HUBBLE EXPANSION IN A EUCLIDEAN FRAMEWORK

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Abstract. There now seems to be strong evidence for a non-cosmological interpretation of the QSO redshift – in any case, so strong that it is of interest to investigate the consequences. The purpose of this paper is to construct a model of the Hubble expansion which is as far as possible from the conventional Big Bang model without coming in conflict with any well-established observational results (while introducing no new laws of physics). This leads to an essentially Euclidean metagalactic model (see Table I) with very little mass outside one-third or half of the Hubble radius. The total kinetic energy of the Hubble expansion need only to be about 5% of the rest mass energy.

Present observations support backwards in time extrapolation of the Hubble expansion to a 'minimum size galaxy' R_m, which may have any value in $0 < R_m < 4 \times 10^{26}$ cm. Other arguments speak in favor of a size close to the upper value, say $R_m = 10^{26}$ cm (Table II). As this size is probably about 100 times the Schwarzschild limit, an essentially Euclidean description is allowed. The kinetic energy of the Hubble expansion may derive from an intense QSO-like activity in the minimum size metagalaxy, with an energy release corresponding to the annihilation of a few solar masses per galaxy per year.

Some of the conclusions based on the Big Bang hypothesis are criticized and in several cases alternative interpretations are suggested. A comparison between the Euclidean and the conventional models is given in Table III.

I. PRESENT STATE OF METAGALAXY

1. A New Approach to Cosmology

In the sixties the cosmological discussion was centered on the question of the Big Bang hypothesis or the Continuous Creation hypothesis being the most promising approach. The discussion demonstrated that there were fatal objections against the latter, but no decisive objections against the former were presented forcefully enough. The result was that the interest concentrated on the development of the Big Bang hypothesis, and in wide circles this has now been accepted as the final solution to the cosmological problem. Observations are primarily interpreted according to its formalism, and the large body of observations which are not in agreement with the Big Bang hypothesis are either neglected or accounted for by a large number of *ad hoc* hypotheses. This applies to the claim by Ambartzumian (1958) and Arp (1978) that there are ejections from galaxies which demonstrate the existence of 'an unknown force' which counteracts gravitation. Arp (1978) concludes that a number of observations indicate that the Big Bang hypothesis is much too simple and at least requires considerable modifica-

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tion. Independent of this, de Vaucouleurs (1970) has demonstrated that observations support a 'hierarchical cosmology' of the Charlier type.

There has been remarkably little discussion on whether the basic Big Bang hypothesis is correct. The purpose of this paper is to make a critical evaluation of this cosmology and to present a possible alternative approach to cosmological problems.

2. Homogeneity and Mean Density of Metagalaxy*

If the mean density ϱ_M of the metagalaxy were above the Laplace–Schwarzschild limit $\Omega = 1$ with

$$\Omega = \frac{8\pi G}{3H_0^2}\varrho_M, \tag{2.1}$$

it would be difficult to avoid the Big Bang hypothesis. Great efforts have been expended on finding the 'missing mass', but so far without success. Gott *et al.* (1974) have made a critical analysis of the most reasonable value. They find an upper limit of $\Omega = 0.06$. If only that mass is included for which there is rather *decisive observational evidence*, they find $\Omega = 0.0013$. With $H_0 = 3 \times 10^{-18}\ \mathrm{s}^{-1}$, we find that

$$\varrho_c = 2.0 \times 10^{-29}\ \mathrm{g\ cm^{-3}} \qquad \text{and} \qquad \varrho_M = 2.6 \times 10^{-32}\ \mathrm{g\ cm^{-3}}.$$

On the one hand, this is a lower limit because there is certainly a considerable amount of invisible matter. On the other hand, this lower limit itself is likely to be too high because it is derived under the assumption of a homogeneous density in the metagalaxy, which is unlikely to be correct, as we shall now discuss.

The Friedmann model takes for granted that the 'Universe' should have a uniform mass density. It is obvious that this a very far from correct for our 'close neighborhood' out to at least 10^{26} cm and perhaps 10^{27} cm. The real distribution of mass seems to be in better agreement with de Vaucouleurs' 'hierarchical' model with galaxies forming groups or clusters which are parts of superclusters.

