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Strengths and weaknesses of the big bang cosmology*

Jayant V. Narlikar
Inter-University Centre for Astronomy and Astrophysics, Ganeshkhind, Pune 411 007

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Abstract. This talk reviews the achievements and shortcomings of the standard hot big bang models of the universe. The achievements lie in the predictions of the expanding universe, the abundances of light nuclei and the microwave background. These are, however, outweighed by the shortcomings *e.g.* evidence for anomalous redshifts, the age problem, the low abundances of helium and the failure to find any feature in the microwave background as predicted by the theories of structure formation. It is suggested that cosmologists should keep their minds open for alternative theories also. A few such suggestions are given.

Key words : cosmology—microwave background—steady state—big bang

1. Introduction

The majority of cosmologists have by now taken for granted that the standard hot big bang model of the universe is the correct starting point for the study of cosmology. Whatever differences of opinion there are concern matters of detail rather than the fundamentals. Thus some may prefer the universe to have an inflationary phase while some may opt for cosmic strings or textures. Opinions may differ as to whether there is a lot of hot dark matter or cold dark matter in the universe. Amongst theorists there may be a wide variety of scenarios of structure formation (see, for example, Silk & Peebles 1990) to argue upon. Observers may still continue to argue whether the universe is open or closed, whether the cosmological term is needed or not. The consensus, however, is that the broad picture provided by the big bang theory of the expanding universe is correct and whatever unsolved problems remain will go away in the course of time given the huge brainpower concentrated on their solutions.

My purpose here is to take a critical look at this complacent attitude and to show that the lack of successes of the standard model in explaining diverse extragalactic observations is serious enough to warrant a fresh look at the cosmological problem. To start with I will briefly enumerate the strong points in favour of the hot big bang model (HBBM). In my critical assessment to follow I will endeavour to show that the pillars of

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evidence on which the HBBM rests are not as strong as they appeared a quarter century ago.

2. The Strengths of HBBM

In this section I will be as pro-big-bang as possible and present the case in its favour as follows.

(a) *The evidence for expansion of the universe* : Friedman (1922; 1924) obtained models of the expanding universe as solutions of the newly proposed theory of general relativity. The Friedman models remained neglected for a few years largely because the astronomers believed the universe to be static. It was only in 1929 that Hubble gave a linear law relating the redshifts of galaxies in our neighbourhood to their distances, thereby lending strong observational support for expansion of the space in which these galaxies are embedded.

Thus we have here the healthy situation in which a scientific theory made a prediction which was subsequently verified by observers who were essentially unaware of the theory. (This remark counteracts the unkind criticism that if an observer is consciously looking for a theoretical effect he is either biased in favour of it and so finds it or is biased against it and does not find it!)

Since Hubble's 1929 paper extensive work has been done on extending the redshift-distance relation to more remote sources. For galaxies, Sandage has played the pioneering role in establishing that the first ranked (*i.e.*, brightest) member galaxies of clusters serve as good standard candles so that their apparent magnitudes are good indicators of distance. A good Hubble type redshift-magnitude relation emerges for such galaxies. For a review see Sandage (1991).

Another evidence in favour of the expansion of the universe is the more recent work by Sandage and Perelmuter (1990a, b; 1991) showing that the surface brightness of galaxies goes down with redshift as $(1 + z)^{-4}$. This result is predicted by the expanding world models.

(b) *The microwave background* : In the early 1950s Alpher & Herman (1948) and Gamow (1953) had, from their calculations, predicted the existence of a thermal radiation background peaking in the microwaves. Because cosmology was considered too speculative by the physicists the prediction was not consciously followed up but was only serendipitously verified in 1965 when Penzias & Wilson (1965) discovered the microwave background (MBR). Since 1965 the MBR has been measured at several wavelengths and its intensity spectrum conforms remarkably closely to the thermalized Planckian form. The more recent demonstration of this came from the observations of the Cosmic Background Explorer (COBE) satellite (Mather 1990). Again we have observations coming independently of (and after) the theoretical prediction.

(c) *Primordial nucleosynthesis* : The prediction of MBR by Gamow *et al.* came as a by-product of their work on the hypothesis that most, if not all the nuclei of chemical elements we see today in the universe were synthesized in the first few minutes after the big bang. Although some technical details of the work of Gamow (1946) and Alpher *et al.* (1948) turned out to be inaccurate, their hypothesis was at least partially successful. Later Burbidge *et al.* (1957) and Wagoner *et al.* (1967) have shown that although bulk of the heavier nuclei from carbon onwards are made in stars light nuclei (which are difficult to make in stars in the observed abundances) can be made in the first 200 seconds or so in the HBBM.

