The Genesis of the Big-Bang and Inflation

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Abstract The standard model of cosmology posits that some time in the remote past, labelled as \( t = 0 \), a Big-Bang occurred. However, it does not tell what caused the Big-Bang and subsequently the Inflation. In the present work the cause of the Big-Bang and Inflation is suggested on the basis of the hints provided by the experimental findings at CERN and RHIC. The model used is singularity free Newtonian, i.e., non-relativistic, oscillatory model of the universe in which the space does not expand whereas all the relativistic cosmological models of the universe including the standard model, except the now discredited Einstein’s static model, imply that apart from the matter and the radiation in the universe the space is also expanding. However, there is no observational evidence whatsoever of the expansion of the space and as such, in all probability, the space is not at all expanding. A critique of the singularity theorems is also given on the basis of the experimental findings at CERN and RHIC and it is emphasized that no gravitationally collapsing object can collapse to a singularity, if it does, the time honoured Pauli’s exclusion principle would be violated.

1 Introduction

Gamow’s Hot Bing-Bang (HBB) model of the universe has withstood the test of the time. It successfully explains the observed Hubble expansion of the universe, i.e., the recession of galaxies away from each other, the existence of the 2.73K cosmic microwave background radiation (CMBR) as a relict of the big-bang, first predicted by Gamow [1946, 1948] and his collaborators (Alpher [1948] Alpher et al. [1948] Alpher & Herman [1948, 1950] and subsequently observed by Penzias & Wilson [1965] and others, and the cosmic abundance of light elements \( H, D, ^3He, ^4He, \) and \( Li \) (Steigman [1976, 1979]; Olive et al. [1981]; Yang et al. [1984]; Boesgaard & Steigman [1985]; Audouze [1987a,b]). Thus there are compelling evidences of the occurrence of the big-bang in the remote past despite the desperate attempts of its detractors to disprove it.

However, the so called standard cosmology based on the Friedmann models of the universe (Friedmann [1922, 1924]) is plagued with a number of problems, e.g., singularity (Penrose [1965]; Hawking & Penrose [1970]; Geroc [1966, 1968]), horizon (Rindler [1956]; Guth [1981]) and flatness (Dicke & Peebles [1975]; Guth [1981]). Moreover, it does not tell what caused the big-bang. The cause of the big-bang remains a mystery in the standard cosmology. Besides, it has no answer to the intriguing question: What preceded the big-bang?.

The implication of the singularity in the standard cosmology is that before the big-bang the universe was just a geometrical point of zero volume in the 3-space of the four-dimensional space-time (i.e., in what is called space in common parlance), and the entire matter in the universe, if at all it was there before the big-bang, was squeezed at that point and occupied zero volume in the space. After the big-bang that point started expanding continually, i.e., its volume increased continually from its initial zero value to larger and larger values and eventually reached the enormously large value of \( \sim 15 \times 10^{84} \text{cm}^3 \) (Allen [1973]) that the universe has today. If at all there was no matter in the universe before the big-bang, then the matter in the universe was also created by the big-bang. Essentially then, the implication of the standard cosmology is that both matter and the space were created as a result of the big-bang.

Various attempts have been made to resolve the problems of singularity, horizon, and flatness. Starobinsky...
(1981), and Israelit & Rosen (1989) have proposed singularity free cosmological models. To resolve the difficulties of the horizon and flatness associated with the standard model of cosmology inflationary models of the universe have been invoked (Guth 1981; Linde 1982; 1983; Albrecht & Steinhardt 1982). Another attempt at resolving the problems of singularity, horizon, and flatness is through the conformal transformation (Infeld & Schild 1945; Been 1978a; Kembhavi 1978; Narlikar & Padmanabhan 1980). In 1992 the author also proposed a singularity free model of the universe that not only resolves the problems of singularity, horizon, and flatness but also attempted, for the first time, to suggest the cause of the big-bang (Thakur 1992, 1993).