The mean densities ϱ of these formations (with radius R) obey the empirical law (de Vaucouleurs, 1970)

$$\varrho \leqslant 1.5 \times 10^{15}\, R^{-1.7}. \tag{2.2}$$

Theoretically relevant laws with which this formula should be compared are the Charlier limit for convergence of large-scale structures in a Euclidean cosmology

$$\varrho = kR^{-2}, \tag{2.3}$$

where k is a constant, and the Laplace–Schwarzschild limit is

$$\varrho_{\mathrm{Sch}} = \frac{3c^2}{8\pi G}R^{-2} = 1.6 \times 10^{27}\, R^{-2}\ \mathrm{g\ cm^{-3}}. \tag{2.4}$$

* The Big Bang hypothesis claims that what was earlier called the metagalaxy is identical with the whole Universe. In a critical review of the Big Bang, the unbiased old term must be used.

The de Vaucouleurs' law is derived from observations up to more than 10^{26} cm. Whether it is valid for still larger systems is an open question. The Big Bang claim that the large-scale structure of the 'Universe' should be homogeneous cannot be disproved at present, but nor is there any decisive observational support for it. Radio astronomical observations are quoted as the best support for homogeneity at very large distances. The results are usually based on the *assumption* that the QSOs are at cosmological distances. As we question this hypothesis we have to reinterpret the data (see Section II.6).

If we tentatively extrapolate the de Vaucouleurs' hierarchy up to distances comparable to the Hubble distance, we find for $R = 10^{27}$ a density $\varrho = 19 \times 10^{-32}$, and for $R = 10^{28}$ a density $\varrho = 0.38 \times 10^{-32}$. If we accept a value of these orders as reasonable for the average density in the metagalaxy (compare Gott's value), we may interpret the metagalaxy as a member of the hierarchy (cf. Section II.8).

3. Hubble Expansion

As no acceptable alternative seems to exist, we interpret the observed galactic redshifts as due to the Doppler effect (longitudinal or transverse). This means that at present the metagalaxy is in a state of general expansion.

If the Hubble parameter were really isotropic, this would be strong support for the Big Bang hypothesis. This is obviously not the case; for example, de Vaucouleurs and Bollinger (1979) find variations between 70 and 110 km s^{-1} Mpc^{-1} for galaxies in different directions. Such variations are believed to be associated with the supercluster and hence not fatal to the Big Bang, because it is possible to interpret them by auxiliary *ad hoc* assumptions. However, it makes the homogeneity of the Friedmann model increasingly remote from observational realities.

4. Non-Cosmological Redshifts of Some QSOs. A QSO Model

More serious is the redshifts of some QSOs. Whereas many QSOs have the same redshifts as galaxies to which they seem to belong, there are a large number of QSOs with redshifts vastly different from that of a galaxy with which they obviously are closely associated. For this and other reasons, Burbidge (1973, 1979) and others have concluded that the redshifts of some QSOs must be 'non-cosmological'.

As an example, Arp (1978) has observed clusters of QSOs with $z = 0.6$–2.2 close to a galaxy with $z = 0.01$, and shows that the location of these is such that it is impossible to avoid the conclusion that they have been emitted by the galaxy. The velocity of the QSOs with reference to the galaxy must exceed $\beta = 0.8c$. A body with this velocity has a fraction $\alpha = \gamma - 1 = 0.7$ of its rest mass in the form of kinetic energy. The only reasonable explanation for such high kinetic energies seems to be that the body has emitted radiation and/or plasma unidirectionally, and has been accelerated by the resulting rocket recoil (Alfvén, 1979; see also Alfvén, 1977, 1978, and Fälthammar *et al.*, 1978). The energy required for such an acceleration should be compared with the energy release which we must assume in order to account for its very large luminosity. In fact, the luminosity of QSOs at a distance given by the redshift of the galaxies is often 10^{41} erg s^{-1}. The distance of a QSO from the galaxy in which it appears to have generated is typically 3×10^{23} cm, which shows that its lifetime must be at least $3 \times 10^{23}/c = 10^{13}$ s. Assuming an average constant luminosity, we find its total energy output during its lifetime must be at least $10^{41} \times 10^{13} = 10^{54}$ erg, corresponding to annihilation of 10^{33} g or approximately one solar mass.

