

# The Case for Alternative Cosmology

J. V. Narlikar

*Inter-University Centre for Astronomy and Astrophysics, Post Bag 4, Ganeshkhind, Pune 411 007, India*

## ABSTRACT

Reasons are given as to why the standard cosmology does not give an entirely satisfactory description of the universe and why one needs to look for alternative cosmology. An alternative cosmology is presented in which matter creation takes place in mini-creation events at regular intervals and in response the universe oscillates on short term period of  $\sim 50$  Gyr while it also has a steady (exponential) long term expansion at a characteristic time scale of  $\sim 1000$  Gyr. The explanation of the major observed features of the universe in terms of this cosmology is given and new observations distinguishing it from standard cosmology are proposed.

**Key words:** Standard Model – Quasi-Steady-State – Theory of Gravity – Thermalization Process

## 1 INTRODUCTION

Any proposal to describe the universe in terms different from the so-called standard cosmology is met with the criticism that, "If the standard model is working so well and now it is possible to quantify that model with great precision, why look for an alternative?" Before describing the quasi-steady state cosmology (QSSC in brief) I will therefore spend some time in pointing out the weaknesses of standard cosmology, weaknesses that rob it of much of its merits as a scientific theory. First let me talk of the three claimed successes of standard cosmology.

The big bang cosmology began with the advantage that the models predicting expansion of the universe by Friedmann (1922, 1924) and Lemaitre (1929) came before the discovery of the phenomenon of recession of galaxies and Hubble's law (1929). Thus one can say that as a scientific theory the big bang cosmology made a prediction (namely, that the universe is expanding) that was successfully verified.

The second success claimed by standard cosmology is, however, of a mixed character. The early expectation of George Gamow was to be able to demonstrate that the origin of chemical elements came from nucleosynthesis in the early universe. This idea worked so far as light elements are concerned. Beyond the atomic weight 4, one needs to look towards other astrophysical processes, namely inside stars, for explaining the origin and abundances of most other nuclei. Even the making of light nuclei in the big bang nucleosynthesis (BBN) demands a rather finely tuned relation of the kind  $\rho = \eta T^3$ , with the value of the parameter  $\eta$  put in by hand, as Burbidge and Hoyle (1998) have argued. Also, they have shown that alternative astrophysical scenarios are now known that could account for even the light nuclei.

The third and most visible success attributed to stan-

ard cosmology was the prediction of the cosmic microwave background radiation (CMBR) by Alpher and Herman (1948) and its subsequent finding by Penzias and Wilson (1965). Again, Hoyle, et al. (2000) have given the historical perspective which brings up the prior finding of this radiation by McKeller (1941), and the rather strange coincidence that if all of the helium were made in stars, the starlight resulting from such a process would have a thermalization temperature very close to the actual temperature of CMBR today. This coincidence remains unexplained in the standard model.

The standard model since 1965 has acquired an image of being the right theory of the universe, despite the fact that it has had to be modified several times since then. I shall refer to these modifications as 'epicycles' in the classical Greek tradition.

The first major epicycle was introduced in 1981 through the concept of inflation, i.e., rapid exponential expansion of the universe for a very short time ( $\sim 10^{-36}$  second) when its linear size grew by a factor in excess of  $10^{50}$ . This idea was needed to get rid of the fundamental problems of initial spacetime singularity, very small particle horizons, very large curvature and the entropy problem. Although it is still not clear *which* of the several inflation ideas is the accepted one in terms of a well-established fundamental particle theory, the general belief seems to be to accord an uncritical acceptance to the phenomenon of inflation.

Inflation prompted another epicycle when linked to dark matter. The total density of the universe must be equal to the critical density, if the concept of inflation is correct. The visible density of the matter is hardly a few percent of this value. There are indications of dark matter in considerably larger amounts than the visible matter, if the Newton-Einstein gravity theory is correct and provided most clus-

ters are dynamically relaxed. However, even this dark matter does not make up the deficit present if inflation is accepted. So it became necessary to postulate dark matter in quantities large enough to make up the closure density, even though there was no observational support for it.