Subsequently the claim has been made Yang *et al.* (1979) that the HBBM prediction of ^{4}He abundance depends so sensitively on the number of neutrino flavours that one can confidently assert that this number cannot exceed 3. The fact that particle physicists also believe this number to be 3 from the data from accelerator experiments therefore lends further credibility to the HBBM.

(d) *Evidence for evolution* : The HBBM has the universe evolving from a very hot dense state to the currently observed diffuse cool state. This evolution over a time scale of $\sim 10^{10}$ yrs will have its impact on the time dependence of the physical properties of its contents, *e.g.*, on the populations of discrete sources like galaxies, radio galaxies, quasars, etc. From Hubble's law and the expansion hypothesis it follows that redshift is an indicator of universal epoch : *i.e.*, in a chronological sequence an epoch of high redshift preceded an epoch of low redshift. It has been argued that the populations of objects like these at high redshift do differ in morphology, luminosity etc. from their counterparts at low redshifts [see for example Schmidt (1947); Peacock (1985); Kapahi (1985)]. Such evidence therefore supports the HBBM picture.

Surely, are these not sufficient grounds to place a vote of confidence in the HBBM? Peebles *et al.* (1991) have made this case and taken the stand that the HBBM has now attained sufficient maturity to be able to serve as the broadly correct theory for the universe. There are problems with the HBBM, they argue, but these are not serious enough to warrant abandoning the model altogether.

In the remaining part of this paper I will question this standpoint and argue that the problems encountered by the HBBM are not just superficial but are serious and now becoming insurmountable. And so, a stage may already have reached where cosmologists should seriously start considering alternative scenarios.

3. The validity of Hubble's law

The Hubble law is the foundation on which the expanding universe models rest. If the law is known to be valid for all extragalactic objects then only can we use it to claim that an object at high redshift is farther away from us and being viewed at an earlier epoch than an object of low redshift. The claims for evolution therefore rest on the Hubble law being correct.

Is there any observational way that can be used to assert that a relation of the following kind

$$z = f(D) \qquad \ldots(1)$$

indeed exists between the redshifts z and distances D of all extragalactic objects that has (i) z increasing with D, and (ii) z proportional to D at small distances?

As mentioned earlier thanks to the work of Allan Sandage and his coworkers it is possible to have a relation like (1) for first ranked cluster member galaxies out to redshift of ~ 0.75. Contrast this result, however, with the redshift magnitude plot for all quasars in the Hewitt-Burbidge catalogue (1987), which is a scatter diagram with no relation of the kind (1) emerging from it. Attempts to arrive at a Hubble type relation have, of course, been made but not in a convincing manner. The best that can be said is that with suitable caveats the scatter diagram can be made consistent with (1) which is a much weaker statement than the claim that Hubble's law necessarily holds for all extragalactic objects. How does the consistency argument work?

The conventional cosmologist argues that the scatter is due to a variation of intrinsic luminosity. In other words, the value of z as an indicator of the expansion redshift is reliable but the magnitude m as a measure of distance is not. Once this is admitted the cosmologist can no longer claim that a faint object is necessarily far away. Yet such claims are frequently made by those who wish to claim evolution on the grounds that fainter populations are different from brighter ones.

A more pragmatic approach would have been to admit variation not only in intrinsic luminosity but also in the redshifts. Thus the scatter could also be due to objects of varying redshifts with same luminosity. This possibility admits an 'intrinsic' noncosmological component in the redshift :

$$(1 + z) = (1 + z_c)(1 + z_i). \qquad \ldots(2)$$

Thus the cosmological component (z_c) obeys Hubble law (1) but the intrinsic component (z_i) introduces the scatter in the Hubble diagram. I will elaborate on the evidence for z_i in the next section.

4. Anomalous redshifts

Returning to (2) what is the evidence for z_i, the intrinsic component of the redshift? Any evidence that is anomalous with respect to the Hubble law (1) is basically evidence for z_i. For details of such evidence see Arp (1987), Bertola *et al.* (1988) and Narlikar (1989). Here I will summarize the different categories of evidence.