All the above cosmological models of the universe are based on one or another of the relativistic cosmological models of the universe. These relativistic cosmological models of the universe are based on Einstein’s field equations of the general theory of relativity (GTR) and hence assume that the geometry of the space-time of the universe is not Euclidean, it is Riemannian. However, there is no sound physical justification for this assumption. It may also be noted that all the relativistic cosmological models of the universe, except the now discredited Einstein’s static model of the universe, imply per se, that apart from the matter and the radiation in the universe the space is also expanding. However, there is no observational evidence whatsoever of the expansion of the space. The observed recession of the galaxies away from each other and the expansion and consequent cooling of the radiation produced during the big-bang as evinced by its relic, CMBR, have been misconstrued as the evidences of the expansion of the space also. Actually, they are only evidences of the expansion of the matter and the radiation respectively in the universe. They are not at all the evidences of the expansion of the space. This is obvious from the following analogy also. When a gas expands, the separation, i.e., the distance between each and every pair of molecules in the gas increases. Thus, the increase in the distance between each and every pair of molecules in the gas implies only that the gas is expanding, i.e., it is gradually occupying more and more space. It in no way implies that the space in which the gas is embedded is also expanding with the gas. So, how can the gradual increase in the distance between each and every pair of galaxies in the universe with the passage of time, i.e., the recession galaxies away from each other, be construed to be the evidence of the expansion of the space in which they are embedded.? It certainly cannot be.

Actually, the purported expansion of the space has been unwittingly assumed while postulating that the space-time of the universe is Riemannian and as such the line element $ds$, i.e., the “distance” between two neighboring points $(x^0, x^1, x^2, x^3)$ and $(x^0, x^1, x^2, x^3)$ in the space-time is given by the metric

$$
 ds^2 = g_{\mu\nu}dx^\mu dx^\nu 
$$  \hspace{1cm} (1)\hspace{1cm}

where $\mu, \nu$ take on the values 0,1,2,3 and the summation over repeated indices is implied. In eq.(1) the metric tensors $g_{\mu\nu}$ are functions of time co-ordinate $x^0 = ct$ also apart from that of the spatial co-ordinates $x^1, x^2, x^3$. This implies that not only $ds$ but also the spatial separation $dl$ between each and every pair of spatial points in the universe is a function of time and consequently changes with time, it cannot remain constant thereby implying expansion or contraction of the space. This is more obvious on perusal of the spatial parts of the metrics of various relativistic cosmological models of the universe (Thakur 2009). Consequently, no solution of Einstein’s field equations

$$
 R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} = -\kappa T_{\mu\nu} 
$$ \hspace{1cm} (2)\hspace{1cm}

can be static; every solution will be a function of time. It is surprising how this point escaped the genius of Einstein who was dismayed on obtaining non-static solution of eqs.(2) when he used them to solve the “cosmological problem”. At that time Einstein believed that the universe was static. Therefore, in order to obtain a static solution Einstein modified his eqs.(2) to

$$
 R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} + \lambda g_{\mu\nu} = -\kappa T_{\mu\nu} 
$$ \hspace{1cm} (3)\hspace{1cm}

The term $\lambda g_{\mu\nu}$ in eq.(3) is called “cosmological term” and the constant $\lambda$ is called “cosmological constant”; it has dimension $L^{-2}$.

That the expansion of space is an inherent feature of Riemannian geometry is further evident from de Sitter’s solution of eqs.(3) for an empty space (i.e. for $T_{\mu\nu} = 0$) which has nothing to do with the universe in which we live. This solution, known as the de Sitter Universe, is not static. The de Sitter universe expands though it is empty! Obviously, the space expands in the de Sitter universe, neither matter nor radiation, because it is empty. Two pertinent questions in this connection are;

1. What triggers off the expansion of the de Sitter universe, i.e., of the empty space?
2. What maintains the continual expansion of the de Sitter universe, i.e., of the empty space?

The only possible answer to these questions is: The assumed Riemannian geometry of the space-time! For,
their is as yet no known physical process that can trigger off and maintain the continual expansion of an empty space.

The de Sitter universe reveals another flaw in the conceptual foundations of the GTR. For, according to the GTR, the curvature in space-time is produced by the gravitational field; however, the space-time of the de Sitter universe is curved (though the de Sitter universe is spatially flat) despite the fact that there is no gravitational field in it since it is empty; existence of gravitational field requires presence of matter somewhere.