The next epicycle came when this density was found to be incompatible with the requirements of BBN. It reduced the expected abundance of deuterium to nearly zero. To sustain the BBN therefore it was necessary that the bulk of the matter were declared to be 'non-baryonic'. Although there are no observations to date either in the labs or in the cosmos to directly indicate the existence of non-baryonic dark matter (NBDM), it is now accepted uncritically.

Moreover, NBDM is needed to explain why the microwave background is homogeneous at least at the level of  $10^{-5}$  for temperature fluctuations despite the inhomogeneities of matter in the form of galaxies. In standard cosmology, matter and radiation were fully interacting in the early stages and so any inhomogeneities of one would be shared by the other. Since NBDM does not react with radiation, this problem is solved. However, further epicycles are needed on the nature of NBDM, whether it is hot (HDM) or cold (CDM) or mixed (MDM) and how it is distributed in relation to visible matter, which is specified by a biasing parameter. Additionally structure formation theories bring their own epicycles like the transfer function, the assumption of percolation, etc.

The most recent epicycle is paradoxically the very first one used in cosmology, namely the one associated with the *cosmological constant*. In 1917, Einstein introduced this constant  $\lambda$  into general relativity in order to get a static model of the universe, since in those days the concept of an expanding universe was not known. When Hubble's observations became established, Einstein was the first to abandon this constant and revert to the original general relativity. Other cosmologists had from time to time dabbled in the usage of this constant whenever they felt that the observations demanded it. However, as has happened frequently, observational errors often turned out to have been underestimated and the need to have the constant diminished after a time. As late as 1997, most cosmologists did not feel that the constant was needed.

This situation changed dramatically with Type Ia supernovae. These are regarded as standard candles in the determination of distances of far away galaxies, with redshifts as high as  $\sim 1$  or more. The distant supernovae seemed fainter than expected if the standard models without the cosmological constant were used. So the constant ( $\lambda$  or  $\Lambda$ ) was brought into the picture. However, it now appears that a fixed (i.e., constant)  $\lambda$  is not sufficient to understand the data. Today cosmologists talk of a *variable cosmological constant*, and a universe that changed from deceleration to acceleration in its expansion, because the supernova data so demand. Notice that such an exercise has no predictive value since the extent of variability of  $\Lambda$  is decided by fitting models to data.

The magnitude of the cosmological constant, if it is a constant, posed a problem first highlighted by Weinberg (1989). If it is assumed that it arose out of inflation, through the phase transition from 'false' to 'true' vacuum, then its magnitude is too high compared to what is required by the present day observations. The factor by which it needs to be

reduced is as low as  $10^{-108}$ . Thus one needs a fine tuning of unacceptably high order.

Going back to inflation, therefore, now it is proposed that there is *today* a redistribution of visible matter, NBDM and A. The last arrival on the scene takes up nearly 72% of the closure energy, the NBDM is relegated to second place at  $\sim 24\%$  while the visible matter that the astronomer sees accounts for only  $\sim 4\%$ . In other words, cosmology as per the standard model does not put much stress on what you see but on *what you do not see*.

Perhaps I have been too harsh in passing judgement on a collective exercise that some of the greatest intellects in science are participating in today. But the exercise seems to me to be far more speculative than any scientific theory demands. Certainly I do not see any justification for the phrase 'precision cosmology' prevalent today suggesting that the cosmological model is more or less well determined. Another popular phrase (indicative of complacency) is 'concordance cosmology', wherein it is argued that now we know, more or less, all details of the universe and how well they fit the overall standard paradigm.

