QSSC:

REQUIEM FOR BIG BANG?

Modern cosmology began in 1917 with Einstein's model of the universe, in which the universe was homogeneous and isotropic and also static. The general belief in a static universe in which the galaxies ,etc,are at rest was so strong that when in 1922 Aleksandr Friedmann proposed expanding models of the cosmos, they were largely ignored by everybody, including Einstein.

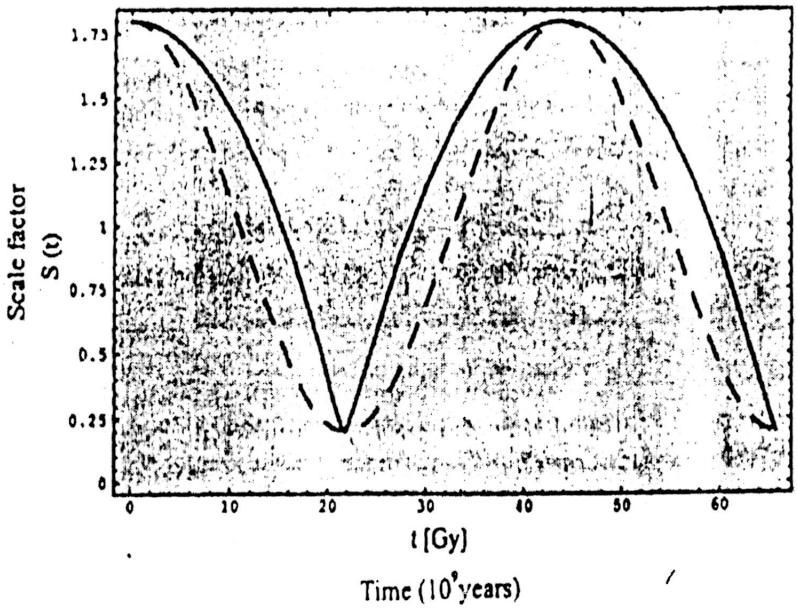

Figure 1. Typical oscillations of period Q in the QSSC. The long term expansion (barely noticeable here) is on a time scale P>>Q

The now- accepted standard cosmological model, which presupposes a hot big bang origin of the universe has several weaknesses that the Quasi Steady-State Cosmology is not beset with, as JAYANT V.NARLIKAR, one of its proponents, describes

However ,the first significant observational result in cosmology came in 1929 when Edwin Hubble announced the velocity-distance relation for galaxies, based on the red shifts observed in their spectra.

This led people to the conclusion that the universe is not static but expanding. And the Friedmann models, which had also been independently found by Abbe Lemaitre in 1927, became the recognized models for the universe. As Lemaitre had observed, these models appeared to start from the state of infinite density, which he interpreted to mean a dense primordial 'atom'. In modern jargon this is called the state of 'Big Bang'.

For a decade or so after World War II , George Gamow , Ralph Alpher, Robert Herman and others explored this supposed dense primordial state. They concluded that it was dominated by high-temperature radiation and other subatomic particles moving at near–light speeds. They felt that this was ideally suited for nuclear fusion making all the chemical elements from protons and neutrons. However, they soon learned that this could not be done because of the absence of stable nuclei at mass numbers 5 and 8. But they also realized that, if there had been such an early ultra-dense stage, the universe might well contain an expanding cloud of primordial radiation that would preserve its blackbody form as the universe evolved.

In the 1940s, however, another new idea challenging the hot Big Bang evolved, and in 1948 three British astrophysicists, Hermann Bondi, Tommy Gold and Fred Hoyle, proposed the steady state model. It not only assumed the universe to be homogeneous and isotropic in space, but also unchanging in time. Thus there was no Big Bang , no hot phase: in fact, the universe was essentially without a beginning and without an end. It, however, steadily expanded, thus creating new volumes of space which got filled up with new matter that was continually created. Hoyle, in fact, proposed a slight modification of Einstein's general relativity to account for matter creation out of a negative energy reservoir of energy. As more and more matter created, got created, energy conservation required the reservoir to become more and more negative ;but taking into consideration the fact that space was expanding, the energy density of this reservoir remained steady.

Thus in the steady state theory there was no mystical event like the 'Big Bang' and no sudden appearance of all the matter into universe (in violation of the energy conservation law). Instead there was a steady expansion supported by a continuous creation of matter. In 1948, the estimates of the age of the big bang universe showed it to be very small (of the order of 2×10^9 years), smaller than the geological age of the earth ($\sim 4.6 \times 10^9$ years).

