Proceedings of the Conference

Evolution of Cosmic Objects through their Physical Activity

dedicated to
Viktor Ambartsumian's
100th anniversary

Evolution of Cosmic Objects through their Physical Activity

Cosmology and Mini-Creation Events

Jayant V. NARLIKAR
Inter-University Center for Astronomy and Astrophysics,
Pune 411007, India

1. Introduction

The most perceptive astronomer in recent history was Viktor Ambartsumian the famous Armenian theorist. Starting in the 1950s and 1960s (Ambartsumian, 1965) he stressed the role of explosions in the universe arguing that the associations of galaxies (groups, clusters, etc.) showed a tendency to expand with far larger kinetic energy than is expected by assuming that the gravitational virial condition holds.

Here we take up the issue emphasized by Ambartsumian that there apparently exist phenomena in nuclei of galaxies where matter seems to appear with large kinetic energy of motion directed outwards. Later we will also include other phenomena that share the same property, namely explosive creation of matter and energy. We shall refer to such events as *mini-creation* events (MCEs, hereafter).

Since these phenomena appear on the extragalactic scale and involve quasi-stellar objects, active galaxies, powerful radio sources and clusters and groups of galaxies at all redshifts, we believe they must have an intimate connection with cosmology. Indeed, if one looks at standard cosmology, there too the paradigm centers around the 'big bang' which is itself an explosive creation of matter and energy. In the big bang scenario the origin of all of the phenomena is ultimately attributed to a single origin in the very early universe. No connection has been considered by the standard cosmologists between this primordial event and the MCEs that Ambartsumian talked about. In fact, the QSOs and AGN are commonly ascribed to supermassive black holes as 'prime movers'. In this interpretation the only connection with cosmology is that it must be argued that the central black holes are a result of the processes of galaxy formation in the early universe. So far no rationale for such an outcome is given in standard cosmology.

We first show that the dynamics of the universe is governed by the frequency and power of the MCEs, and there is a two-way feedback between the two. That is, the universe expands when there is a large MCE activity and contracts when the activity is switched off. Likewise, the MCE activity is large when the density of the universe is relatively large and negligible when the density is relatively small. In short, the universe oscillates between states of finite maximum and minimum densities as do the creation phases in the MCEs.

This was the model proposed by Hoyle, Burbidge and Narlikar (1993) and called the *quasi-steady state cosmology* (QSSC in brief). The model was motivated partly by Ambartsumian's ideas and partly by the growing number of explosive phenomena that are being discovered in extragalactic astronomy. We first discuss the cosmological model and then turn to the various phenomena which are beginning to help us understand the basic cosmogony. Then we discuss and look at the phenomena themselves in the framework of this cosmology.

2. The QSSC Model

The mathematical framework for our cosmological model has been discussed by Hoyle, Burbidge and Narlikar (1995; HBN hereafter), and we outline briefly its salient features. To begin with, it is a theory that is derived from an action principle based on Mach's Principle, and assumes that the inertia of matter owes its origin to other matter in the universe. This leads to a theoretical framework wider than general relativity as it includes terms relating to inertia and creation of matter.

Thus the equations of general relativity are replaced in the above theory by

$$R_{ik}-\frac{1}{2}g_{ik}R+\lambda g_{ik}=8\pi G\left[T_{ik}-f\left(C_iC_k-\frac{1}{4}g_{ik}C^iC_i\right)\right], \qquad (1)$$

with the coupling constant f defined as

$$f=\frac{2}{3\tau^2}. \qquad (2)$$

[We have taken the speed of light c = 1.] Here $\tau=\hbar/m_P$ is the characteristic life time of a Planck particle with mass $m_P=\sqrt{3\hbar/8\pi G}$. The gradient of *C* with respect to spacetime coordinates $x^i\,(i=0,1,2,3)$ is denoted by Cj. Although the above equation defines f in terms of the fundamental constants it is convenient to keep its identity on the right hand side of Einstein's equations since there we can compare the C-field energy tensor directly with the matter tensor. Note that because of positive f, the C-field has *negative* kinetic energy. Also, the constant λ is *negative* in this theory.