We conclude that the radiated energy is of the same order of magnitude as is needed to accelerate a QSO of about one solar mass up to very high z-values.

Hence, with no assumption other than that the energy source of a QSO is intrinsic, we find that the observed radiated energy and the energy required for acceleration to relativistic velocities are of comparable orders of magnitude.

A suggested, essentially semi-empirical model seems to account for the observed properties (Alfvén, 1979). It is concluded that only annihilation can provide the energy required. The model is still in an early state of development.

As there seems to be a general taboo against the existence of antimatter, it is important to stress that our cosmological conclusions are *not based* on the existence of antimatter. Any other intrinsic energy source is acceptable if it satisfies the above conditions.

Hence, in summary:

(1) accepting the QSOs to be at non-cosmological distances,
(2) accepting that the energy source must be intrinsic,
(3) assuming that the energy is emitted unidirectionally (which is necessary in order to explain the absence of blueshift), and
(4) assuming that the mass of the QSOs is comparable to the solar mass,

we conclude that they can be accelerated up to relativistic velocities.

This conclusion is not based on any assumption about the source of energy.

5. Consequences of 'Non-Cosmological' Interpretation of the QSO Redshifts

If we accept some QSOs to have 'non-cosmological' redshifts – i.e., that they are accelerated by an intrinsic release of energy, perhaps (but not necessarily) of the same kind discussed above – this has far-reaching consequences for cosmology. Not only the QSOs themselves, but also clouds emitted from them during their acceleration (and observed as absorbers of their emission) should be explained as due to a QSO intrinsic release of energy. Hence, they should be excluded from the analysis of the general Hubble expansion of galaxies. This means that the large-scale structure of the metagalaxy must be derived from the measurements of objects which, with certainty, can be identified as galaxies.

We shall study three cases with the outer limits given by $\beta = 0.3, 0.4$, and 0.5, which means $z = 0.37$, 0.53, and 0.73, with $\beta = 0.4$, $z = 0.53$ as our main alternative. In the most recent publication by the Sandage group (Kristian *et al.*, 1978), there is no galaxy in excess of $z = 0.75$ and less than a dozen in excess of $z = 0.37$. Observing that de Vaucouleurs defines the effective radius by the condition that there should be as many object outside as inside the limit, our choice of outer limits is rather generous and will be valid even if many more distant galaxies are observed. As, in the cosmological discussion, there has been a strong drive to accommodate all observational facts within the Big Bang framework, it seems justified to do the opposite here in order to explore what latitude observational facts give to theories.

6. Metagalactic Models

The implications of these assumptions are shown in Table I; the values of R_H and T_H derive from de Vaucouleurs. The density ϱ is an average of values for $\beta = 0.3$, 0.4 and 0.5 extrapolated from (2.2) but its small variation with β is neglected. The kinetic energy W_k depends on whether we assume a constant density or a density distribution inside the metagalaxy according to (2.2). The value of 0.25 of the coefficient in the kinetic energy formula is a compromise. The microwave energy is based on a black-body radiation of 3 K, giving an energy density of $W = 1.53 \times 10^{-13}$ erg cm^{-3}.

II. EVOLUTION OF METAGALAXY

1. Origin of Kinetic Energy of Hubble Expansion

After the rest mass energy, the largest amount of energy in the metagalaxy is the kinetic energy of the Hubble expansion (Table I). Accounting for this energy must be our first priority.

In the Big Bang hypothesis the kinetic energy associated with the Hubble expansion is much larger than in our model because it is a homogeneous model with Hubble velocities up to c. In the more popular presentations of the Big Bang model, it is often claimed that this is due to an 'explosion', but as in the Friedman model there is no pressure gradient, this cannot be correct. In reality the high velocities are postulated and their 'explanations' are attributed to supernatural effects associated with an *ex nihilo* creation of the Universe. As our approach is based on the assumption of no new laws of nature – including no supernatural mechanisms – we cannot accept such an explanation. Instead we must investigate in the usual scientific way from what phenomena the Hubble expansion gets its energy.