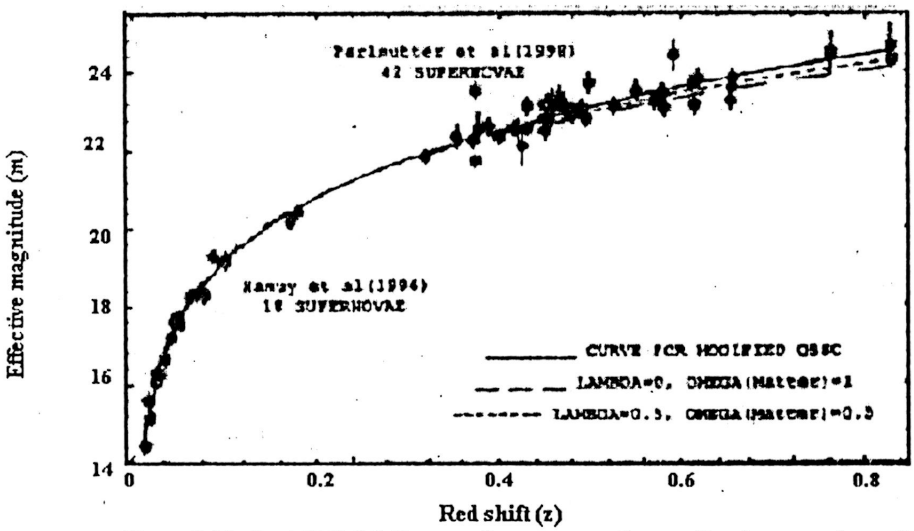

Figure 2. The best fit Q S S C curve shown as a continuous line in comparison with observed points on the red shift magnitude diagram. Magnitudes are indirect measures of distance. The two other dotted and broken curves represent big bang versions with or without the cosmological constant.

"Standard cosmology argument on relic radiation can be countered by a still more precise calculation with very different implication."

In the 1950s and the 1960s, the debate between the big bang and steady state theories continued unabated. However, two events in the mid-1960s swung the argument in favour of the big bang cosmology. One was the realization that the observed abundances of light nuclei in the universe required their manufacture in a very hot dense stage. The other was the observation of the microwave background radiation which was quickly interpreted as the relic of the early hot era. Thus the Big Bang model acquired the status of the 'standard model' of the universe. However, as we will now discuss, this reasoning may have been too simplistic.

Standard Cosmological Model: Some Critical Issues

In 1967, Robert Wagoner, William Fowler and Fred Hoyle repeated a calculation originally reported by Alpher and Herman.

They calculated that a synthesis of the light elements in the early hot universe yielded abundances of deuterium, ^{3}He, ^{4}He and ^{7}Li that were satisfactorily in agreement with astrophysical observations if the average cosmological density ? (in g/cm^3) of baryonic matter was related to the radiation temperature T (in Kelvin) by ? + $10^{-32}T^3$. Cosmological theory requires this relationship between density and temperature to be maintained throughout the expansion of the universe from its early hot state. So, putting in the measured value of the present background temperature ,T = 2.73 K, yields about 2 x 10^{-31} g/cm^3 for the present-day average density of the cosmos.

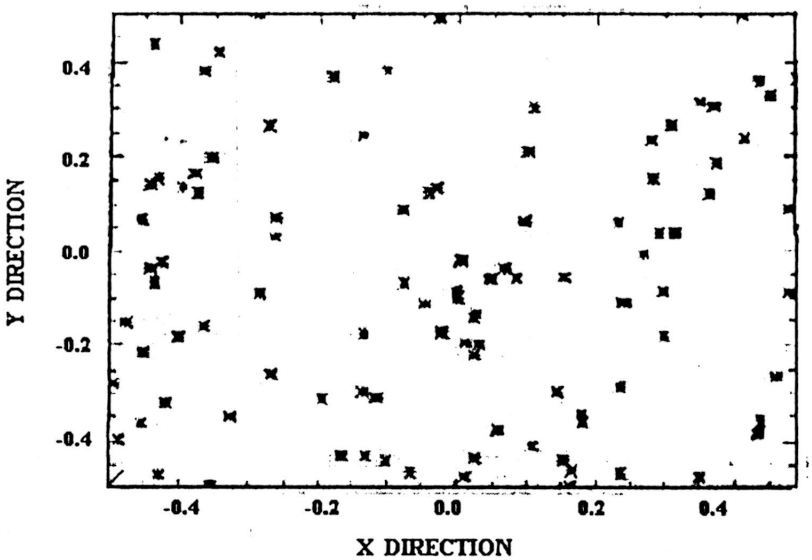

Figure 3. A 3 D plot of clustering and voids across a 'slice' of space with thickness corresponding to a red shift difference of 0.001. This has N = 100,000 points in the cube with x = 0.3, and after five cycles