The question now arises of why astrophysical observation suggests that the creation of matter occurs in some places but not in others. For creation to occur at the points $A_0, B_0, \ldots$ it is necessary classically that the action should not change (i.e. it should remain stationary) with respect to small changes in the spacetime positions of these points, which can be shown to require

$$C_i(A_0)C^i(A_0)=C_i(B_0)C^i(B_0)=\ldots=m_P^2. \qquad (3)$$

This is in general not the case: in general the magnitude of $C_i(X)C^i(X)$ is much less that m_P^2. However, as one approaches closer and closer to the surface of a massive compact body $C_i(X)C^i(X)$ is increased by a general relativistic time dilatation factor, whereas m_P^2 stays fixed. For a Schwarzschild-type solution around an object of mass M, this factor at distance R from the centre is

$$\gamma=\left(1-\frac{2GM}{R}\right)^{-1}. \qquad (4)$$

This suggests that we should look for regions of strong gravitational field such as those near collapsed massive objects. In general relativistic astrophysics such objects are none other than black holes, formed from gravitational collapse. Theorems by Penrose, Hawking and others (see Hawking and Ellis 1973) have shown that provided certain positive energy conditions are met, a compact object undergoes gravitational collapse to a spacetime singularity. Such objects become black holes before the singularity is reached. However, in the present case, the negative energy of the C-field intervenes in such a way as to violate the above energy conditions. What happens to such a collapsing object containing a C-field apart from ordinary matter? We argue that such an object does not become a black hole. Instead, the collapse of the object is halted and the object bounces back, thanks to the effect of the C-field. We will refer to such an object as a compact massive object (CMO) or a near-black hole (NBH). For a model of *NBH* see Narlikar et al. (2007).

It is worth stressing here that even in classical general relativity, the external observer never lives long enough to observe the collapsing object enter the horizon. Thus all claims to have observed black holes in X-ray sources or galactic nuclei really establish the existence of compact massive objects, and as such they are consistent with the NBH concept. A spinning NBH, for example can be approximated by the Kerr solution limited to region outside the horizon (- in an NBH there is no horizon). In cases where *C* has not gone to the level of creation of matter, an NBH will behave very much like a Kerr black hole.

The theory would profit most from a quantum description of the creation process. The difficulty, however, is that Planck particles are defined as those for which the Compton wavelength and the gravitational radius are essentially the same, which means that, unlike other quantum processes, flat spacetime cannot be used in the formulation of the theory. A qualitative discussion would go somewhat like this. A gravitational disturbance is necessarily involved and the ideal location for triggering creation is that near a CMO. The C-field boson far away from a compact object of mass M may not be energetic enough to trigger the creation of a Planck particle. However, on falling into the strong gravitational field of a sufficiently compact object, the boson energy is multiplied by a large 7- factor, for a local Schwarzschild metric.

Bosons then multiply up in a cascade, one makes two, two makes four, ..., as in the discharge of a laser, with particle production multiplying up similarly and with negative pressure effects ultimately blowing the system apart. This is the explosive event that we earlier referred to as a *mini-creation event* (MCE). Unlike the big bang, however, the dynamics of this phenomenon is *well defined and non-singular*. For a detailed discussion of the role of a NBH as well as the mode of its formation, see Hoyle et al. (2000), (HBN hereafter) p. 244-249.

While still qualitative, we shall show that this view agrees well with the empirical facts of observational astrophysics. For, as mentioned in the previous section, we do see several explosive phenomena in the universe, such as jets from radio sources, gamma ray bursts, X-ray bursters, QSOs and active galactic nuclei, etc. Generally it is assumed that a black hole plays the lead role in such an event by somehow converting a fraction of its huge gravitational energy into large kinetic energy of the 'burst' kind. In actuality, we do not see infailing matter that is the signature of a black hole. Rather we see outgoing matter and radiation, which agrees very well with the explosive picture presented above.

The qualitative picture described above is too difficult and complex to admit an exact solution of the field equations (1). The problem is analogous to that in standard cosmology where a universe with inhomogeneity on the scale of galaxies, clusters, superclusters, etc., as well as containing dark matter and radiation is impossible to describe exactly by a general relativistic solution. In such a case one starts with simplified approximations as in models of Friedmann and Lemaitre and then puts in specific details as perturbation.

In the same spirit we approach the above cosmology by a mathematical idealization of a homogeneous and isotropic universe in which there are regularly phased epochs when the MCEs were active and matter creation took place while between two consecutive epochs there was no creation (-the MCEs lying dormant). We will refer to these two situations as creative and non-creative modes. In the homogeneous universe assumed

here the C-field will be a function of cosmic time only. We will be interested in the matter-dominated analogues of the standard models since, as we shall see, the analogue of the radiation-dominated state never arises except locally in each MCE where, however, it remains less intense than the C-field. In this approximation, the increase or decrease of the scale factor $S(t)$ of the universe indicates an average smoothed out effect of the MCEs as they are turned on or off. The following discussion is based on the work of Sachs, et al. (1996).