Accepting the non-cosmological interpretation of the QSO velocities we find that in these objects there must be a mechanism which can accelerate large masses to the relativistic velocities of the QSOs and also of the ejected gas clouds. Hence *without reference to any specific model* we can suspect that similar phenomena during an early phase of metagalactic development might have accelerated galaxies up to the observed Hubble velocities.

TABLE I

Hubble radius $R_H = 10^{28}$ cm
Hubble time $T_H = R_{H/c} = 10^{10}$ yr
Hubble volume $V_H = \frac{4\pi}{3} R_H^3 = 4.2 \times 10^{84}$ cm^3
Density $\varrho = 2 \times 10^{-32}$ g cm^{-3}
Galaxies are supposed to have $R_G = 10^{22}$ cm, $M_G = 2 \times 10^{43}$ g, $\varrho = 5 \times 10^{-24}$ g cm^3

	$\beta_l = 0.3$	$\beta_l = 0.4$	$\beta_l = 0.5$	
Radius of metagalaxy				
$R_l = R_H \beta_l$	3×10^{27}	4×10^{27}	5×10^{27}	cm
Rest mass				
$M_M = 8.4 \times 10^{52} \beta_l^3$	2.27	5.38	10.5	$\times 10^{51}$ g
$N_\odot^M = \frac{M_M}{M_\odot} = 4.2 \times 10^{19} \beta_l^3$	1.14	2.70	5.28	$\times 10^{18}$
$N_G^M = \frac{M_M}{M_G} = 4.2 \times 10^{9} \beta_l^3$	1.14	2.70	5.28	$\times 10^{8}$
Rest mass energy				
$W_M = 7.5 \times 10^{73} \beta_l^3$	204	483	944	$\times 10^{70}$ erg
Kinetic energy				
$W_k = W_M 0.25 \beta^2 = 2 \times 10^{73} \beta_l^5$	4.59	19.3	59.0	$\times 10^{70}$ erg
Microwave energy				
$W_\mu = 6 \times 10^{71} \beta_l^3$	1.62	3.84	7.50	$\times 10^{70}$ erg

Compare:
Gravitational energy of metagalaxy $\sim 10^{69}$

We assume that the metagalaxy in an earlier state, when its radius was a fraction α of the present studies, converted part of its rest mass into kinetic energy by some process (which we need not define here) and that this accelerated the Hubble expansion from zero to the present value. We assume that this action proceeded during a time

$$T_{\rm acc} = 2R_{\rm min} v^{-1},$$

where $R_{\min}$ ($= \alpha R_M = \alpha\beta R_{\mathrm{H}}$) denotes the minimum size of the metagalaxy and $v = \beta c$. Hence

$$T_{\mathrm{acc}} = 2\alpha T_{\mathrm{H}}.$$

As Table II shows, the kinetic energy equals $0.25\beta^2$ of the rest mass energy. Putting the efficiency of the process equal to 25% (see below), we must annihilate a fraction β^2 of the rest mass during the acceleration. Hence, in a galaxy consisting of 10^{10} solar masses, an energy release corresponding to annihilation of $10^{10}\beta^2$ solar masses should take place during the time T_{acc}. Expressing the required power P in annihilated solar mass per year, we find that

$$P = 10^{10}\beta^2(2\alpha \times 10^{10})^{-1} = \frac{0.5\beta^2}{\alpha}.$$

TABLE II

Radius: $R_m = 10^{26}$ cm (2 or 3% of present size)
Mass equals present mass increased by less than 50%, say: $M_m = 0.3\text{–}1.0 \times 10^{52}$ g
Density: $\frac{3}{4\pi} \times \frac{10^{52}}{R^3} = 1\text{–}3 \times 10^{-27}$ g cm^{-3}
Column density: ~ 1 g cm^{-2}
Escape velocity: $(2GM/R)^{1/2} = 2\text{–}4 \times 10^9$ cm s$^{-1} \approx 0.1c$
Laplace–Schwarzschild limit: $R_{\mathrm{Sch}} = 10^{24}$ cm
Correction for general relativity $\approx R_{\mathrm{Sch}}/R_m \approx 1\%$
Correction for special relativity $\approx \beta^2 \approx 10\text{–}25\%$ (except for QSO-related phenomena)