For a comparison, the standard model predicted the present density of the universe to be close to 2x10^{-29} g/cm^3. This density is sometimes referred to as the closure density; models more dense than this are closed in the topological sense, while those with less density are open.

Although this result was almost two orders of magnitude less than the standard model's closure density, it agreed with galactic astronomor Jan Oort's estimate for the cosmic average density of observable material. The higher 'closure' value of about 10^{-29} g/cm^3 given by standard cosmological theory is explained in terms of non-baryonic matter that has changed its identity over the years from neutrinos to esoteric "cold-dark matter" particles, perhaps with some remaining admixture of neutrinos. For some of us, it is not reassuring that this line of reasoning from the 1960s is still the best available in favour of Big Bang cosmology, despite the continuing failure of attempts to identify the required non-baryonic matter.

"We regard creation as being triggered locally in minibangs."

This standard - cosmology argument on relic radiation can be countered by a still more precise calculation with a very different implication. We know that ^{4}He is synthesized from hydrogen in stars with an energy yield of about 6 x 10^{18} ergs for each gram of helium, the energy being radiated by the stars to produce a radiation background. If all of the ^{4}He in the universe has been produced in this way (the observed abundance is about one ^{4}He for every 12 hydrogen atoms), then the accompanying radiation background should have an energy density of 4.37 x 10^{-13} erg/cm^3. That is quite close to the observed energy density of the microwave background, namely 4.18 x 10^{-13} erg/cm^3.

Either this agreement is coincidental, or we must conclude that the ^{4}He was created, not by Big Bang nucleosynthesis, but rather by hydrogen burning inside stars (a process that we know to exist), and that the radiation background from stars has become subsequently thermalized into the far Infrared (as discussed in detail below).

We turn now to further problems associated with the so-called standard model. If negative values of the energy density are prohibited, one can argue that the observed expansion of the universe requires not only that the universe was more compressed in the past, but additionally that it was also expanding in the past. If we denote the time dependence of the linear scale
factor of the universe S (T), general relativity tells us that the scale factor has always been increasing in the past and, as we look back in time, we see the universe become more and more compressed at earlier and earlier times. Ultimately to what?

In attempts to answer this question, it is accepted that particle energies increase up to values in the TeV (1 TeV = 10^{12}eV) range, and then, by speculation, all the way to the Big Bang. Up to IO^{15}GeV, (1 GeV = 10^9 eV) symmetry arguments are invoked and the theory departs increasingly from known physics, until ultimately the energy source of the universe is put in as
an initial condition, as are other physical conditions like the fluctuations of matter density that became enhanced later to form
galaxies in an otherwise homogeneous universe. Because the initial conditions are beyond the present observer's ability to observe and verify, and because particle physics has remained untested at energies of the order of 10^{15}Gev , we are completely at the mercy of speculations! More so, as the primordial conditions are never repeated at any later stage, and so we are, in fact, violating the repeated testability criterion of a physical theory.

These and other unsatisfactory features led Fred Hoyle, Geoffrey Burbidge and myself to take a fresh look at cosmology and try a new approach.

Quasi Steady – State Cosmology

Since 1993, we have been developing an alternative cosmology ,beginning from an action principle by which we seek to explain how matter and radiation appeared in the universe. That is to say, the action principle includes the possibility that a typical world-line of a particle can have a beginning. The details involve a scalar field analogous to that which appears in popular inflationary models which are favoured by standard cosmology. As it does in the inflationary models, the scalar field exerts a negative pressure that explains the universal expansion. In our theory, the field also acts negatively in the creation process, balancing the positive energy of matter production. That permits new matter to appear in an already existing universe, instead of requiring the creation of the entire universe de novo, in a Big Bang.