We write the field equations (1) for the Robertson-Walker line element with $S(t)$ as scale factor and k as curvature parameter and for matter in the form of dust, when they reduce to essentially two independent equations :

$$2\frac{\ddot{S}}{S}+\frac{\dot{S}^2+k}{S^2}=3\lambda+2\pi Gf\dot{C}^2, \tag{5}$$

$$\frac{3(\dot{S}^2+k)}{S^2}=3\lambda+8\pi G\rho-6\pi Gf\dot{C}^2, \tag{6}$$

where we have set the speed of light c = 1 and the density of dust is given by ρ. From these equations we get the conservation law in the form of an identity:

$$\frac{d}{dS}\{S^3(3\lambda+8\pi G\rho-6\pi Gf\dot{C}^2\}=3S^3\{3\lambda+2\pi Gf\dot{C}^2\}. \tag{7}$$

This law incorporates "creative" as well as "non-creative" modes.

The creative mode has $T^{ik}_{;k}\neq 0$ and the right hand of (7) non-zero. The non-creative mode has $T^{ik}_{;k}=0$. The old steady state theory arises as a special case of the creative mode.

The quasi-steady state cosmology is described by a combination of the creative and the non-creative modes. For this the general procedure to be followed is to look for a composite solution of the form

$$S(t)=\exp\left(\frac{t}{P}\right)\left\{1+\eta\cos\frac{2\pi t}{Q}\right\}, \tag{8}$$

wherein $P >> Q$. Thus over a period Q the universe is essentially in a non-creative mode. However, at regular instances separated by the period Q it has injection of new matter at such a rate as to preserve an average rate of creation over period P. It is most likely that these epochs of creation are those of the minimum value of the scale factor during oscillation, because then the level of the C-field background is the highest. There is a sharp drop at a typical minimum but the $S(t)$ is a continuous curve with a zero derivative at $S = S_{\min}$.

Suppose that matter creation takes place at the minimum value of $S = S_{\min}$, and that N particles are created per unit volume with mass m_0. Then the extra density added at this epoch in the creative mode is

$$\Delta\rho = m_0 N. \qquad (9)$$

After one cycle the volume of thespace expands by a factor exp $(3Q/P)$ and to restore the density to its original value we should have

$$(\rho + \Delta\rho)e^{-3Q/P} = \rho\text{, i.e.,} \quad \Delta\rho/\rho \cong 3Q/P. \qquad (10)$$

The C-field strength likewise takes a jump at creation and declines over the following cycle by the factor $\exp(-4Q/P)$. Thus the requirement of "steady state" from cycle to cycle tells us that the change in the strength of $\dot{C}^2$ must be

$$\Delta\dot{C}^2 = \frac{4Q}{P}\dot{C}^2. \qquad (11)$$

The above result is seen to be consistent with (10) when we take note of the conservation law (7). A little manipulation of this equation gives us

$$\frac{3}{4}\frac{1}{S^4}\frac{d}{dS}\left(f\dot{C}^2S^4\right) = \frac{1}{S^3}\frac{d}{dS}\left(\rho S^3\right). \qquad (12)$$

However, the right hand side is the rate of creation of matter per unit volume. Since from (10) and (11) we have

$$\frac{\Delta\dot{C}^2}{\dot{C}^2} = \frac{4}{3}\frac{\Delta\rho}{\rho}. \qquad (13)$$

and from (5) and (6) we have $\rho = f\dot{C}^2$, we see that (13) is deducible from (10) and (11).

To summarize, we find that the composite solution properly reflects the quasi-steady state character of the cosmology in that while each cycle of duration Q is exactly a repeat of the preceding one, over a long time scale the universe expands with the de Sitter expansion factor $\exp(t/P)$. The two time scales P and Q of the model thus turn out to be related to the coupling constants and the parameters λ, f, G, η of the field equations. Further progress in the theoretical problem can be made after we understand the quantum theory of creation by the C-field.

These solutions contain sufficient number of arbitrary constants to assure us that they are generic, once we make the simplification that the universe obeys the Weyl postulate and the cosmological principle. The composite solution can be seen as an illustration of how a non-creative mode can be joined with the creative mode. More possibilities may exist of combining the two within the given framework. We have, however, followed the simplicity argument (also used in the standard big bang cosmology) to limit our present choice to the composite solution described here.

Coming next to a physical interpretation of these mathematical solutions, we can visualize the above model in terms of the following values of its parameters:

$$P = 20Q, \qquad Q = 5\times10^{10}\,yrs, \qquad \eta = 0.811,$$
$$\lambda = -0.358\times10^{-56}(cm)^{-2}.$$

To fix ideas, we have taken the maximum redshift observable in the present cycle, $z_{\max} = 5$. This set of parameters has been used in recent papers on the QSSC (Narlikar, et al. 2002, 2003, 2006). For this model the ratio of maximum to minimum scale factor in any oscillation is around 9.6.