Hence, for $\beta = 0.4$ we need to have a QSO-like activity giving an output of about $0.1 \times \alpha^{-1}$ solar masses annihilated per year per galaxy. In view of the fact that some QSOs have been reported to radiate comparable amounts of energy we conclude that if α is not too small it would be possible to account for the Hubble kinetic energy (in a non-supernatural way!) by a very large, but not necessarily unreasonably large QSO-like activity at an early state of the metagalaxy.

A model of this process should start from the observed properties of the QSO release of very large quantities of energy, which in part are converted into kinetic energy of the QSO and of emitted clouds. If the end of the life of a QSO is a complete burn out, its activity will result in accelerating plasma clouds up to very large kinetic energies. If the clouds can pass the metagalaxy without colliding with other clouds, they will leave the minimum size metagalaxy. If they collide with other clouds they may distribute their energy to these clouds in a way that will result in general expansion.

As we shall see in Section II.3, other models giving a similar output are perhaps more likely.

So far we have not committed ourselves to a specific model of the QSO release of energy, but as nuclear energy is insufficient, and gravitational energy of an object cannot by any reasonable process be converted into net kinetic energy of the object, there seems to be no other alternative than annihilation. This gives support to the view that the Universe is matter–antimatter symmetric.

In an energy release by annihilation, half of the annihilated rest mass energy is lost by neutrino emission. If half goes into kinetic energy and half into radiation of different kinds, the overall efficiency would be 25% (which is the value we have assumed). If the produced radiation is converted into microwave energy by some process, this is several times more than the 3 K radiation in the whole metagalaxy.

After these remarks it should again be stressed that we *do not base* our cosmological conclusions on the existence of antimatter. Any other energy source would be acceptable if it can deliver the same quantities of energy.

2. Extrapolation of the Hubble Expansion

The Hubble expansion shows beyond doubt that, at earlier epochs, the metagalaxy was smaller than it is now. If the Hubble parameter were *exactly* constant and all apparent deviation from it were *exclusively* due to observational errors, an extrapolation to a 'singular point' would be inevitable. Such conclusions are not observationally justified. Even if all QSO-related phenomena are excluded, there is strong evidence for systematic variations in the observed Hubble parameter (Rubin, de Vaucouleurs) which, however, can be interpreted in different ways. To some extent these can be accommodated in the Big Bang hypothesis by *ad hoc* assumptions (about the motion of our galaxy in relation to other galaxies, etc.), but it is not obvious that an interpretation according to our approach would be less attractive. Furthermore, there are considerable statistical errors, often 10% or more, which may be due to observational uncertainties. However, we cannot exclude *intrinsic variations of the Hubble constant of several per cent.*

Suppose that during a finite time ΔT there are a number of independent explosions by which 'protogalactic' matter, which later will form galaxies, is sent out in random directions with random velocities v. Suppose further that all these explosions take place within a sphere with radius R_e. Seen from one of the accelerated protogalaxies (which later may form our galaxy) the other protogalaxies will initially have both blueshifts and redshifts. However, when our protogalaxy has left the sphere R_e, the number of blueshifts will decrease rapidly (for geometrical reasons) until only redshifts are left. As time proceeds the expansion will be increasingly similar to a Hubble expansion.

After a time $T \gg \Delta t$, and when they have reached a distance $R \gg R_e$, Hubble's law will be well satisfied. In fact, at a time $T = \Delta T \alpha^{-1}$ there will be spread in the Hubble values by $\Delta H/H = \Delta T/T$ to which should be added the spread $\Delta H/H = R_e/R$.