We regard the creation as being triggered locally in what we call mini-creation events or minibangs, with the negative field component subsequently escaping from the region of creation, which has experienced an accumulation of positive energy. It is in this way, we argue, that black holes are formed –not through the infall of matter. The popular black hole paradigm at present assumes that the high energy activity in the nuclei of certain 'active' galaxies is triggered by a spinning massive black hole with several billion solar masses. However, this interpretation runs into problems like the following.

Matter moving at velocity c transverse to the radius vector from the center of a spherical black hole of mass M = 10^{10} solar masses (M®.), at the critical distance 2 GM/c^2, has angular momentum of order 10^{26} cm^2 per s per gram. But matter rotating about a galactic centre typically has ten thousand times more angular momentum than that. Therefore it is difficult for us to see how a large quantity of matter in a galaxy could come to be packed into the small scale of a black hole, even when the black hole has a mass as large as 10^{10} solar masses.

The conventional interpretation has, as yet, found no satisfactory way around this difficulty. But if, at the centres of galaxies, there are black holes that act as mini-creation events, the escape of the negative energy field generated in the creation process provides a ready explanation for the accumulation of the positive material component, leading to an easily understood development of the central black hole.

"The ease with which complexities of the microwave background can be understood in QSSC is a strong indication that the theory is on the right track."

While there are several interesting applications of this idea to high energy astrophysics, we will discuss next how the combined effect of such mini-creation events drives the dynamics of the universe. It turns out that while the long term result of this interaction is the steady state model, there are significant short-term effects which make the universe oscillate around the steady state solution. Which is why the cosmology is called the 'quasi-steady state cosmology'.

Cosmological Solutions

The space time geometry of our quasi-steady state cosmology (QSSC) is described, just as in standard cosmology, by the Robertson-Walkar line element, with the expansion of the universe determined by the scale factor S (t). The difference in our theory is that the equation for the square of the time derivative of S now carries a negative term that decreases like S^{-4}. Thus, in a time-reversed picture, in which the scale factor S grows smaller, a stage will eventually be reached in which this new term will dominate over the positive term, due to the material content of the universe, that goes like S^{-3}.

The effect, as one goes backward in time, is to produce an oscillation of the scale factor:
$S(T)=F_Q$ (t).exp(t/P).
In the time-dependent scale factor, the parameter Q is the temporal period of the periodic function F_Q (t), which turns out to be
5-10 times longer than the "age of the universe" arrived at in the Big Bang scenario. The other characteristic-time parameter, P»Q, describes an exponential growth that is very slow on the time scale of the periodic function. P is determined by the rate of matter creation averaged over a large number of mini-creation events.

The quasi steady-state model also has two dimensionless parameters:
the ratio S_{max} / S_{min} between the amplitudes of S(t) at its maxima and minima, and the ratio $S(t_0)$/ S_{min} of the present scale factor to its periodic minimum.

Typical values of these four parameters that best fit the observational data are Q = 4.4 x 10^{10} years, P =20 Q,

$$S_{max} / S_{min} = 9 \text{ and } S(t_0)/ S_{min} = 6.$$

For these parameter values, the form of the oscillation of the cosmic scale factor is shown in Figure 1.

"Mini creation events play a key role in forming the large scale structure observed in the universe today."

Among the broad observational data that these parameters must reproduce are (i) the relationship between the red shifts of galaxies and their visual magnitudes , (ii) the angular sizes of quasars at different red shifts , (iii) the population counts of galaxies and radio sources, (iv) the largest observed red shifts , (v) microwave back ground, and (vi) the cosmic abundances of the lightest nuclear isotopes. We begin with the discussion of the microwave background first, as it represents the tour de force for the standard model.

The Microwave Background:

As seen in the cosmological model described above, the stars shining in the previous cycles would leave a relic radiation background. This can be estimated with the help of starlight distribution in the present cycle, since all cycles are ideally identical.

It turns out that the total energy density of this starlight at the present epoch is adequate to give a radiation background of ~2.7 K, in good agreement with the observations. The question is, would this relic radiation be thermalized to a near-perfect blackbody spectrum and distributed with a remarkable degree of homogeneity?

The answer to the first question is 'yes'. The thermalizers are metallic whiskers which work most efficiently for this process, much more so than the typical spherical grains. These are formed when supernovae make and eject metals in vapour form.

