiguously and directly, for example, galaxy morphology type, pecularities of the radiation spectrum, the structure of the galactic nucleus, or other established types such as, for example, Seyfert galaxies, and so on.

We should note that our results on normal distributions of galaxy luminosities and linear dimensions, respectively $\log L$ and $\log l$, are in sharp contradiction to the generally accepted Schechter distribution. The latter was determined by L data for the galaxy set at $10^{-3} \le z \le 10^{-1}$ obtained by calculation from the apparent luminosity $m(z)$ using the formulae from standard cosmology (1) and (2). This has resulted in a mixture of experimental data with unproved (and apparently now erroneous) theory. Actually Schechter introduced a distortion in the distribution with errors in determining L. This led to an asymmetric distribution. A pure experimental distribution of m (and L) is possible for galaxies in a sufficiently narrow z-interval. It is also possible to determine the distribution over all galaxies or all quasars separately and together within all $10^{-3} \le z \le 4$ intervals if we substract regressions $\overline{m(z)}$ from he set $m(z)$ and find the distribution from the difference. In so doing, we take away the regular part from the dataset $m(z)$, leaving the purely random part $m(z) - \overline{m(z)}$ with zero mean value. In our case, the regression $\overline{m(z)}$ for the galaxies and quasars is given in equation (5). The calculated distribution is presented in Figure 14 separately for all galaxies within interval $10^{-3} \le z \le 0.1$ and all quasars at $10^{-1} \le z \le 4$, as well as for all together within $10^{-3} \le z \le 4$. This is what we call a true normal $\log L$, *i.e.* m distribution.

In conclusion, we might suggests that galaxy catalogues with experimental data of apparent parameters are not to be added with different reductions and corrections, such as the K-correction or

Tolman's effect, and others derived from an unproved theory. This makes for catalogues that are ill suited for objective experimental investigations.

X. Theoretical conclusions

This section arises from a need to discuss the theoretical consequences and new cosmological hypotheses that follow from the experimental results, namely, the nature of the redshift and microwave background, the size and lifespan of the Metagalaxy, the structure and evolution of matter in the universe, and others.

a) On the nature of the redshift

The experimental dependence $z = R^2/R_o^2$ found here, and the demonstration that the redshift occurs in the process of light propagation, severely limit the scope of possible hypotheses to explain the nature of the redshift. The scope is further narrowed if we require that a new explanation of the redshift should be grounded in known processes that are studied in physics. These conditions are met by the well-known gravitational shift. In fact, according to classical physics a spherical light wave propagating in an infinite medium with a uniform matter density r will do work against the gravitational force of the matter enclosed by the spherical wave. This causes a decrease of the energy quantum $e = hn$ by an amount $de = e c^{-2}\, dj$, where $j = -4pGR^2/3$ is the gravitational potential of a sphere of matter and \varepsilon $e c^{-2}$ is the equivalent photon mass. From this we obtain $dn/n = -8\, pGr\, R\, dR/3c^2$. Integrating over R from $R = 0$ and taking into account that the radiation frequency changes from n_1 at the time of emission to n_o at the time of observation, we have