These parametric values are not uniquely chosen; they are rather indicative of the magnitudes that may describe the real universe. For example, $z_{\max}$ could be as high as 10 without placing any strain on the model. The various observational tests seek to place constraints on these values. Can the above model quantified by the above parameters cope with such tests? If it does we will know that the QSSC provides a realistic and viable alternative to the big bang.

3. The Radiation Background

As far as the origin and nature of the CMBR is concerned we use a fact that is always ignored by standard cosmologists. If we suppose that most of the ^4He found in our own and external galaxies (about 24% of the hydrogen by mass) was synthesized by hydrogen burning in stars, the energy released amounts to about 4.37×10^{-13} erg cm^{-3}. This is almost exactly equal to the energy density of the microwave background radiation with T = 2.74°K. For standard cosmologists this has to be dismissed as a coincidence, but for us it is a powerful argument in favor of the hypothesis that the microwave radiation at the level detected is relic starlight from previous oscillations in the QSSC which has been thermalized (Hoyle, et al. 1994). Of course, this coincidence loses its significance in the standard big bang cosmology.where the CMBR temperature is epoch-dependent.

It is then natural to suppose that the other light isotopes, namely D, ^{3}He, ^{6}Li, ^{7}Li, ^{9}Be, ^{10}B and ^{11}B were produced by stellar processes. It has been shown (cf. Burbidge and Hoyle, 1998) that both spallation and stellar flares (for ^{2}D) on the surfaces of stars can explain the measured abundances. Thus *all* of the isotopes are ultimately a result of stellar nucleosynthesis (Burbidge et al. 1957; Burbidge and Hoyle 1998).

This option raises a problem, however. If we simply extrapolate our understanding of stellar nucleosynthesis, we will find it hard to explain the relatively low metallicity of stars in our Galaxy. This is still an unsolved problem. We believe but have not yet established that it may be that the initial mass function of the stars where the elements are made is dominated by stars which are only able to eject the outer shells while all of the heavy elements are contained in the cores which simply collapse into black holes. Using theory we can construct a mass function which will lead to the right answer (we think) but it has not yet been done. But of course our handwaving in this area is no better than all of the speculations that are being made in the conventional approach when it comes to the "first" stars.

The theory succeeds in relating the intensity and temperature of CMBR to the stellar burning activity in each cycle, the result emphasizing the causal relationship between the radiation background and nuclear abundances. But, how is the background thermalized? The metallic whisker shaped grains condensed from supernova ejecta have been shown to effectively thermalize the relic starlight (Hoyle et al., 1994, 2000). It has also been demonstrated that inhoniogeneities on the observed scale result from the thermalized radiation from clusters, groups of galaxies etc. thermalized at the minimum of the last oscillation (Narlikar et al., 2003). By using a toy model for these sources, it has been shown that the resulting angular power spectrum has a satisfactory fit to the data compiled by Podariu et al (2001) for the band power spectrum of the CMBR temperature inhoniogeneities. Extending that work further it has been shown by Narlikar et al. (2007), that the model is also consistent with the first- and third- year observations of the Wilkinson Microwave Anisotropy Probe (WMAP) (Page et al. 2003; Spergel et al. 2006).

We mention in passing that recent work (Wickramasinghe 2005) indicates that small traces of polarization would be expected in the CMBR wherever it passes through optically thin clouds of iron whiskers. These whiskers being partially aligned along the intracluster magnetic fields will yield a weak signal of polarization on the scale of clusters or smaller ojects.

It should be noted that the small scale anisotropics do not constitute as crucial a test for the QSSC model as they do for standard cosmology. Our general belief is that the universe is inhomogeneous on the scales of galaxy-cluster-supercluster and the QSSC model cannot make detailed claims of how these would result in the anisotropy of CMBR. In this respect, the standard model subject to all its assumptions (dark matter, inflation, dark energy, etc.) makes much more focussed predictions of CMBR anisotropy.

It is worth commenting on another issue of an astrophysical nature. The typical QSSC cycle has a lifetime long enough for most stars of masses exceeding $\sim 0.5 - 0.7 M_{\odot}$ to have burnt out. Thus stars from previous cycles will be mostly extinct as radiators of energy. Their masses will continue, however, to exert a gravitational influence on visible matter. The so-called dark matter seen in the outer reaches of galaxies and within clusters may very well be made up, at least in part, of these stellar remnants.

To what extent does this interpretation tally with observations? Clearly, in the big bang cosmology the time scales are not long enough to allow such an interpretation. Nor does that cosmology permit dark matter to be baryonic to such an extent. The constraints on baryonic dark matter in standard cosmology come from (i) the origin and abundance of deuterium and (ii) considerations of large scale structure. The latter constraint further requires the nonbaryonic matter to be cold. In the QSSC, as has been shown before, these constraints are not relevant. For other observational issues completely handled by the QSSC, see Hoyle et al. (2000).