Experimental work on the cooling of carbon and metallic vapors has shown that there is a strong tendency for condensates to appear as long thread-like particles, often called whiskers. Carbon and metal whiskers are particularly effective at converting optical radiation into the far infrared. Calculations show that a present-day intergalactic density of 10^{-35} g/cm^3 for such whiskers would suffice to thermalize the accumulated starlight at an oscillatory minimum. Such a whisker density could readily be accounted for by the ejecta of supernovae, which can easily leave the confines of their parent galaxies.

But near an oscillatory maximum, the universe is sufficiently diffuse that such intergalactic particulates have a negligible effect on starlight. Light propagation is then essentially free and, because of the long time scale of the maximum phase of each cycle, there is a general mixing of starlight from widely separated galaxies. Because of this mixing and the large-scale cosmic homogeneity and isotropy, the energy density of the radiation also acquires a high degree of homogeneity. That homogeneity persists, because the absorption and reemission of the starlight at the next minimum does not change the energy density. Thus we have an explanation of the remarkable uniformity for the cosmic microwave background.

Small deviations from this uniformity, in the order of a part in 10^5, are expected for regions near rich clusters of distant galaxies. This implies that the microwave background should exhibit temperature fluctuations on the sky of a few tens of micro Kelvin on an angular scale determined by the clustering of distant galaxies. For a

distant cluster of diameter 10 mega parsecs observed at a red shift z = ?? / ? of 5 (about the highest red shift that's been seen), that angular scale is about 0.7°, in good agreement with the largest observed fluctuations in the microwave background.

The ease with which the complexities of the microwave background can be understood in the quasi steady-state cosmology is, in our opinion, a strong indication that the theory is on the right track. Rather than being put in by parametric choices, the observed fluctuations of the microwave background arise naturally from the clustering of galaxies

Origin of The Light Nuclei :

There are more than 320 known isotopes of the elements. In 1957 Geoffrey and Margaret Burbidge, Willy Fowler and Fred Hoyle showed that, with the possible exceptions of deuterium, ^{3}He, ^{4}He and ^{6}Li ,^{9}Be and ^{10}B, and "B, all the isotopes were synthesized by nuclear processes in stellar interiors. We have recently surveyed what has been learned about the origins of these light nuclear species in recent decades.

The list of eight problematic cases was soon reduced to five, as ^{6}Li, ^{10}B, and ^{11}B were found to be produced in the spallation reactions of cosmic rays. More recently, it has been found that the depletion of Fe in old stars correlates closely with the abundance of ^{9}Be, strongly suggesting that ^{9}Be was produced in association with the iron in the supernovae. Thus the original list of eight light nuclear species that at one time were candidates for association with a hot Big Bang cosmology was, in our view, reduced to four. Of these, lithium can possibly be made under stellar circumstances, in view of the finding of lithium-rich super giant stars.

"Massive near-black holes are undoubtedly present in the centers of galaxies."

Then we, re-stress the striking fact that the energy density of the microwave background is very close to what we calculate for the production of the observed ^{4}He abundance solely by hydrogen burning in stars. When all this is put together, we are left with only two of the eight special cases, as they seemed in 1957-namely deuterium and ^{3}He.

What is the like hood, we now ask, that even these last two will turn out to have purely astrophysical origins? ^{3}He is accumulated in large quantities in dwarf stars whose masses are too small for the isotope to be destroyed by the reaction $^{3}He + ^{3}He - ^{4}He + 2p$. There is also a class of earlier-type, more massive stars (including 3 Cen A), in which most of the helium is ^{3}He.On the Q »10^{11} year time scale of the quasi steady-state cosmology, it seems likely that the cosmic abundance of ^{3}He (Big Bang nucleosynthesis predicts about one for every ten thousand ^{4}He nuclei) is to be explained by an escape from stars of these types in stellar winds.

Deuterium, the last survivor from our original list of problematic light nuclei, is a particularly difficult case. It is both produced and destroyed by astrophysical processes. Deuterons are made in high-energy processes, such as solar flares, that generate free neutrons, and destroyed by burning in stellar interiors. Arguments over whether astrophysical production suffices, with no need to invoke cosmological deuteron production, therefore, turn on measurements of the cosmic D/H abundance ratio, which are difficult to accomplish with precision. In these circumstances, I think that the deuterium case can reasonably be regarded as uncertain. With all other nuclides (except, of course, ^{1}H) produced in adequate abundance by astrophysical means, it would seem best to extend this generalization to the deuteron and presume that any nucleus heavier than the proton has been synthesized by processes associated with stars.