One example will suffice to indicate the unease I feel at the way the situation is developing. When astrophysicists discovered neutron stars, they realized that the theory required central density of such a star to be as high as  $10^{15}$  times the density of water. Considerable work was done by nuclear physicists and astrophysicists together to understand the nature of such matter and its equation of state. In cosmology, at the time of inflation the density of matter was in excess of  $10^{55}$  times the density of water. Yet no one seems to be worried about the state of this matter. At the more fundamental level, one may also ask, what is the operational definition of measurement of time at  $10^{-36}$  second. Clearly we have no practical devices to measure such small intervals. The best known atomic clocks can go down only to  $10^{-15}$  s.

Some of us feel that these issues are worrisome and one needs to address them in standard cosmology if one believes that therein lies the correct solution. On the other hand one may also take the view that given these internal weaknesses of standard cosmology, searches for alternatives are not out of place. In any case supporters of the standard model often react to such criticism by asking: "Given that the standard model is imperfect, do you have any alternative to offer?" It is in response to this question that I will now present an alternative approach to cosmology that was proposed by the late Fred Hoyle, Geoffrey Burbidge and myself (see: Hoyle, Burbidge and Narlikar 1993). We refer to this cosmology as the *quasi-steady state cosmology* (QSSC).

## 2 THE QUASI-STEADY STATE COSMOLOGY: THEORY

In this cosmology, one begins with the proposal made by Victor Ambartsumian in the 1960s that the universe provides evidence for explosive phenomena on various scales. Today we see these in quasars, active galactic nuclei, gamma ray bursts, etc. on the galactic and extragalactic scale. Additionally Ambartsumian (1961) felt that even the clusters of galaxies seem to indicate lack of equilibrium of the kind that suggests that they may be expanding from an initial explo-

sive origin, an origin where new matter was appearing in the universe. In standard cosmology it is assumed that the clusters are in dynamical equilibrium and to sustain that assumption non-baryonic dark matter is postulated. Today, there is indication of relaxation or equilibrium in only a few clusters. Thus the issue of whether the clusters as a whole are relaxed is still an open one.

Following Ambartsumian's ideas, Fred Hoyle, Geoffrey Burbidge and I felt that a quantitative expression can be given to them in terms of the gravitation theory developed by Hoyle and I in 1964-66, based on Mach's principle (see: Hoyle and Narlikar 1964, 1966), suitably extended to describe creation of matter. Such a theory ultimately leads to equations like those of general relativity, together with (1) a negative cosmological constant and (2) a scalar field of negative energy and stresses to describe creation of matter. In the usual notation these are given below:

$$R_{ik} - 1/2g_{ik}R + \lambda g_{ik} = -8\pi G\{T_{ik} - f(C_i C_k - 1/4g_{ik}C^m C_m)\} \quad (1)$$

Here  $C$  is a scalar field of negative energy and pressure that describes creation of new matter. (In standard cosmology, the spacetime singularity denotes the instant when the whole universe was created: since the event is singular, one is permitted to ignore the violation of the law of conservation of energy and momentum.) The new matter in the QSSC appears at the expense of the  $C$ -field. Thus there is overall conservation of energy and momentum in the universe. The negativity of the  $C$ -field is evident from the fact that  $f$  in (1) is positive. In the 1960s physicists were hostile to the idea of a negative energy field. Today's so-called phantom fields popular amongst a growing section of theoretical cosmologists are no different from the  $C$ -field.

The  $\lambda$ -term in this theory is related to the rest of the matter in the universe and is in fact negative in sign. Its magnitude is of the order of  $10^{-56} \text{ cm}^{-2}$ , which is of the right magnitude when considered in the context of modern cosmological observations. (Vide and contrast with the cosmological constant problem of the standard cosmology!) For details of the derivation of the field equations, see Hoyle, et al. (1995).

The simplest assumption one could make about the universe is that it is homogeneous and isotropic and that matter is created in it *also homogeneously*. This model is none other than the old steady state model. However, it fails to give expression to the explosive creation events of the kind mentioned above. To describe them one needs to look at the equations in a region of strong gravitational field.