(i) *High redshift quasars near bright galaxies* : Arp (1987), for example, has reported three quasars of redshifts 0.34, 0.95 and 2.20 triangularly distributed around a bright galaxy NGC 3842 of redshift 0.020. The angular separations are of the order of 60-100 arc seconds. Is this configuration accidental? If quasars are distributed randomly as background objects to the above galaxy the chance of finding the three of them within such a small angular separation is as low as $< 10^{-5}$.

Cases like these make one wonder whether these are exceptions or generic. A recent study by Burbidge *et al.* (1990) shows that quasars tend to cluster around bright galaxies in a manner that cannot be ascribed to chance projection effects whether or not their redshfits match those of the galaxies. Again, probability calculations are made to show the significant non-randomness of the quasar distribution. Faced with such an evidence the responses of the conventional cosmologists have typically been as follows:
"(a) We will accept those cases where the quasar-galaxy redshifts match as true examples of physical association because they bear out Hubble's law.
(b) Those cases which have anomalous redshifts are either due to selection effects or the statistical significance of their observed closeness is suspect."

Evidently if the data have to be treated as 'right' or 'wrong' depending or not whether they 'confirm' or 'disprove' Hubble's law, this attitude will never lead to a genuine test of Hubble's law!

A further twist was added to this saga when in the late-1980s experts on gravitational lensing began to argue that if the quasar population is gravitationally microlensed by foreground objects one would expect to see quasars preferentially clustered round galaxies. On this basis it was argued by Stocke *et al.* (1987) :

"For several years now there has been some evidence for a slight statistical excess of QSOs projected on the sky near bright galaxies. Over most of the history of these observations, the sole interpretation has been that these QSOs were physically associated with the bright galaxies near them and that the QSO redshifts were, therefore, "non-cosmological". Because this interpretation was contrary to the well-accepted cosmological redshift hypothesis, this evidence was largely dismissed on the grounds that the data were either statistical fluctuations or were due to an improper statistical analysis. More recently, another interpretation has arisen following the discovery of multi-range QSOs in which QSOs near foreground galaxies are brightened by the gravitational effects of individual stars in these galaxies near to our line of sight, so-called minilensing or microlensing. This new interpretaiton is consistent with the cosmological redshift hypothesis and has revitalized interest in the observational data on QSO-galaxy associations."

Again this statement brings out the theoretical bias : accept the data as valid only if you have a conventional explanation for it. Unfortunately it is now recognized that gravitational lensing cannot account for most of the anomalous clustering of quasars with bright galaxies (see Kovner 1989; Schneider 1991).

(ii) *Connections and alignments* : In 1980 Arp and Hazard found two triplets of quasars aligned in straight lines. Since the positional accuracy is ~ 1 arc second, the probability of three quasars aligning this way by chance is $\sim 10^{-2}$. The chance of two triplets appearing on the same photographic plate is even lower, at 10^{-4}. There are other cases where quasars of different redshifts appear aligned across a galaxy.

Then there are examples of a different kind involving galaxies only. In a typical case we see two galaxies connected by a filament. Clearly this implies that they are physical neighbours in tidal interaction and so according to Hubble's law both should have the same redshift. However, one member of the pair turns out to have significantly higher redshift than its companion. This is hard to explain conventionally.

(iii) *Redshift periodicities* : If the redshifts arise purely from the expansion of the universe their distribution is not expected to show any periodicities. Claims for periodicities have, however, been frequently made and not all of them can be dismissed as worthless.

In a more recent survey Duari *et al.* 1992 have found a periodicity of ~ 0.0565 in the redshift distribution of some 2000 quasars from the Hewitt-Burbidge catalogue. Considering the fact that the catalogue is heterogeneously compiled the appearance of such a periodicity is puzzling. More so, since the claim for a periodicity of ~ 0.06 was first made by Burbidge (1968) from a sample of only 70 quasars!

W. Tifft was the first to report in the mid-1970s a periodicity in the redshift velocity differentials Δcz of galaxies in pairs or groups (1977). He found that Δcz has peaks in multiples of 72 km s^{-1}. Since then several samples of nearby galaxies have been studied (Tifft & Cocke 1984; Arp & Sulentic 1985) and the claim holds out despite rigorous statistical analyses (Guthrie & Napier 1990).

So far there is no conventional explanation for such 'quantized' redshifts. The theoretician's wish that such awkward results would 'go away' when more data are found or when 'correct' statistical studies are made has not so far been realized.