Observations of Discrete Sources:

One of the most interesting developments in recent times in extragalactic astronomy is the use of Type IA supernovae to determine distances of galaxies and using the results to test the red shift-distance relations predicted by different cosmological models. Standard cosmology, after years of discounting the cosmological constant introduced by Einstein in his static model of 1917 as unnecessary, suddenly found it a very attractive parameter! There are two reasons for the same, (i) that the age of the universe comes out too low for comfort when compared to the estimated ages of stars and galaxies, and (ii) the extension of Hubble's law to distant galaxies does not fit the standard models. By introducing the cosmological constant these difficulties can be overcome. On the other hand, as shown in Figure 2, there is excellent agreement between the Hubble relation based on the measured distances of galaxies, using Type IA supernovae and the predictions of the QSSC. This happens precisely because of the absorption caused by intergalactic dust postulated by the QSSC to thermalize the microwave background. So far as stellar and galactic ages are concerned, the long time scales of the QSSC model ensure that there are no such problems.

There are also excellent agreements on two other cosmological tests. In one we look at the angular sizes of the tiny cores of distant radio sources whose red shifts are known. The angular size red shift relation predicted by the QSSC provides a very good fit to the data. The other test counts radio sources up to varying levels of flux density. This number-flux density relation can also be closely simulated by the QSSC.

Mini-creation Events, Dark Matter and Active Nuclei:

In the period 1958-74, Ambartsumian first developed the idea that many groups and clusters of galaxies are systems of positive total energy - that is to say, expanding systems not gravitationally bound - and that many small galaxies were formed in and ejected from the nuclei of larger systems. He also accepted the evidence of explosive events in radio sources and Seyfert galaxies. In the 1960s, when quasi-stellar objects with large red shifts were being identified in increasing numbers, it was realized that they are also highly energetic objects closely related to explosive events in galaxies.

How are we to understand such great outpourings of matter and energy? As far as the associations and clusters of galaxies are concerned, most theorists, unlike Ambartsumian, have simply not been prepared to accept the observations at face value. For many years, they have clung to the belief that the protogalaxies and galaxies were formed early in the history of the universe. From that point of view, it is impossible to believe that many galaxies are less than a billion years old, which must be the case if galaxies are, even now, being formed and ejected in expanding associations. It is generally agreed that, in such groups and clusters, the kinetic energy of the visible objects is much greater than their potential energy. The conventional way out nowadays is to assume that such groupings are indeed gravitationally bound - by large quantities of unseen "dark matter". This conjecture was already put forward for some of the great clusters of galaxies by Fritz Zwicky in the 1930s. In the 1970s, the view that the masses of systems of galaxies on all scales are proportional to their sizes became widely believed, but it was not stressed that this result is only obtained by assuming that they are bound and therefore obey the virial condition for which there is no other evidence.

The QSSC suggests that these open systems are in fact the remnants of mini-creation events and that their excess kinetic energy is the result of their explosive origin. As we shall see later in this article, the mini-creation events play a key role in forming the large scale structure observed in the universe today.
At the same time, we do have considerable evidence - from the flat rotation curves of spiral galaxies -for the existence of dark matter in them. This dark matter could very well be stars of previous cycles which are burnt out and devoid of any radiation. They could also be white dwarf of very large ages of the kind not possible in the relatively limited lifespan of the standard model. What about radio sources, active galactic nuclei, quasi-stellar

objects? It is generally accepted that they all release very large amounts of energy from dense regions with dimensions no larger than our solar system. It, has been clear since the early 1960s there are only two possibilities: this energy is either gravitational in origin, or it is released in creation processes. Conservatively, the total energy release in powerful sources is at least $10^5 M_\odot c^2$, where $M_\odot$ is the mass of the Sun. In the radio sources, much of this energy resides in highly relativistic particles.

To get such enormous energy releases in gravitational collapse it is necessary to consider processes very close to the Schwarzschild radius, where it would be very difficult to get the energy out. Even if the efficiency of the initial process is as high as few percent, the efficiency with which the gravitational energy is then converted through several stages into relativistic particles and magnetic flux would be very small. Despite these difficulties, the standard model explaining active galactic nuclei asserts that, in all such situations, there is a massive black hole at the center of the galaxy, surrounded by an accretion disk, and that all of the observed energy, emitted in whatever form, is gravitational in origin.