If $\Delta T/T$ and R_e/R are both of the order α, a maximum value of α can be calculated from $\Delta H/H$. A detailed study of how large an α the observational results allow is highly desirable. If $\alpha = 10\%$ the value of $R_{\min}$ would be 4×10^{26} cm. It is claimed that most of the variations in the H-values are observational, so $R_{\min}$ is likely to be lower, say, for the order of magnitude

$$R_{\min} = 10^{26}\ \text{cm},$$

which gives a rate of annihilation

$$P \approx 3\ M_{\odot}\ \text{yr}^{-1}.$$

This means that we replace the Big Bang in a singular point with an 'extended Big Bang' in a volume of 10^{26} cm produced by what we may identify with the Ambartzumian 'unknown force' (for which we have given a possible explanation).

3. Mean Free Path in Metagalaxy

As we have seen, it is important to decide whether clouds emitted from a QSO can escape from the metagalaxy near its minimum size. In the simple model of the metagalaxy we have used, this is supposed to consist of N_G galaxies all with radius $R_G = 10^{22}$ cm. There is no obvious reason why the galaxies should change their size in connection with the Hubble expansion, so we assume R_G to be constant. Further, we assume that when an emitted cloud collides with a galaxy it transfers its kinetic energy to it, whereas it can travel freely in intergalactic space. Hence, direct ejection can take place if $N_G^M \sigma_G < \sigma_M$, where $\sigma_G = \pi R_G^2$ and $\sigma_M = \pi R_M^2$. Hence, we find $R_M = 10^{22}(N_G^H)^{1/3}$. As $N_G^M = 4.2 \times 10^9 \beta^3$ we have

$$R_M = 1.6 \times 10^{25} \beta \approx 0.6 \times 10^{25}.$$

We see that if the minimum metagalaxy were of the order 10^{25} cm or less there would not be a direct emission of QSO clouds. We would have a rate which could not so well be described in terms of a QSO activity. We could very well have the same release of energy, but this should be distributed over the whole metagalaxy. The galaxies within it would collide, and if they contain both kinds of matter the collisions may be 'hyperelastic' and lead to an intense release of energy (Thompson, 1978). The emission of matter would no longer be a volume phenomenon but a surface phenomenon. This would reduce the spread in the Hubble parameter. At the same time there may be a strong coupling between matter and radiation, so that protogalactic matter and a radiation field, which later deteriorates to microwave radiation, is emitted with the same Hubble velocities. Hence we see that an extrapolation from the present state of the metagalaxy could not go as far as 10^{25} cm, so for the order of magnitude we should stop at 10^{26} cm.

4. Model of Minimum Size Metagalaxy

Again, following the principle that we should investigate how far from the Big Bang model we can go without risking a conflict with observations, we should put the radius of the minimum size metagalaxy equal to 10^{26} cm.

Hence, a possible model of the metagalaxy at its minimum size would be a sphere with the properties according to Table II. It is evident that according to this model the evolution of the metagalaxy can be treated with Euclidean geometry to a first approximation.

5. Formation of Minimum Size Metagalaxy

Going backwards in time, the next problem is how the minimum size metagalaxy was formed. As this will drag us into the jungle of cosmological speculation, we will not attempt to clarify the problem in this paper. In a Euclidean model time may be infinite, and for every early period we explore a new problem of earlier states will appear. The further we go back in time the less we can say with any degree of certainty. Cosmology as a science should work toward clarifying the conditions in ever-increasing regions of space and time, but a discussion of a possible 'ultimate cause' belongs to philosophy or religion.

It should be remembered, however, that Klein assumed that the minimum size metagalaxy was formed by infall of matter from an immensely large – but not infinite – sphere containing a homogeneous ambiplasma (mixture of koinomatter and anti-matter). This view is reconcilable with the results we have reached, with the rather important reservation that Klein's model is homogeneous. We know now that most of the early homogeneous models in astrophysics are grossly misleading and must be replaced by inhomogeneous models. For our problem, this is important because an infall of matter–antimatter might very well take place in part also during the present period when the dominating dynamic phenomenon is the Hubble expansion.