5. Evidence for the evolving universe

Given that the redshifts may have an intrinsic component for at least a subset of extragalactic objects like QSOs and companion galaxies, the claim for evolution is naturally weakened. It is instructive to review briefly a few examples of evolution.
(i) *Radio source counts* : The log N-log S test has been used for over three decades to test whether the observed counts (N) of radio sources brighter than specified flux levels (S) conform with the predictions of any given cosmological model. For example, in a Euclidean universe with a uniform distribution of sources we expect to observe

$$\frac{d \log N}{d \log S} = -1.5. \qquad \ldots(3)$$

The claim made is that the observed relation is steeper (with a slope ~ -1.8) at the high flux end and it becomes flatter as we go towards lower fluxes where it becomes sub-Euclidean. In a standard Friedman cosmology with a constant comoving density of unevolving sources or in a steady state model, the steepness of slope is not predicted. Hence the conclusion is drawn that the universe must have an evolving source population, which, of course rules out the steady state model but can be managed in a Friedman universe with several adjustable parameters.

To test the claim of evolution it is necessary to know the redshifts of the sources and to be sure that they do not have intrinsic components. The former are available today for only the bright source surveys while the latter can be assumed with confidence only for radio galaxies. Recently Das Gupta *et al.* (1988) have investigated the source counts of the 3CR radio galaxies (Bennett 1962) and those in the Wall-Peacock high frequency survey (Wall & Peacock 1985). In the former almost all sources have redshifts measured while for the latter the redshifts are either measured or inferred from the optical magnitudes of the identified galaxies using Hubble's law. These authors found that in any Friedman model one can (i) determine the radio luminosity function (RLF) from the observed number counts on the assumption of no evolution, (ii) use the RLF to generate a theoretical two dimensional plot of redshift z versus flux density S and (iii) compare the observed z-S plot with the theoretical one. Using an adaptation of the 2-dimensional Kolmogorov-Smirnov statistics, Das Gupta *et al.* 1988 showed that the two plots differ from one another within permissible random fluctuations. Thus it is not necessary to invoke evolution to understand the data.

Das Gupta (1989) later repeated the exercise for the steady state cosmology, finding the fit even better. Thus so far as the radio galaxies are concerned, the hypothesis of no evolution fits the data quite well. The apparent steepness of the log N-log S curve at high flux densities can be linked to our being in a 'local hole' with fewer sources at the brightest ends compared to the universal average. The size of the hole $\sim$ 50 - 100 Mpc is comparable to the voids found in our local region (see Bahcall 1988).
(ii) *Quasars* : The evidence for evolution of Quasars is related to observations of several kinds, *e.g.* (a) the number counts, (b) the variation of angular size with redshift and (c) the evolution of spectra. Because of evidence discussed in section 4 the redshifts against

which changes of physical properties are assessed are themselves suspect as epoch indicators, and so evidence of this kind cannot be claimed to be of cosmological significance.

Nevertheless, this evidence will be of interest towards understanding the physical structure of QSOs. For, if the redshift is intrinsic, it is natural to expect (as the evidence implies) that it be related to other intrinsic properties of QSOs like size, luminosity, spectrum etc. In other words, the redshift dependence of physical properties can be as much evidence in support of intrinsic redshift as it is claimed for an evolving universe.

(iii) *Age of the universe* : The Friedman models predict a clear relation between the age and the density parameter Ω_0. As the Ω_0 parameter increases from $\Omega_0 = 0$, the age decreases from H_0^{-1}. If we believe in inflation, as the present fashion has it, $\Omega_0 = 1$ and the age is $2/3H_0$, *i.e.*, $\sim 6.6h_0^{-1}$ billion years. (H_0 = Hubble's constant at present = $100h_0$ km s^{-1} Mpc^{-1}).

Stellar evolution and nuclear cosmochronology place the ages of our Galaxy between ~ 13-18 billion years. These limits are clearly inconsistent with the Friedman cosmology for $h_0 = 1$. Even for $h_0 = 0.5$ (a value less favoured by the extragalactic astronomers) the inconsistency remains, unless one reduces Ω_0 and brings in a λ-term.