The situation in the new cosmology is the following. In general the creation of matter is in the form of Planck particles, which are particles of Planck mass (corresponding approximately to energy of  $10^{19} \text{ GeV}$ ), which are unstable and decay into smaller particles like baryons and leptons. The creation occurs, however, only if the overall energy momentum of the creation field equals the threshold of momentum of the Planck particle. This condition is not normally satisfied at a typical point in space. However, in regions of strong gravitational field the background level of the scalar field can be raised high enough for creation to occur.

Take for example a massive collapsed object of mass  $M$ , spherically symmetric. One can show that if the  $C$ -field

background is not strong the original Schwarzschild solution will provide a reasonable approximation to the actual solution in the neighbourhood of  $M$ . In this case, the energy density of the  $C$ -field behaves as

$$C^m C_m \sim (\text{constant})/[1 - 2GM/r] \quad (2)$$

For creation of a Planck particle of mass  $m_P$ , one must have (2) equalling  $m_P^2$ , the speed of light being taken as unity. This will happen only close to the Schwarzschild radius.

This is why only in pockets of strong gravitational field matter is created. Once it is created, it is also accompanied by compensatory creation field. The latter being negative has a repulsive gravitational effect and so the created matter is ejected with large energy. Thus explosions are generated, without requiring conditions of spacetime singularity as in big bang. We term these events as *minibangs* or *microcreation events* and the massive objects, *creation centres*.

There is a feedback mechanism between these local events and cosmology: for, the locally produced explosions expand space. In the next simplest model after the steady state theory referred to earlier, the universe oscillates about the steady state solution. In such a solution, the scale factor  $S$  of the universe expands and contracts with a shorter oscillatory time scale  $Q$  compared to the longer scale of steady expansion  $P$ . In a simplified version of the solution:

$$S = \exp[t/P] \times \{1 + \eta \cos(2\pi\theta(t)/Q)\} \quad (3)$$

where the parameter  $\eta$  is less than unity in magnitude and  $\theta(t)$  is a monotonic function of  $t$ , which behaves almost as  $t$ , except close to the turning points of  $S$ . The mathematical and physical properties of such solutions has been described in detail by Sachs, et al. (1996).

The feedback mechanism works this way. Consider the minimum of scale factor during a local oscillation. Since the energy density of the  $C$ -field varies as  $S^{-4}$ , it is maximum at this stage. This enables most creation events to work fully, thus creating new matter and also  $C$ -field, the latter causing expansion to go fast. However, as  $S$  increases, the  $C$ -field drops in strength and the creation centres begin to work less and less efficiently. This slows down the expansion of the universe and eventually the negative cosmological constant takes over and it begins to contract the universe. However, during the contraction stage, the  $C$ -field strength rises and more and more creation centres come on line with the result that the contraction slows down and is ultimately reversed. Thus we have a complete cycle of period  $Q$ .

In such an oscillatory universe the period  $Q$  may be as long as 50 Gyr, while the exponential time scale  $P$  is even longer at around 1000 Gyr. It is easy to see that because the magnitude of  $\eta$  is less than 1, the scale factor never becomes zero. The largest redshift  $z_{\text{max}}$  one sees in the present cycle is of the order 6-10. Although the universe has an exponential expansion, each of its oscillations is physically identical to the previous one. This is because, creation of matter takes place (in minibangs all over the universe) when the scale factor is at its minimum, and the intensity of the creation field is highest. This new matter compensates for the density reduction that would otherwise have taken place due to exponential expansion. Likewise, even though dissipatory processes would have increased the entropy density, the same is brought down by the injection of low entropy new matter.

The numbers quoted above are partly put in by hand and are partly related to the fundamental constants appearing in the theory, namely  $G$ ,  $\lambda$  and  $f$ . In all one can say that there are four independent parameters in the theory,  $P$ ,  $Q$ ,  $z_{\max}$  and the epoch  $t_0$  at which we are observing the universe. We will now see how the observable features of the universe get explained.