4. Explosive Cosmogony

4.1. Groups and clusters of galaxies

We have already stated that it was Ambartsumian (1965) who first pointed out that the simplest interpretation of many physical systems of galaxies ranging from very small groups to large clusters is that they are expanding and coming apart. Since most of the observations are of systems at comparatively small redshifts it is clear that this takes place at the current epoch, and while we do not have direct evidence of the situation at large redshifts, it is most likely a general phenomenon.

Why has this effect been so widely ignored? The answer to this is clearly related to the beliefs of earlier generations of cosmologists. From an historical point of view, the first physical clusters were identified in the 1920s, and it was Zwicky, and later others who supposed that they must be stable systems. By measuring individual redshifts of a number of the galaxies in such a cluster it is possible to get a measurement of the line-of-sight random motions. For stability the virial condition $2E_K + \Omega = 0$ needs to be satisfied where E_K and Ω are the average values of the kinetic energy and potential energy of the cluster members. Extensive spectroscopic studies from the 1950s onward showed that nearly always the kinetic energy of the visible matter far exceeds the potential energy apparent from the visible parts of the galaxies. Many clusters have structures which suggest they are stable and relaxed. Thus it was deduced that in these clusters there must be enough dark matter present to stabilize them. This was, originally, one of the first pieces of evidence for the existence of dark matter.

The other argument was concerned with the ages of the galaxies. Until fairly recently it has been argued that all galaxies have stellar populations which include stars which are very old, with ages on the order of H_0^{-1}, i.e. that they are all as old as the classic big bang universe. However we now know that young galaxies with ages $<< H_0^{-1}$ do exist. But the major point made by Ambartsumian was, and is, that there are large numbers of clusters of galaxies, and many small groups, which are physically connected but clearly from their forms and their relative velocities, appear to be unstable.

In this situation the use of the virial theorem is totally inappropriate. It is worthwhile pointing out that if the virial theorem holds the random motions of the galaxies should follow a steady state distribution such as

$$F(v) \propto \exp\left[-\frac{v^2}{2\sigma^2}\right]. \qquad (14)$$

So far there is no observational demonstration that this is indeed the case. The conclusion drawn from $2E_K + \Omega > 0$ as based on visible components only should rather be that the clusters are manifestly *not* in dynamical equilibrium.

Modern evidence concerning the masses of clusters has been obtained from x-ray studies, the Sunyaev-Zeldovich effect, and gravitational lensing (cf. Fabian 1994; Carlstrom et al. 2002; Fort and Mellier 1994 and many other papers). All of these studies of rich clusters of galaxies show that large amounts of matter in the form of hot gas and/or dark matter must be present. However, evidence of enough matter to bind small or irregular clusters has not been found in general, and these are the types of configurations which Ambartsumian was originally considering. A system such as the Hercules Cluster is in this category. Also the very compact groups of galaxies (cf. Hickson 1997) have been a subject of debate for many years since a significant fraction of them (~ 40%) contain one galaxy with a redshift very different from the others. Many statistical studies of these have been made, the orthodox view being that such galaxies must be "interlopers"; foreground or background galaxies. Otherwise they either have anomalous redshifts, or are exploding away from the other galaxies.

We also have the problem of interacting galaxies, briefly referred to earlier in Section 1. In modern times it has been generally supposed that when two galaxies are clearly in interaction they must be coming together (merging) and never coming apart. There are valid ways of deciding whether or not mergers are, or have occurred. The clearest way to show that they are coming together is to look for tidal tails (Toomre and Toomre 1972), or, if they are very closely interwoven, to look for two centers, or two counter rotating systems. For some objects this evidence does exist, and mergers are well established. But to assume that merging is occurring in all cases is unreasonable: there may well be systems where we are seeing the ejection of one galaxy from another as Ambartsumian proposed. Thus when the virial condition is not satisfied, and the systems are highly irregular and appear to be coming apart, then perhaps they *are* coming apart, and never have been separate. Here we are clearly departing from the standard point of view.

If one assumes that clusters may not be bound, their overall astrophysics changes from that of bound 'steady' clusters. Issues like the nature of intra-cluster medium, the role of the halo, generation of x-rays will require a new approach in the case where clusters are expanding. Further, the ejection of new matter provides additional inputs to the dynamics of the system. For example, the energy of ejection will play a role in heating the intracluster gas. This important investigation still needs to be carried out. However, a preliminary discussion may be found in Hoyle, et al. (2000), Chapter 20.

4.2. Explosions in individual galaxies

By the early 1960s it had become clear that very large energy outbursts are taking place in the nuclei of galaxies.