6. Shortcomings of the early and the very early scenarios

The HBBM got the biggest boost in the mid-sixties with the discoveries of the microwave background and the measurements of cosmic helium abundance. Its rival, the steady state cosmology could explain neither of these observations which seemed to fit naturally in the early hot big bang scenario. Then towards the end of the 1970s, the particle physicists got interested in the HBBM for it alone offered an opportunity for trying out the consequences of their theories of very high energy interactions (GUTs, baryon non-conservation, spontaneous symmetry-breaking etc.). The outcome of these inputs, so far as observational astronomy is concerned, has been negligible. Never have so many bright brains worked for so many human hours on so many daring ideas to produce so few tangible results. In this section we review these shortcomings briefly.

(i) *Abundances of light nuclei* : The strongest point claimed on behalf of the HBBM is that it not only explained the observed cosmic abundances of light nuclei but also made the clear prediction, subsequently verified by particle accelerators, that the number of neutrino flavours cannot exceed three. These claims do not bear closer scrutiny.

For example, the mass fraction of ^{4}He predicted by the hot big bang with 3 neutrinos is 0.24. Since helium cannot be easily destroyed, the actually observed ^{4}He must not be less than this fraction. It *can* be more because of contributions from stars. However, recent studies [see, for example, Terlevich *et al.* (1990)] of galaxies of poor metal content, implying minimal stellar contamination, show the mass fraction of ^{4}He as low as 0.21. Even allowing for error bars this is far too low to match theory.

There are also problems with the ^{7}Li, ^{9}Be and other similar nuclei. These nuclei can form by break up of heavier nuclei in the cosmic rays. They can also form in the hot nucleosynthesis phase of the universe. However, the observed ^{7}Li abundances, or rather the upper limits on their values, seem to be *below* the minimum produced by the standard model. So far as beryllium and boron are concerned, other processes are needed to explain their observed abundances and it is hard to see how they can fail to disturb the precarious situation regarding ^{7}Li abundances given by the primordial process.

To get round these difficulties some nuclear cosmologists propose that in the quark-hadron transition stage in the very early universe, there could emerge some regions which have more protons and some with more neutrons than the near-equality assumed in the thermodynamic equilibrium value of the standard model. This variation in the n/p ratio could generate an additional parameter space within which some room for manouvre becomes available. Such an approach, however, robs the standard model of the predictive value that had been one of its attractions.

(ii) *The homogeneity of the microwave background (MBR)* : The COBE satellite has been in operation for more than two years and has been steadily looking for small scale fluctuations of intensity—but as yet without success. The COBE data (Redhead 1989) so far tells us that the temperature fluctuations $\Delta T/T$ if present cannot be larger than 2×10^{-5} on scales of ~ 30 arc min. Other measurements at different wavelengths have also failed to reveal any fluctuations (Narlikar 1992). The positive detection claimed in 1992 poses new problems for many scenarios.

In the standard hot big bang scenario the MBR is primordial and up to the recombination epoch, matter and radiation were strongly coupled. So if there were fluctuations in matter density they should be imprinted as $\Delta T/T$ on the MBR and would be observable to this day. In the 1960s the matter fluctuations leading to galaxies were taken to be of baryonic matter and hence the expected $\Delta T/T$ was $\sim 10^{-3}$. Over the years, with the progressive improvement of measuring $\Delta T/T$, the detection limit has steadily come down, with null results posing severe difficulties for galaxy formation theories.

The evidence for dark matter in galaxies and clusters raised the possibility during the 1980s that the bulk of the dark matter may be non-baryonic and so its interaction with radiation would be much less than that of baryonic matter. This allowed new scenarios to lower the theoretically predicted $\Delta T/T$ to as low as $\sim 10^{-5}$ or even lower in some models. The credibility of these scenarios is, however, getting considerably constrained by the present observational limits as new parameters like *biasing* have to be invoked.

(iii) *Structure formation theories* : The investigations of the very early universe were motivated by the goal of understanding the large scale structure in the universe along with the observed hierarchy galaxy → group → cluster → supercluster → filaments and voids. Numerous recipes for inflation along with various brands of dark matter, cosmic strings, textures etc. have been tried. So far no working scenario has emerged that will explain :

(a) the hierarchy of structures with the different mass and length scales observed,
(b) the large scale streaming motions with respect to the cosmological rest frame,
(c) the observations of galaxies at redshifts $\lesssim 4$ as well as the evidence for very young galaxies observed now,
(d) the evolution of structures without disturbing the very smooth MBR.

Is the failure of finding the right scenario a matter of detail, or are we barking up an entirely wrong tree?