Even in the Friedmann models of the universe expansion of the empty universe, i.e., of the space is inherent. This is obvious from the following dynamical equation governing the Friedmann models of the universe [Weinberg 1972a):

\[ \dot{R}^2(t) + k = \frac{8\pi G}{3} \rho(t)R^2t \]  \hspace{1cm} (4)

where \( R(t) \) is the scale factor of the universe (not the scalar curvature \( R \) occurring in equs. \( \text{(2)} \) and \( \text{(3)} \) above), \( \rho \) the density of matter and radiation in the universe, and \( k = 0, +1, -1 \) according as the space-time of the universe is spatially flat, positively curved, or negatively curved respectively. From eq. \( \text{(4)} \) we see that in the limiting case of \( \rho(t) = 0 \)

\[ \dot{R}^2 = -k \]  \hspace{1cm} (5)

This implies that even in the absence of matter and radiation \( \dot{R}(t) \neq 0 \) when \( k \neq 0 \). When \( k = -1 \), \( \dot{R}^2(t) = 1 \) and hence \( \dot{R}(t) = \pm 1 \), which means the empty universe, i.e., the space either expands or contracts. However, for \( k = +1 \), the expansion of the empty universe is imaginary. For \( k = 0 \), \( \dot{R}(t) = 0 \), i.e., the empty universe neither expands nor contracts. In other words, when \( k = 0 \), the space neither expands nor contracts, an inference which is quite realistic since there is no observational evidence of the expansion or contraction of the space. This fact may be used as an argument in favour of the flat model of the universe by the relativistic cosmologists.

From the foregoing considerations it is evident that the purported expansion of the space is a built-in feature of the relativistic cosmology and may be far from the reality, in all probability, the space is not at all expanding. Consequently, none of the relativistic cosmological models of the universe in general, and standard cosmology in particular, should be held sacrosanct. Moreover, it may be noted that the problems of singularity, horizon, and flatness with which the relativistic cosmological models, except the steady state model and its variants, are plagued stem from the assumption that the geometry of the space-time of the universe is Riemnnian.

However, we are so much enamoured of the elegance of the Riemnnian geometry and the mathematical formulation of the relativistic cosmology based on it that we are not prepared to consider any alternative approach to cosmology. Attempts are being made to geometrize even the whole of physics. ‘At one time it was even hoped that the rest of physics could be brought into a geometric formulation, but this hope has met with disappointment, and the geometric interpretation of the theory of gravitation has dwindled to a mere analogy, which lingers in our language in terms like “metric”, “affine connection”, and “curvature”, but is not otherwise very useful. The important thing is to be able to make predictions about images on the astronomers’ photographic plates, frequencies of spectral lines, and so on, and it simply doesn’t matter whether we ascribe this predictions to the physical effect of gravitational fields on the motion of planets and photons or to a curvature of space and time, (The reader should be warned that these views are heterodox and would meet with objections from many general relativists.)’ [Weinberg 1972a].

Of late, with a view to resolving some of the problems with which the standard cosmology is plagued, Cyclic models of the universe [Steinhardt & Turok 2001a,b, 2004; Frampton 2006; Baum & Frampton 2007a,b] and Loop quantum cosmology [Bojowald 2001, 2003, 2007; Ashtekar et al 1998, 2001, 2003, 2007] have been ingeniously invented. However, they are based on dubious assumptions. Moreover, so far none of the predictions of these models has been observationally validated. But they certainly testify to the mathematical ingenuity of their innovators. However, all these models have their roots in geometry rather than in physics. Some of these models are based on spaces of more than 4 dimensions. But they do not give the physical significance of the higher dimensions, i.e., they do not spell out what physical entity these higher dimensions represent. Some are based on string theory which has not yet been validated experimentally. Despite their mathematical elegance Cyclic models and Loop quantum cosmology appear to be quite far-fetched.