The first evidence came from the discovery of powerful radio sources and the realization that the nuclei of the galaxies which they were identified with, had given rise to at least 10^{59} - 10^{61} ergs largely in the form of relativistic (Gev) particles and magnetic flux which had been ejected to distances of $>$ 100 kpc from the region of production.

A second line of evidence comes from the classical Seyfert galaxies which have very bright star-like nuclei which show very blue continua, and highly excited gas which has random motions $>$ 3000 Km sec^{-1}, and must be escaping from the nucleus. We know that the gas is being ejected because we see it through absorption in optical and X-ray spectra of Seyfert nuclei, and the wavelengths of the absorption lines are shifted to the blue of the main emission. The speeds observed are very large compared with the escape velocity. Early data were described by Burbidge et al. (1963).

In the decades since then it has been shown that many active nuclei are giving rise to x-rays, and to relativistic jets, detected in the most detail as high frequency radio waves. A very large fraction of all of the energy which is detected in the compact sources is non-thermal in origin, and is likely to be incoherent synchrotron radiation or Compton radiation.

Early in the discussion of the origin of these very large energies it was concluded that the only possible energy sources are gravitational energy associated with the collapse of a large mass, and the ejection of a small fraction of the energy, or we are indeed seeing mass and energy being created in the nuclei (cf. Hoyle, Fowler, Burbidge and Burbidge 1964).

Of course the most conservative explanation is that the energy arises from matter falling into massive black holes with an efficiency of conversion of gravitational energy to whatever is seen, of order 10%. This is the argument that has been generally advanced and widely accepted (cf. Rees 1984).

Why do we believe that this is not the correct explanation? After all, there is good evidence that many nearby galaxies (most of which are not active) contain collapsed supermassive objects in their centers with masses in the range 10^6 - 10^8 $M_\odot$.

The major difficulty is associated with the efficiency with which gravitational energy can be converted into very fast moving gas and relativistic particles, a problem that has haunted us for more than forty years (Burbidge and Burbidge 1965). In our view the efficiency factor is not 10% but close to 0.1% - 1%. The reasons why the efficiency factor is very small are the following. If the energy could be converted directly the efficiency might be as high as ~ 8%, or even higher from a Kerr rotating black hole. But this energy will appear outside the Schwarzschild radius as the classical equivalent of gravitons. This energy has to be used to heat an accretion disk or generate a corona in a classical AGN, or generate very high energy particles which can propagate outward in a radio source, then heat gas which gives rise to shock waves, which accelerate particles, which in turn radiate by the synchrotron process. Thermodynamics tells us that the efficiency at each of these stages is < 10%. If there are 3 to 4 stages the overall efficiency is ~ 10^{-3} – 10^{-4}. This is borne out by the measured efficiency by which relativistic beams are generated in particle accelerators on earth, and by the efficiency associated with the activity in the center of M87. (cf. Churasov et al. 2002).

If these arguments are not accepted, and gravitational energy is still claimed to be the only reasonable source, another problem appears.

For the most luminous sources, powerful radio sources and distant QSOs the masses involved must be much greater than the typical values used by the black hole-accretion disk theorists. If one uses the formula for Eddington luminosity (cf. for details pages 109-111, 408-409 of Kembhavi & Narlikar 1999) one arrives at black hole masses of the order 10^8 $M_\odot$ on the basis of perfect efficiency of energy conversion. An efficiency of < 0.01 would drive the mass up a hundred fold at least, i.e. to 10^{10} $M_\odot$ or greater. So far there is no direct evidence in any galaxy for such large dark masses. The largest masses which have been reliably estimated are about 10^9 M©.

In general it is necessary to explain where the bulk of the energy released which is not in the relativistic particle beams, is to be found. A possible explanation is that it is much of this energy which heats the diffuse gas in active galaxies giving rise to the extended X-ray emission in clusters and galaxies.

An even harder problem is to explain how the massive black holes in galaxies were formed in the first place. Were they formed before the galaxies or later? In the standard model both scenarios have been tried, but no satisfactory answer has been found.

In our model the energy comes with creation in the very strong gravitational fields very close to the central NBH, where the process can be much more efficient than can be expected in the tortuous chain envisaged in the classical gravitational picture.

Would very massive galaxies result if the universe allows indefinitely large time for galaxy formation? In the present case two effects intervene to make massive galaxies rather rare. The first one is geometrical. Because of steady long-term expansion, the distance between two galaxies formed, say, n cycles ago, would have increased by a factor ~ $\exp\left(n\frac{Q}{P}\right)$, and their density decreased by the factor ~ $\exp\left(-3n\frac{Q}{P}\right)$. For $n >> 1$, we expect the chance of finding such galaxies very small.