7. Alternative cosmologies?

Having spent the large part of this talk in a critical vein, let me now briefly consider alternatives to the standard hot big bang. The community of cosmologists has been somewhat ambivalent towards alternatives. There are those who argue (*cf.* Peebles *et al.* 1991) that whatever difficulties there may be vis-a-vis big bang, these are a matter of detail which can be sorted out. To these cosmologists the thought of an alternative is anathema. On the other hand there are those who say "Granted there are problems with the big bang—but in the absence of any other viable alternative we have no other choice but to continue working with it." My talk from here onwards is directed towards this latter class of cosmologists.

I will consider three non-standard ideas, one dealing with redshifts, one with nucleosynthesis and the third with the MBR.

(i) *Redshift sans expansion* : The conformally invariant theory of gravity proposed by Hoyle and me (1964, 1966) allows one to look at cosmology in the flat Minkowski spacetime :

$$ds^2 = c^2 d\tau^2 - dr^2 - r^2 (d\theta^2 + \sin^2\theta \, d\phi^2). \qquad \ldots(4)$$

This line element is conformal to the Robertson-Walker line element of standard cosmology

$$ds^2 = c^2 dt^2 - S^2(t) \left[\frac{dr^2}{1 - kr^2} + r^2 (d\theta^2 + \sin^2\theta \, d\phi^2)\right] \qquad \ldots(5)$$

where $S(t)$ is the expansion factor and $k(= 0, 1, -1)$ is the curvature parameter.

In the Hoyle-Narlikar cosmology, mass is of Machian origin. That is, it arises from inertial contributions from all other particles in the universe. Moreover, mass is a scalar function of spacetime that transforms conformally under a conformal transformation. Thus a constant mass in (5) (standard cosmology) changes to $m \propto \tau^2$ in (4). Hence a galaxy (G) at a distance r whose light is received by us at the present epoch τ_0 has particle masses smaller than ours. This effect is seen as redshifted spectral lines from that galaxy. The redshift z_G is given by

$$1 + z_G = \frac{\tau_0^2}{(\tau_0 - r/c)^2} \, . \qquad \ldots(6)$$

This relation reproduces Hubble's law and other effects commonly associated with the expansion of the universe. However, it has the adaptability to accommodate anomalous redshifts. For, it can be shown (Narlikar 1977) that if at an instant $\tau_1 > 0$ a quasar (Q) is created from the active nucleus of a galaxy, the particles in it begin to acquire inertial mass from the instant of creation with the result that the relation $m \propto \tau^2$ for the galactic particles becomes $m \propto (\tau - \tau_1)^2$ for the particles in the quasar. Hence (6) is altered to

$$1 + z_Q = \frac{\tau_0^2}{(\tau_0 - (r/c) - \tau_1)^2} \, . \qquad \ldots(7)$$

We therefore have $z_Q > z_G$ although both the Q and G are at the same distance from us. The anomaly in redshift is traced to τ_1 the age gap between the quasar and the galaxy. As both get older the anomaly decreases. Thus the companion galaxies are late stages of quasars, exhibiting smaller excess redshifts. Das and I (1980) have discussed the dynamics of QSO ejection within the framework of this gravity theory.

(ii) *Nucleosynthesis* : The quasar ejection is an example of a white hole, *i.e.*, a scenario describing primary creation of matter. A white hole is in a sense a 'minibang' : replacing the big bang event of standard cosmology by several such minievents occuring frequently over an infinite time axis is therefore a synthesis of the big bang cosmology with the steady state cosmology.

White holes can generate matter conglommerations of varying masses with the most generic ones giving rise to clusters and superclusters. A simple calculation of the dynamics of an expanding white hole of mass M gives a density-temperature relation

$$\rho = \frac{3}{4\pi}\left(\frac{20\pi a}{9G}\right)^{3/4} \frac{T^3}{M^{1/2}}. \qquad \ldots(8)$$

For $\rho_{\text{baryon}} = Q\rho$, say, we get the above as :

$$\rho_{\text{baryon}} = 1.4 \times 10^5 Q \left(M_\odot / M\right)^{1/2} T_9^3 \ \text{gcm}^{-3} \qquad \ldots(9)$$

where T_9 is the temperature measured in units of 10^9K. Now a local region of this kind can also synthesize light nuclei if ρ_{baryon} is $\sim 10^{-5}\, T_9^3$. This requires

$$M \approx 2 \times 10^{22}\, Q^2 M_\odot. \qquad \ldots(10)$$

For $Q \approx 0.03$ as indicated by observations, we have the baryonic component of M as

$$M \approx 5 \times 10^{15}\, M_\odot. \qquad \ldots(11)$$

It is of interest to find that this mass is of the same order as a supercluster mass! Thus we are able to relate sizes of discrete structures to 'primordial' nucleosynthesis. Further checks with the dynamics of the local region leads to the size of the supercluster to be ~ 70 Mpc.