6. Radio Astronomy Data

Radio astronomy results are very important for exploring metagalactic structure. It is often claimed that they have shown that the 'Universe' is very isotropic at distances approaching the Hubble distance. In fact, this is often considered to be one of the most important supports of the Big Bang cosmology. However, when studying the observational results – e.g., as presented at the IAU Symposium No. 74 (Jauncey, 1977) – one cannot avoid a feeling that much of the observational support for Big Bang derives from a firm belief that this hypothesis must necessarily be correct. It is true that the data clearly discriminate between steady state cosmology and evolutionary cosmologies, but accepting an evolutionary cosmology does not necessarily mean accepting the conventional Big Bang hypothesis (our approach is also evolutionary!). It seems that to some extent the observational material is not analyzed with the purpose of deciding whether the Big Bang is acceptable or not, but how the observation should be accommodated in its framework. As Kellerman (loc. cit., p. 80) puts it: '... although the experimental situation has changed drastically during the past twenty years, the conclusions [drawn from the source counts] have not!'

As the distances to the radio sources cannot yet be measured in a reliable way, the interpretation of radio data are model dependent. In his clear survey von Hoerner (1974) stresses that the cosmological interpretation of the radio observations depends completely on the 'helpful but unproven assumption that quasars are at cosmological distances'. Since it is the aim of this paper to discover the consequences of questioning this assumption, we must reinterpret the radio results. However, it is far beyond our ambitions to do so in this paper, and we must therefore confine ourselves to a few remarks.

A comparison between the results of different observers – for example, as presented at the IAU Symposium No. 74 – demonstrates how controversial the results still are in important respects. Some authors – e.g., Mills (loc. cit., p. 31), Kellerman (loc. cit., p. 80), and Pauliny-Toth (loc. cit., p. 63) – claim to have shown that the distribution of the radio stars shows a marked clumpiness, whereas others – Fanti and Lari (loc. cit., p. 25), Wall (loc. cit., p. 55), and Webster (loc. cit., p. 75) – claim to have shown that there is no inhomogeneity exceeding a few percent. A remarkable result is that no increase in the number of sources is observed in the direction of the Virgo cluster (Mills, loc. cit., p. 31). This is very difficult to reconcile with visual observations, which very clearly show that matter is concentrated in galactic clusters and superclusters, not the least at very large distances. The only possible interpretation seems to be that the radio data do not refer to those distances which are covered by visual observations, and one may ask whether this depends on the assumption of cosmological quasar distances. Bahcall and Turner (loc. cit., p. 295) demonstrate that there is a strong correlation between the maximum apparent magnitude and the redshift, but only up to $z = 0.35$. This is what would be expected also according to our approach for the QSOs which are located in galaxies. Hewish *et al.* (loc. cit., p. 139) have demonstrated that the angular diameters of compact components in radio sources are substantially independent of redshift in the range $0.2 < z < 2.0$. This result – if confirmed – seems to speak in favor of non-cosmological distances of the QSOs.

The general impression of the radio data is that they may as well be accommodated in the cosmological approach that has been outlined here. However, before we draw such a conclusion a thorough analysis of the data must be made, and this must be reserved for future investigations.

7. Other Cosmological Problems

There are a number of other important cosmological problems which a Euclidean approach to cosmology has to account for – sooner or later. Some of them may be solved by a straightforward application of the matter–antimatter symmetry (if we accept this!). Examples are the *γ-ray bursts* (Sophia and van Horn, 1974, 1975; Vincent, 1976), and the *X-ray background radiation* (Carlqvist and Laurent, 1976). These phenomena can be explained by the Big Bang cosmology only by a number of questionable *ad hoc* assumptions.

The *production of elements* might take place in QSOs where the temperature varies from normal temperatures of stellar interiors to extremely high temperatures in the layers in close contact with the 50 MeV $= 5 \times 10^{10}$ K e^+e^- gas in the Leidenfrost layer (Alfvén, 1979). The present theories need both the moderately high temperatures in stellar interior and the extreme temperatures at the Big Bang and at the supernova explosions. Both seem to be available in QSOs.