The second reason working against the growth of mass in a region comes from the negative energy and pressure of the C-field. As the mass grows through creation, the C-field also mounts and its repulsive effect ultimately causes enough instability for the mass to break up. Thus the large mass grows smaller by ejecting its broken parts.

What is ejected in an MCE? Are the ejecta more in the form of particles or radiation or coherent objects? All three are produced. For a discussion of the mechanism leading to ejection of coherent objects, see Hoyle, et al. (2000), Chapter 18.

4.3. Quasi-Stellar Objects

In the early 1960s QSOs were discovered as star-like objects with large red-shifts. Very early on, continuity arguments led to the general conclusion that they are very similar to the classical Seyfert glaxies, i.e. they are the nuclei of galaxies at much greater distances. However, also quite early in the investigations, it became clear that a good case could also be made for supposing that they are more likely to be compact objects *ejected* from comparatively local, low redshift active galaxies (Hoyle and Burbidge 1966). This conclusion has generated considerable controversy.

However, if this is accepted, it provides direct evidence that in the creation process active galaxies are able to eject compact sources with large intrinsic redshifts. What was not predicted was the existence of intrinsic redshifts. They present us with an unsolved problem, but one which must be closely connected to the creation process. A remarkable aspect of this problem is that the intrinsic redshifts show very clear peaks in their distribution with the first peak at $z = 0.061$ and with a periodicity of the form $\Delta\log(1+z) = 0.089$ (cf. Karlsson 1971, Burbidge and Napier 2001). The periodicity is in the intrinsic redshift component *(zi),* and in order to single out that component, either the cosmological redshift component z_c must be very small i.e., the sources must be very close to us, or it must be known and corrected for by using the relation $(1+z_{obs}) = (1+z_c)(1+z_i)$.

It is admitted that the evidence from gravitational lensing provides an overall consistent picture for the standard cosmological hypothesis. The evidence on quasars of larger redshift being lensed by a galaxy of lower redshift, together with the time delay in the radiation found in the two lensed images can be explained by this hypothesis. This type of evidence needs to be looked at afresh if the claim is made that quasars are much closer than their redshift-distances. In such cases, the lensing models can be 'scaled' down but the time-delay will have to be checked for lower values. To our knowledge no such exercise has been carried out to date.

4.4. Gamma Ray Bursts

One of the most remarkable phenomena discovered in recent years relate to very short lived (< minutes) bursts of high energy photons (7-ray and x-ray) which can apparently occur anywhere in the sky, and which sometimes can be identified with a very faint optical and/or radio source, an afterglow, which may fade with time. Sometimes a very faint object remains. The first optical observation in which a redshift could be measured led to the conclusion that those sources are extragalactic. Using the redshifts as distance indicators this has led to the conclusion that the energies emitted lie in the range 10^{50} - 10^{54} ergs, with most of them > 10^{53} ergs, if the explosions take place isotropically. If

energies involving single stars are invoked the energies can be reduced if beaming is present. The most recent observations have suggested that the events are due to forms of supernovae which are beamed. In the usual interpretation it is assumed that the redshifts which have been measured for the gamma ray bursts are cosmological (cf Bloom et al. 2001). However in a recent study using all (more than 30) gamma-ray bursts (GRBs) with measured redshifts it was shown that the redshift distribution strongly suggests that they are closely related to QSOs with the same intrinsic redshift peaks (Burbidge 2003, 2004). Also an analysis of the positions of all of the GRBs for which we have positions (about 150) shows that a number of them are very near to already identified QSOs (Burbidge 2003). All of this suggests that the GRBs are due to explosions of objects (perhaps *in* QSOs) which have themselves been ejected following a creation process from active galaxies. In general they have slightly greater cosmological redshifts and thus are further away (< 500 Mpc) than the galaxies from which most of bright QSOs are ejected. While we do not claim that this hypothesis is generally accepted, Bloom (2003) has shown that there are peculiarities in the redshift distribution interpreted in the conventional way. More observations may clarify this situation.

5. Concluding Remarks

The oscillating universe in the QSSC, together with a long-term expansion, driven by a population of mini-creation events provides the missing dynamical connection between cosmology and the 'local' explosive phenomena. The QSSC additionally fulfills the roles normally expected of a cosmological theory, namely (i) it provides an explanation of the cosmic microwave background with temperature, spectrum and inhomogeneities related to astro-physical processes (Narlikar et al. 2003), (ii) it offers a purely stellar-based interpretation of all observed nuclei *(including* light ones) (Burbidge et al. 1957; Burbidge and Hoyle 1998); (iii) it generates baryonic dark matter as part of stellar evolution (Hoyle et al. 1994), (iv) it accounts for the extra dimming of distant supernovae *without* having recourse to dark energy (Narlikar, Vishwakarma and Burbidge 2002; Vishwakarma and Narlikar 2005), and (v) it also suggests a possible role of MCEs in the overall scenario of structure formation (Nayeri et al. 1999). For limitations of time I have not described (iv) and (v).