$$\frac{n_1}{n_o} = (z+1) = \exp\left(\frac{R^2}{2r_g^2}\right) \qquad (23)$$

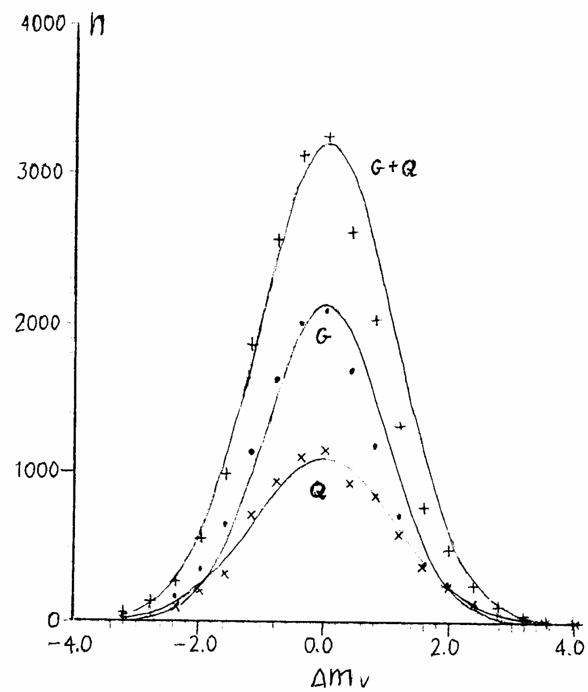

Figure 14. Distribution laws $p[m(z) - \overline{m(z)}]$ for galaxies and quasars in the set of Figure 4. Solid lines represent Gaussian law. Points are the experimental distribution; G for 12,440 galaxies, Q for 4,000 quasars; $G+Q$ is the total for galaxies and quasars. Corresponding standard deviations are equal in magnitudes to $s_1 = 0.95$, $s_2 = 1.15$, $s_3 = 1.1$. Averaging interval is $\Delta m = 0.4$.

where $r_g^2 = 3c^2/8pGr$ is the gravitational radius of matter uniformly distributed in space. In the relativistic interpretation $n_1/n_o = g_{oo}^{-1/2}$ where g_{oo} is the metric tensor component for weak gravitational fields equal to $g_{oo} = 1 + 2\, j/c^2$, which yields a redshift $(z+1) = 1\big/\sqrt{1 - R^2/r_g^2}$. For $R \ll r_g$, $z = R^2/2r_g^2$ in both cases. According to (19) in our case, $z = R^2/R_o^2$; therefore, to match the gravitational redshift hypothesis, R_o should be equal to r_g. With $R_o = 600$ Mpc, it is easy to see that the average matter density in the Metagalaxy should be $r = 2\cdot10^{-28}$ g cm^{-3}. This is 3 orders more than existing estimates of the density of radiating matter. The same situation arises in standard cosmology, where for a closed model the matter density is required to be equal to $r = 10^{-29}$ g cm^{-3}. This has led to the conclusion that 99 per cent of the mass is in a hidden state. Following this hypothesis, in our case we might assume the existence of a nearly thousand times more hidden mass than visible mass. However, the search for hidden mass has not yielded results. Hence, it follows in our opinion that a new hypotheses should be developed to account for the quadratic dependence on distance. At present a number of hypotheses have been proposed concerning the nature of the redshift in the work of Kropotkin (1989), Rvachov (1994), Popov (1978) and others, which it would be worthwhile to develop further in light of the present experimental results.

b) The microwave background radiation

According to the results obtained here, the universe appears as a practically unlimited system of galaxies. This makes it possible to explain the observed microwave background radiation as the total thermal radiation of stars in the optical and radiowave ranges (Troitskij 1994, 1995). Briefly the findings are as follows. The radiation flux at frequency n of stars of a given spectral class at distance R in solid angle Ω of a radiotelescope antenna pattern in a volume element $\Omega R^2\, dR$ is

$$d\, j = pr^2 nmrR^2 F(n,T)\, d\, n\, dR$$

where $F(n,T) = 2hn^3/c^2[\exp(hn/kT) - 1)]$ is Planck's function for the emissivity of a star with photosphere temperature T, n is the radiation frequency in the star's reference frame, n is the volume density of galaxies, m is the number of stars in the galaxy, and r is the star's radius.

In addition to a regular attenuation of R^2 times on the way to an observer, the flux $\mathrm{d}j$ will undergo an attenuation due to the redshift of $(z+1)$ times, equal to the ratio of emitted and received radiation frequencies, as well as due to radiation screening (absorption) by galaxies encountered along its way. It is readily seen that a quantum of the screened radiation is equal to the ratio of the sum of galaxy areas $nl^2R^3/3$ along the line of sight and the total area of the antenna pattern cross-section ΩR^2, *i.e.* $nl^2R/3$. Hence, a quantum of transmitted energy is equal to $g = (1 - 0.33l^2\ nR)$. As a result, the luminosity at the point of observation will be $\mathrm{d}E/\ \mathrm{d}n_o = g\ \mathrm{d}j/(z+1)R^2$. Integrating this expression over R at $R = R_o\sqrt{z}$ and taking into account that $\mathrm{d}n/(z+1) = \mathrm{d}n_o$ we have the observed luminosity spectral density $E(n_o)$ at frequency n_o from srars of the given spectral class. Summing over all star spectral classes in the main sequence, we obtain the total flux. Comparing this with the blackbody radiation at the same frequency n_o, we find the effective temperature T_b of stellar radiation according to

$$\frac{1}{2} p n_{sol}^2 n m R_o \sum_{-5}^{19} r^2(M_p) j(M_p) \int_0^z \frac{(z+1)^3 g(z)\,\mathrm{d}z}{\sqrt{z}\left[\exp\left(\frac{h n_o (z+1)}{kT_p}\right)-1\right]} = \left[\exp\left(\frac{h n_o}{KT_b}\right)-1\right]^{-1} \qquad (24)$$