### 3 THE QSSC: OBSERVATIONS

*A. The CMBR* : It is interesting to see how the microwave background arises in this cosmology. It is the thermalized relic radiation left behind by stars which were born and which shone during all the previous cycles. For, as mentioned earlier, each cycle is identical with others and in each new matter is born and gets made into stars and evolves through normal processes of stellar evolution. Although the exponential expansion of the universe prevents any occurrence of the classical Olbers Paradox, the question remains as to what happened to all the relic radiation left behind by stars in the previous cycles. As optical radiation it will have energy density far in excess of that in the normal night sky background. The answer to the question is that with passage of time and physical processes mentioned below, this radiation gets thermalized and is seen as CMBR. For details of this discussion see Hoyle, et al. (1994, 2000).

From the present stellar activity one can estimate the expected energy density of such radiation and its temperature on thermalization. The answer comes very close to 2.7 K at the present epoch! In fact, this is the same old 'coincidence' referred to in section §1, resurfacing here. However, we now see its relevance in terms of the thermalization of starlight from previous cycles. Thus it is no longer a coincidence. However, we need to know how the thermalization is carried out.

The thermalization is shown to be carried out by metallic whiskers which are naturally created and ejected by supernovae. This activity is at its most effective at the oscillatory minima of the scale factor  $S$ . For evidence for such whiskers, see Narlikar, et al. (1997). The dust density required to thermalize starlight is of the order of  $10^{-34} \text{ g cm}^{-3}$ , well within the limit of the cosmic metal abundances.

One can also estimate the power spectrum of inhomogeneities since these arise from the latest thermalization of starlight (for details, see: Narlikar, et al. 2003) As this has cluster-wise inhomogeneity, the largest signal will be given by the angular distribution of clusters at redshifts of  $\sim 6-10$ . This turns out to give the peak at  $l \sim 200$  commonly ascribed to Doppler shift at the last scattering in the standard cosmology. This is an instance of how the same observation may have a different explanation depending on the paradigm used.

Since iron whiskers get aligned by intergalactic magnetic fields, it is natural to expect some signature, howsoever weak, to be found in terms of polarization of the CMBR. This is being estimated at present.

*B. Light nuclear abundances* : The light nuclear abundances can be explained in two modes in the QSSC. The minicreation events in the sense of high energy events are similar to the classical big bang *sans singularity*, of course. Thus one can show (vide Hoyle, et al. 1993) that light nuclei like

deuterium or helium can be made in the minibangs. The density-temperature relation seems to be different, however, from that of the big bang and it demonstrates the non-uniqueness of the BBN process. Alternatively, so far as helium is concerned, one can get most of the abundance from relic helium made by stars from previous cycles. Since over long time scales available to the QSSC, most contribution will come from low mass stars, this process does not increase the abundance of heavy elements, since these stars do not proceed to the stages of making carbon or heavier nuclei. As Burbidge and Hoyle (1998) pointed out, stellar processes can make all of the nuclei found in the universe. Even deuterium can be made in processes like solar flares.

*C. Magnitude-redshift relation for Type Ia supernovae* : How does the QSSC cope with the observations of  $m-z$  relation for extragalactic supernovae of Type Ia? It may appear that since standard cosmology demands a large positive cosmological constant, the QSSC with a negative  $\lambda$  is bound to fail. However, this is not so as was demonstrated by Narlikar, et al. (2002). The solution lies in the intergalactic dust in the form of whiskers that provide mild but significant dimming of distant supernovae. One can obtain the best-fit density of such dust, keeping it as a free parameter. The result is a value that very well lies in the range required to thermalize the starlight to produce CMBR.