The last mentioned work shows that preferential creation of new matter near existing concentrations of mass can lead to growth of clustering. A toy model based on million-body simulations demonstrates this effect and leads to clustering with a 2-point correlation function with index close to — 1.8. Because of repulsive effect of the C-field, it is felt that this process may be more important than gravitational clustering. However, we need to demonstrate this through simulations like those in our toy model, *together with* gravitational clustering.

Acknowledgements. It has been a pleasure and honour for me to describe these ideas at the birth centenary of Viktor Ambartsumian whose work I have long admired. I thank the conference

organizers for giving me this opportunity. The work presented here was done largely in collaboration with Geoffrey Burbidge, who would have very much liked to attend this meeting but could not because of health reasons. This presentation may be considered as a reflection of his ideas as well.

References

Ambartsumian, V.A. 1965, *Structure and Evolution of Galaxies, Proc. 13th Solvay Conf. on Physics, University of Brussels,* (New York, Wiley Inter-science), 24

Bloom, J.S. 2003, *AJ,* **125,** 2865

Bloom, J.S., Kulkarni, S.R., Djorgovsky, S.G. 2001, *A. J.,* **123,** 1111

Burbidge, E.M., Burbidge, G.R., Fowler, W.A., Hoyle, F. 1957, *Rev. Mod. Phys.,* **29,** 547

Burbidge, G. 2003, *ApJ,* **585,** 112

Burbidge, G. 2004, "The Restless High Energy Universe", *Conf. Proc. Nuclear Physics B.,* **305,** 132

Burbidge, G., Hoyle, F. 1998, *ApJ,* **509,** LI

Burbidge, G., Napier, W. M. 2001, *A. J.,* **121,** 21

Burbidge, G., Burbidge, E.M., Sandage, A. 1963, *Rev. Mod. Phys.,* **35,** 947

Carlstrom, J., Holder, G., Reese, E. 2002, *A.R.A.A.,* 40, 643

Churasov, E., Sunyaev, R., Forman, W., Bohringer, H. 2002, *MNRAS,* **332,** 729

Fabian, A.C. 1994, *A.R.A.A.,* **32,** 277

Fort, B., Mellier, Y. 1994, *A&A Rev.,* 4, 239

Hawking, S.W., Ellis, G.F.R. 1973, *The Large Scale Structure of Space-time,* Cambridge

Hickson, P. 1997, *A.R.A.A.,* **35,** 377

Hoyle, F., Burbidge, G. 1966, *ApJ,* **144,** 534

Hoyle, F., Burbidge, G., Narlikar, J.V. 1993, *Ap.J,* **410,** 437

Hoyle, F., Burbidge, G., Narlikar, J.V. 1994, *MNRAS,* **267,** 1007

Hoyle, F., Burbidge, G., Narlikar, J.V. 1995, *Proc. Roy. Soc,* **A448,** 191

Hoyle, F., Burbidge, G., Narlikar, J.V. 2000, *A Different Approach to Cosmology,* (Cambridge, Cambridge University Press).

Hoyle, F., Fowler, W.A., Burbidge, E.M., Burbidge, G. 1964, *Ap.J,* **139,** 909

Karlsson, K.G. 1971, *A&A,* **13,** 333

Kembhavi, A.K., Narlikar, J.V. 1999, *Quasars and Active Galactic Nuclei,* (Cambridge, Cambridge University Press).

Narlikar, J.V., Burbidge, G., Vishwakarma, R.G. 2007, *JAA,* 28, 67

Narlikar, J.V., Vishwakarma, R.G., Burbidge, G. 2002, *PASP,* **114,** 1092

Narlikar, J.V., Vishwakarma, R.G., Hajian, A., Souradeep, T., Burbidge, G., Hoyle, F. 2003, *ApJ,* **585,** 1

Page L., et al., 2003, Astrophys. J. Suppl. **148,** 233

Podariu, S., Souradeep, T., Gott III, J. R., Ratra, B., Vogeley, M. S. 2001, *ApJS,* **559,** 9

Rees, M.J., Ostriker, J.P. 1977, *MNRAS,* **179,** 541

Sachs, R., Narlikar, J.V., Hoyle, F. 1996, *A&A,* **313,** 703

Spergel, D.N., et al, 2006, astro-ph/0603449

Toomre, A., Toomre, J. 1972, *Ap. J.,* 178, 623

Wickramasinghe, N.C. 2005, *Current Issues in Cosmology,* Proc. Colloquium 'Cosmology: Facts and Problems ', Paris. (Cambridge, Cambridge University Press), 152