All of it, we are told, arises from matter falling into the disk and then into the black hole. But this type of model cannot convincingly explain the many observed phenomena, largely because the efficiency with which gravitational energy can be transformed into relativistic particles and photons is so small. It is much more likely that, in active galactic nuclei, we are seeing the creation of mass and energy as proposed in our quasi steady-state cosmology. Massive near-black holes are undoubtedly present in the centers of galaxies. But when they are detected, the galaxy is typically not active. The important feature is probably the quasi steady-state creation process, which can take place in the presence of large mass concentration.

Large Scale Structure:

The mini-creation centres act as nuclei for large scale structure. Ali Nayeri, Sunu Engineer, Fred Hoyle and this author simulated a toy model on a computer to see how the real process may work. The steps in this simulation are as follows.

(a) Produce $N \sim 10^6$ points randomly in a unit cube.

(b) Around a fraction $f = 1 - \exp(-3Q/P)$ of these points produce a randomly oriented neighbour within a distance $xN^{-1/3}$, where x is a fraction less than 1.

(c) Expand the cube and all scales within it homologously in the ratio $\exp(Q/P)$ in all directions.

(d) From the expanded cube retain the central cubical portion of unit size, deleting the rest.

The operations describe the creation process during one QSSC cycle. We repeated this exercise many times to see how the distribution of points evolves. Figure 3 shows a slice of the cube after 5 cycles. It is clear that the distribution of points has developed clusters and voids, typically like that in the real universe. A two-point correlation analysis confirms this visual impression quantitatively. The relative ease with which this type of distribution can be generated is in sharp contrast to the not inconsiderable efforts spent in standard cosmology in arriving at a cluster + void distribution through gravitational clustering.

Concluding Remarks :

What are the specific tests that may distinguish the QSSC from standard cosmology? A few are as follows:

(1) If a few light sources like galaxies or clusters are found with modest (~0.1) blue shifts, they can be identified with those from the previous cycle, lying close to the peak of the scale factor. In standard cosmology there should be no blue shifts.

(2) If low-mass stars, say with half a solar mass, are found in red giant stage, they will have to be very old, say ~40-50 x 10^9 years old, and as such they cannot be accommodated in the standard model, but will naturally

belong to the previous cycle of the QSSC.

(3) If the dark matter in the galaxies is proved largely to be baryonic, or if other locations like clusters of galaxies turn out to have large quantities of baryonic matter, then the standard cosmology would be in trouble. For, beyond a limit the standard models do not allow for baryonic matter as it drastically cuts down the predicted primordial deuterium and also spoils the scenario for structure formation.

(4) These observations lie just beyond the present frontiers of astronomical observations. So we hope that the cosmological debate will spur observers to scale greater heights and push their observing technology past the present frontiers, as happened fifty years ago with the debate about the original steady state cosmology.

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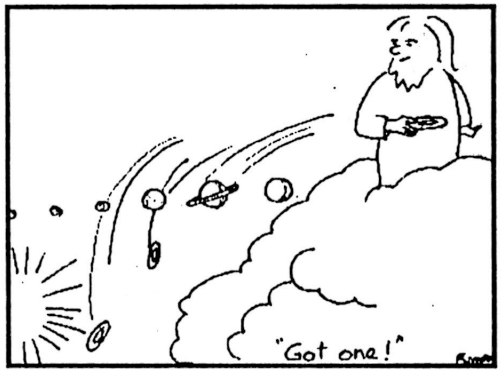

The term "Big Bang" started as a putdown. In the 1940s, there were many competing theories about the nature of the universe. British astrophysicist Fred Hoyle coined the term "Big Bang" as a snide putdown of his competitors, only to have term find its way into the general consciousness as the description of the correct theory.

SCRAMBLE

Unscramble the following words to form five words related to physics:

E	I	A	C	G	N	T	M	Y	O	R
	O		O			O			O	
N	A	R	I	T	B	E	R	A	O	
				O		O	O		O	
	U	H	A	K	A	G	R	N		
	O					O	O	O		
E	H	O	W	T	T	S	N	A	E	
		O				O	O		O	
C	I	A	L	N	S	T	E	I	L	T
O							O	O		



Arrange the circled letters to find the answer for the above picture.

WHAT WAS THE ASTRONOMER UP TO?

OOOOOOO OOOOOOO **THE** OOOOO