It is, however, necessary to recall the history of this test in the period 1960-80, for galaxies, which ultimately resulted in the realization that other uncertain factors intervene to make the conclusions indecisive. In the present case are we sure of the range of variation of the so-called standard candle? Are gravitational lensing events not introducing bias? Is there no evolution over redshifts exceeding 1? In any case whether the QSSC is right or not, the impact of cosmic dust on this test needs to be carefully estimated: more observations are needed to know the nature and extent of intergalactic dust.

*D. Dark matter* : There is no compelling need in the QSSC for non-baryonic dark matter. If such matter exists, it may form part of the total contents of the universe. By and large in a minicreation event, one expects conditions requiring the application of very high energy physics, such as GUTs, SUSY, etc. The difference from the big bang scenario is that here such events are repeatable and so one can study them under observations just like an astronomer studies stars under observation in different evolutionary states.

The stars which have burnt out in the previous cycles will provide dark matter in the present cycle, since they are no longer shining. It is also likely that there are very faint but very old white dwarfs forming part of dark matter.

*E. Large scale structure* : Work by Nayeri, et al. (1999) have shown with the help of a toy model that there is a new way of approaching the problem of large scale structure. The toy model was in the form of a computer simulation with the following protocol.

First take a unit cube in which randomly distribute  $N$  ( $\sim 10^6$ ) points, representing galaxies. Of these choose at random  $\alpha N$  points, where

$$\alpha = \exp\{3Q/P\} - 1. \quad (4)$$

Around each chosen point 'create' a new neighbour randomly within a pre-assigned distance of  $\beta N^{1/3}$ . Then expand

the whole system homologously in all directions by a linear scale of  $\exp[P/Q]$ . This procedure ensures that 'after expansion' the cube has the same number density of points. From this expanded cube, extract the inner cube of unit dimension having the same centre and the same principal directions. Thus we now have a new unit cube with the same number of 'galaxies', including a few created new neighbours. Repeat the procedure a few times and you see emergence of clusters and voids. If we compute the two point correlation function for the set of points in the cube, we discover that the distribution quickly (in 6-7 iterations) settles down to the observed  $r^{-1.8}$  dependence for galaxies and clusters.

This suggests that creation of matter and its ejection may play a vital role in structure formation. The scenario that emerges is one in which a collapsed massive object in the creation centre acquires new matter and grows, until the growth of the  $C$ -field makes it unstable and its exterior breaks apart and is ejected. Clearly work needs to be done to quantify the details of such a model.

#### 4 DIFFERENCES FROM THE STANDARD MODEL

Narlikar and Padmanabhan (2001) have discussed the standard and QSSC models critically. They have stressed the need to work out further details of the QSSC model to the same level of sophistication at which the standard model is worked at. Nevertheless, here are some clear differences between the two models.

*A. Blueshifts* : The QSSC predicts the existence of a population of very faint ( $> 27^m$ ) galaxies with blueshift not exceeding 0.1. These galaxies belong to the previous cycle close to the last maximum value of the scale factor  $S$ .

*B. Very old objects* : The existence of very old stars belonging to the previous cycles, e.g. very faint white dwarfs and stars of half a solar mass or lower that may have become giants, will be clear indications that the universe is much older than what the standard model claims.

*C. Baryonic matter* : The existence of baryonic matter exceeding the limit tolerated by the standard model would be another distinguishing test.

*D. Gravitational radiation* : The minibangs are also expected to yield detectable gravitational radiation. Although the peak emission of these waves will not be at the optimum value for the present generation gravitational wave detectors, one does expect some signal from them. Narlikar and DasGupta (1993) have made tentative estimates which need to be further focussed. They also pointed out that the spectrum of gravitational wave background generated by these minibangs will be different from that generated by inflation. Future technology may be able to express judgement on this issue.

#### 5 CONCLUDING REMARKS

In the last analysis, theories and speculations have to be decided by facts. So the predictions of this alternative cosmology also deserve to be critically examined. To make them

more focussed additional work needs to be done which requires more manpower. This is hard to come by in the present climate wherein most cosmologists are disinclined to look at alternatives.

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