An interesting problem is the generation of *microwave radiation* in a hierarchical cosmology. As seen from Table I, there is more than sufficient radiative energy to produce microwave radiation if this is enclosed in the metagalaxy. We know that nova and supernova explosions produce shells around them which consist of dust and gas (to a large extent presumably in a molecular state). It is reasonable that QSO activity in the minimum size metagalaxy does the same (see Section II.3), and it is conceivable that a 'cocoon' produced in this way surrounds the metagalaxy and converts the radiated energy into an isotropic black-body radiation of, perhaps, 3 K. To check if this hypothesis is realistic is rather difficult. First, we do not know the conditions in the minimum size metagalaxy well enough to derive the chemical and structural composition of such a cocoon. Furthermore, the interaction between matter (dust and molecules) in the spectral region of the microwave radiation is very poorly known. Hence we must necessarily wait until these fields of science are much better developed.

An alternative approach is tentatively suggested in Section II.8.

The advance of X-ray and γ-ray astronomy has demonstrated the existence of a large number of extremely energetic events. The energy source of these are often supposed to be 'black holes'. The mechanisms for energy emission from black holes are very complicated, and Arp has given good arguments for not accepting them. It should also be observed that, according to McVittie (1978), the usual treatment of black holes is not acceptable from a general relativity point of view. It seems that, at least in many cases, annihilation is a more likely energy (if the antimatter taboo can be broken).

8. Other Metagalaxies

An interesting feature of a Euclidean cosmology is that there may be other metagalaxies in the vicinity of ours. It is conceivable that a large number of metagalaxies together may form a still higher order (which has been called a 'teragalaxy') in a hierarchical cosmology. If the microwave radiation is not enclosed in the metagalaxy but fills a larger space with the same energy density 1.5×10^{-13} erg cm^{-3} $= 1.4 \times 10^{-34}$ g cm^{-3}, the Laplace–Schwarzschild limit is reached at $R = 3 \times 10^{30}$ cm. Hence a teragalaxy of this dimension might be closed by the mass of the microwave radiation alone. In this highly hypothetical case, Euclidean geometry is not applicable to the whole Universe but only to minor parts of it, like metagalaxies. But it is possible that the hierarchical and Euclidean model is also valid further out.

9. Concluding Remarks

The Big Bang advocates often claim that a Euclidean cosmology necessarily must be 'homocentric' or 'pre-Copernican' and hence, from a philosophical point of view, 'distasteful'.

First, the Copernican model left the Earth in a rather central position because our solar distance is only one-tenth of the average distance of a planet. If we put the outer limit of the solar system at 40 AU, the Earth is located in the innermost 10^{-5} part of it. If we include the cometary reservoir of 10^4–10^5 AU, the fraction is reduced to 10^{-12}–10^{-15}. Hence, in the language of the Big Bang advocates, the Copernican system should be regarded 'distastefully homocentric'.

Further, our Sun is about ten times the average distance of a star from the center of our galaxy – which does not occupy a central position in our local group, which is peripheral in our cluster of galaxies, which again is far from the center of our supercluster. Hence, even if it were true that a Euclidean model must give our very impressive supercluster a central position in our metagalaxy, this could not be brandished as a homocentric view. However, a Euclidean cosmology need not necessarily do even that because we know that our supercluster moves with a rather large velocity in relation to the microwave background. Furthermore, the relative velocity might

TABLE III

Comparison between the Euclidean model and the conventional Big Bang

	Euclidean	Big Bang
Outer limit of metagalaxy	3×10^{27} cm	10^{28} cm
Outer limit of universe	3×10^{30} or infinity	
Minimum size	10^{26} cm	Singular point
Age of metagalaxy (T_H = Hubble time)	$0.97 \times T_H$	$1.00 T_H$
Age of the Universe	Perhaps infinity	
Source of kinetic energy	Intense QSO-like activity	Postulated, not specified
Density distribution	Hierarchical	Homogeneous
Existence of antimatter	Strongly indicated but not absolutely necessary	Excluded (except in some unconventional models)

be zero if both the supercluster and the background radiation share the same Hubble expansion. It should be noted that the minimum size metagalaxy has a column density of ~ 1 g cm^{-2}, which should give some coupling between matter and radiation.

Finally, the Euclidean cosmology questions whether our metagalaxy really is the whole Universe – which the Big Bang advocates claim. This is opposite to making the Universe – the real infinite Universe – more homocentric.

A comparison between the Euclidean and the conventional models is given in Table III.

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