However, the cause of the big-bang and inflation cannot be explored through geometry, it can be explored only through physics. In this connection it may be noted that subtle hints as to the origin of the big-bang and inflation are provided by the ongoing experiments at CERN, the European Organization for Nuclear Research, at Geneva and at RHIC, the Relativistic Heavy Ion Collider, at Brookhaven National Laboratory (BNL) in Upton, New York. The cause of the big-bang and inflation suggested here is based on the hints
provided by the experimental findings at CERN and RHIC as well as on the well-established laws of physics. The model of the universe used is Newtonian, i.e., non-relativistic, oscillatory model in which the space does not expand.

2 Fundamental Constituents of Matter

Matter is composed of hadrons and leptons. Hadrons are either bosons or fermions having strong interactions as well as electroweak interactions whereas leptons are fermions which do not have strong interactions; they have only electroweak interactions. Leptons are fermions which do not have strong interactions as well as electroweak interactions whereas leptons are point-like objects having radii not greater than $10^{-16}$ cm (Barber et al. 1979). However, hadrons have finite radius, e.g., the radius of a proton is about $10^{-13}$ cm (Hofstadter & Mc Allister 1955). Whereas leptons are fundamental particles, hadrons are not; they are composite particles; they are composed of quarks ($q$) and anti-quarks ($\bar{q}$). Hadrons are classified into two categories, viz., mesons and baryons. Mesons are bosons having baryon number zero whereas baryons are fermions having baryon number different from zero.

Quarks are fermions and have spin $\frac{1}{2}$; they occur in six flavours; viz., $u$ (up, mass $m = 1.5$ to $3.0$ MeV, charge $q = \frac{2}{3}e$), $d$ (down, mass $m = 3$ to $7$ MeV, charge $q = -\frac{1}{3}e$), $s$ (strange, mass $m = 95$ ± $25$ MeV, charge $q = -\frac{1}{3}e$), $c$ (charm, mass $m = 1.25$ ± $0.09$ GeV, charge $q = \frac{2}{3}e$), $b$ (bottom, mass $m = 4.20$ ± $0.07$ GeV, charge $q = -\frac{1}{3}e$), $t$ (top, mass $m = 174.2$ ± $3.3$ GeV, charge $q = 0$).

Existence of quarks of all the six flavours has been established experimentally beyond any shade of doubt. Each quark ($q$) has a corresponding anti-quark ($\bar{q}$). Moreover, each flavour of quarks occurs in three primary colours, red, green, and blue. It may be noted, however, that colours, red, green, and blue of quarks, and anti-red, anti-green, and anti-blue of anti-quarks have nothing to do with the actual visual colours; they are merely labels for describing the additional internal degree of freedom of quarks.

Baryons are composed of three quarks ($qqq$) and anti-baryons of three anti-quarks ($\bar{q}\bar{q}\bar{q}$) whereas mesons are composed of a quark $q$ and an anti-quark $\bar{q}$ ($q$ and $\bar{q}$ need not be of the same flavour). For example, a proton is composed of two up and one down quark ($p : uud$), neutron of one up and two down quarks ($n : udd$), pion $\pi^+$ of $u$ and $d$ ($\pi^+ : ud\bar{d}$), and $\pi^-$ of $d$ and $\bar{u}$ ($\pi^- : d\bar{u}$).

Hadrons are colourless, i.e., white. White means all the three primary colours are equally mixed. This means each baryon contains quarks of all the three colours, whereas a mesons contains a quark of a given colour and an anti-quark of the corresponding anti-colour so that each combination is over all white.

3 Quantum Chromodynamics

The concept of colour first introduced by Greenberg (1964) to account for the apparent violation of the spin-statistics theorem in case of $\Delta^+$ and $\Omega^-$ resonances plays a fundamental role in accounting for the interaction between quarks. The remarkable success of quantum electrodynamics (QED) in explaining the interaction between electric charges to an extremely high degree of precision motivated physicists to explore a similar theory for strong interactions. The result is quantum chromodynamics (QCD), a non-Abelian gauge theory (Yang-Mills theory) which closely parallels QED.