Here M_p is the photometric luminosity, $j(M_p)$ is the luminosity function of the main sequence stars, $r(M_p)$ is the star radius relative to the Sun's radius R_{sol}, and T_p is the star temperature for the given luminosity. The value of z_o is determined from the condition $g(z_o) = 0$ and is equal to $z_o = (5\text{-}7)\cdot 10^3$, which corresponds to the integration interval 40,000 Mpc. The calculation gives the background temperature $T_b = 2.73$ K in the wavelength band $l_o \geq 0.1$ cm. However, for wavelengths $l_o < 0.1$ cm, the background brightness temperature increases sharply up to hundreds of degrees at optical wavelengths. Figure 15 gives the dependence predicted by Troitskij and Aleshin (in press) of background temperature on wavelength as compared with the theoretical data which, as can be seen, confirm the theory.

The other extremely important result of the background star hypothesis is an explanation of the heretofor unsolved coincidence of two fluxes: the optical radiation of all stars in our galaxy and the background radiation. From expression (24) it is seen that the left part appears as radiation of stars from one mean galaxy, since each galaxy on the line of sight contributes only at one frequency n equal to $n_o\ (z+1)$. Placed at different z, all galaxies finally form the radiation of one galaxy, with Planck's distribution of contributions. If we integrate (24) over all frequencies, then stellar radiation gives the volume density ~0.25 eV/cm^3, just as the as 3 K background does. Lastly, the theory suggested here makes it possible to determine the value of small-scale fluctuations $\Delta T/T_b$ and their dependence on the antenna pattern width in minutes as $\Delta T/T_b = 5\cdot 10^{-5}/\sqrt{\Omega}$, which coincides very nearly with the observed value.

c) Structure, size, lifespan and evolution of Metagalaxy

Obviously, astrophysical data cover only the visible part of the universe up to $z = 5$ with a radius according to our data of about $R = 600\sqrt{z} \cong 1{,}500$ Mpc. In this space interval, corresponding to a time interval of about 5 billion years, we does not observe any noticeable evolutionary changes in mean parameters of galaxies, quasars and radiation. On this scale, the Metagalaxy appears as a system in a stationary stable state. Astrophysical data obtained to date do not give any information on the time of the Metagalaxy's origin and its lifespan. However, on the basis of the statistical uniformity of galaxy and quasar properties, we may conclude that the Metagalaxy's lifespan should be at least one-two orders more than the estimated lifetime of galaxies, as well as estimations of the universe's lifespan in the standard cosmology. This conclusion is clear enough, since the time to attain the observed stationary equilibrium state should be much more than the lifetime of objects in the universe. Space appears to be Euclidean, as it follows from experimental expressions for apparent luminosity and angular dimensions of galaxies. The Metagalaxy's dimensions appear to be determined by the distance beyond which electromagnetic signals no longer reach the observer. In the standard cosmology, for a closed model a visible boundary or horizon occurs at the distance $R_H = cH^{-1}_o$ = 6,000 Mpc, for $H_o = 50$ km/s·Mpc. Thus, $r = r_k = 3H_o^2/8pGr_k = 10^{-29}$ g cm^{-3}. It is easy to verify that at this matter density R_H is equal to the gravitational radius $r_g = 3c^2/8pGr_k = cH_o^{-1}$.

In our case, explaining the redshift by the action of the gravitational field, the horizon is the gravitational radius corresponding to the observed mean density of the visible matter in the Metagalaxy, equal to about $r = 10^{-31}$ g cm^{-3} which gives the radius of visibility (radius of the Metagalaxy) $R_g = 40{,}000$ Mpc.