(iii) *A non-relic MBR* : The presently observed MBR is therefore seen as a superposition of background contributions from such local regions. How is a near-Planckian and incredibly smooth distribution obtained this way for the resulting MBR?

The clue lies in multiple absorptions and scatterings produced by intervening dust in the form of graphite or iron whiskers. A typical whisker may be ~ 1 mm long and 10^{-6} cm in diameter. Such whiskers form by condensation of metallic vapours encountering cooler regions, the metals themselves being ejected from supernovae in galaxies and pushed out into the intergalactic space by shock waves arising from explosions. An average density of $\sim 10^{-35}$ g cm^{-3} of iron would suffice to produce enough whiskers for this purpose.

Typically these whiskers would produce an optical depth of $\tau \sim 7$ at redshift ~ 4 so that within this distance the contributions to MBR from all local regions are mixed up and homogenized to produce not only a Planckian spectrum but also smoothness of the order of $\Delta T/T \lesssim 10^{-5}$. The energy density generated by $H \rightarrow$ He conversion which gives ^{4}He abundance of the order of 0.21 by mass will, on thermalization produce a black body of temperture 2.7K.

Thus in this alternative point of view the MBR is not of relic type and its observed smoothness can be understood despite the presence of discrete structures.

In this picture structures of all ages (τ) could in principle exist, with an age spectrum $\propto \exp -3H\tau$ when averaged over regions including several superclusters. If we happen to live in supercluster of age $\sim 1.5H_0^{-1}$, we are more likely to see galaxies of this age in our local neighbourhood, although finding younger, later generation galaxies is not ruled out. The MBR we observe was generated mostly later than epochs of $z \approx 4$.

8. Concluding remarks

Several questions can be raised against the proposed alternatives. For example: Isn't the variable mass interpretation too drastic a resolution of the anomalous redshifts? Is it not worse having several minibangs in place of the one big bang which alone is hard to understand? What evidence do we have for such esoteric objects as iron whiskers in the intergalactic space? Finally, am I not being very strict with the standard cosmology and not so demanding with the alternative?

The variable mass scenario provides a unified look at redshifts, accommodating both the 'regular' and the 'anomalous' within one framework. Thus it opens out the possibility of understanding deviations from Hubble's law without disturbing its successes in the field of galaxies.

The minibangs being several, repetative and within modest redshifts ($z < 4$) are amenable to observations. The phenomenon of explosive creation of matter becomes observable over a wide range of events from active galactic nuclei to the origin of superclusters. The classical big bang is remote from any direct astronomical studies and is wrapped in myths and speculations. Recall that the universe prior to the recombination epoch is essentially unobservable.

Iron (or carbon) whiskers are known to form in the laboratory by the cooling of metallic vapours. It does not require a big jump in speculations to conceptualize them in the intergalactic space. Certainly they are based on known physics, observed in the laboratory and have well determined physical properties which is more than can be said for nonbaryonic dark matter whose existence is readily accepted by the conventional cosmologists.

Standard cosmology has ruled as hot favourite and the 'best sell' theory (is it the 'best buy' theory also?) in cosmology for three decades. As a scientific theory it has raised big expectations and so it should certainly be judged by rigorous standards. The alternative ideas proposed here are new, need to be worked at a good deal more before they too can be subjected to similar rigorous tests. All that I am advocating here is that there are sufficient weaknesses in standard cosmology for us to look at some alternatives also.

Finally, it is also time to think carefully about whether the currently fashionable approach to cosmology in the very early epochs of the standard model is really scientific. It uses particle physics theories that have not been tested (and cannot be tested for a foreseeable future) in the laboratory. It deals with epochs that are beyond the range of any astronomy, since the very early universe is optically thick. And, it has so far made no prediction that can be tested by normal astronomical means. Have the cosmologists already crossed the thin line separating frontier physics from pure speculation?

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