Certainly, this cannot be taken as a boundary beyond which nothing exists, *i.e.* it cannot be the boundary of the universe. Otherwise, the Earth would be in the centre of the universe, *i.e.* in a particular, preferred position. This is hard to believe; it is more likely that the universe is infinite, and for each observer in it there exists a proper Metagalaxy with the same horizon for all observers equal to R_g. This boundary of visibility $R_g = 4\cdot 10^4$ Mpc, according to the relation $R = 600\sqrt{z}$, corresponds to the maximum "visible" redshift to $z_m = 5\cdot 10^3$. We might also define the boundary of visibility as a distance at which projections of central regions of galaxies on the projection (visual) plane fill it completely. This boundary, as was shown above, is equal to $R_m = 1/nl^2\cdot 0.33$ which, with $n = 3$ and $l = 5$ kpc gives $R_m = 40{,}000$ Mpc. Surprisingly, this distance is close to the gravitational radius. By taking the obtained estimate of the horizon we actually eliminate the possibility of explaining the

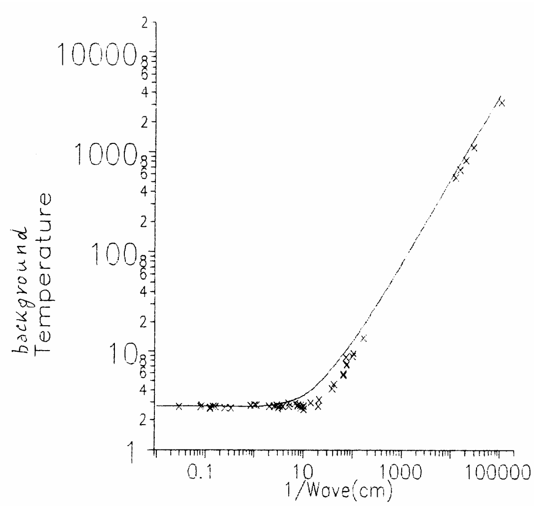

Figure 15. Theoretical dependence of brightness of stellar background temperature on wavelength for a steady-state model of the universe at $z_o = (5\text{-}7)\cdot 10^3$ as compared with the measured data (crosses).

redshift as a gravitational shift. We can find the red gravitational shift for quasars using formula (23) for $R_g = 4 \cdot 10^4$ Mpc. The quasar distance at $z = 5$ according to (20) is equal to $R \cong 1{,}500$ Mpc, so the gravitational shift for quasars should be $z = 3 \cdot 10^{-4}$. As can be seen, this situation arises due to the low matter density in the Metagalaxy, equal to 10^{-31} g cm^{-3}. Thus, we come to a dilemma: either we take the gravitational origin of redshifts, and conclude that there exists a tremendous amount of hidden mass in a small Metagalaxy, which eliminates the explanation of the microwave background by stellar optical radiation; or we take the known measured density of matter, as large Metagalaxy and the possibility of explaining the microwave background radiation by stellar radiation, which prevents us from explaining the redshifts of galaxies and quasars as a gravitational shift. Evidently, we should base ourselves on real measurements and estimates of matter density in drawing further conclusions. The latter version appears to be more experimentally grounded, logically more economical and contains *ad hoc* assumptions, such as a huge hidden mass, *etc*.

XI. Conclusions

An investigation of the problem of the agreement of the standard cosmology with reality has shown that the theoretical redshift-distance relation based on the hypothesis of an expanding universe does not correspond to the experimentally measured dependence. The latter shows that the redshift cannot be explained as a kinematic Doppler effect or by space expansion, in accordance with the relativistic theory of gravitation. According to the available data, the Metagalaxy is a stationary system of galaxies and other objects in Euclidean space, with steady-state mean values of parameters and no noticeable evolution for the past five billion years. Concerning the nature of the redshift, the unambiguous conclusion is that it arises in the process of light propagation in a physical vacuum. An explanation should apparently be sought in a local interaction between electromagnetic radiation and the physical vacuum. We believe that our conclusion regarding the stellar origin of the microwave background radiation, as proven by the background observations, is a conclusive argument in favour of a steady-state universe model.

Finally, it should be said that the standard cosmology was not without its usefulness. For the first time, it put the question of the origin and evolution of the universe on a physical observational basis, developed methods for investigating the properties of space and formulated crucial problems for investigations and experimental testing. This was a necessary, although partly fantastic, stage in the development of ideas about the universe. On the basis of the methods, problems and ideas introduced by the standard cosmology, the next steps can now be carried out with new approaches; the results should be seen not as a total negation of accepted theory, but rather as a further search for truth.

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