Drawing analogy from electrodynamics, Nambu (1960) postulated that the three quark colours are the charges (the Yang-Mills charges) responsible for the inter-quark force just as the electric charge is responsible for the electromagnetic force between charged particles. The analogue of the rule that like charges repel and unlike charges attract each other is the rule that like colours repel, and colour and anti-colour attract each other. Apart from this, there is another rule in QCD, which states that different colours attract if the quantum state is antisymmetric and repel if the quantum state is symmetric under exchange of quarks.

Since colours serve as the Yang-Mills charges, each quark flavour transforms as a triplet of $SU_c(3)$ group that causes transitions between quarks of the same flavour but different colours. However, the $SU_c(3)$ Yang-Mills theory requires the introduction of eight new spin 1 gauge bosons called gluons. Gluons carry colour and as such they strongly interact with each other. Moreover, gluons couple to the left-handed and right-handed quarks in the same manner since the strong interactions do not violate the law of conservation of parity.

Just as the electromagnetic force between electric charges arises due to the exchange of photons, a massless vector (spin 1) boson, the force between coloured quarks arises due to the exchange of gluons. However, there is a striking difference between QED and QCD. Whereas the force between electric charges decreases with increasing distance, the force between quarks increases with increasing distance. This phenomenon leads to two important features of QCD, viz., asymptotic freedom (Gross & Wilczek 1973a, Politzer 1973) and infrared slavery (Alabiso & Schierholz 1976, Chaichian et al. 1981). Asymptotic freedom means that inter-quark
force fades away as two quarks approach each other infinitely closely. Infrared slavery of quarks is responsible for the confinement of quarks in hadrons, and for their being elusive. It has been suggested that the attractive force between two quarks increases with increasing separation at the rate of $1 GeV$ per fermi.

According to QCD at extremely high temperature and/or density, the hadronic matter undergoes a phase transition; from the normal hadronic phase it goes over to the quark-gluon plasma (QGP) phase. This phase consists of (almost) free quarks and gluons. The transition temperature for this phase transition was first predicted by the lattice gauge theory of QCD to be $\sim 2 \times 10^{12} K; (1.90 \pm 0.02) \times 10^{12} K$ according to the more exact calculations. This transition temperature is approximately equal to $175 MeV$ corresponding to an energy density of a little less than $1 GeV/fm^3$.

4 Findings at CERN and RHIC

The notion of QGP is not just a figment of imagination. Efforts have been afoot at CERN and RHIC for quite some time to create QGP in the laboratory. Pioneering attempts to create QGP were first made at CERN’s Super Proton Synchrotron (SSP) in 1980’s and 1990’s. In 1994 the lead beam programme was started at CERN. A beam of $337 eV$ (equivalent to $160 GeV$ per nucleon) lead ions from the SSP was used in the programme. In the programme seven groups of scientists,viz., NA44, NA45/CERES, NA49, NA50, NA52/NEWMASS, WA97/NA57 and WA98 collaborated and measured different aspects of lead-lead and lead-gold collision events. A report released by CERN on Feb. 10, 2000 said that by smashing together lead ions at CERN’s accelerator at temperatures 100,000 times as hot as sun’s centre ( i.e., at $T \sim 10^{12} K$), and energy densities never before reached in laboratory experiments, a team of 350 scientists from institutes in 20 countries succeeded in isolating tiny components called quarks from more complex particles such as protons and neutrons.

"A series of experiments using CERN’s lead beam have presented compelling evidence for the existence of a new state of matter 20 times denser than nuclear matter, in which quarks instead of being bound up into more complex particles such as protons and neutrons, are liberated to roam freely", the report said.

Presenting "Evidence for a new state of Matter : An Assessment of the Results from the CERN Lead Beam Programme" (Heinz & Jacob 2000) said "A common assessment of the collected data lead us to conclude that we now have compelling evidence that a new state of matter has indeed been created, at energy densities which had never been reached over appreciable volumes in laboratory experiments before and which exceed by more than a factor 20 that of normal nuclear matter. The new state of matter found in heavy ion collisions at the SSP features many of the characteristics of the theoretically predicted quark-gluon plasma”.

When two large nuclei, e.g., that of lead or gold, are accelerated to ultrarelativistic speeds and slammed into each other, they largely pass through each other. However, after the collision a hot volume, called “fireball”, is created. This fireball is in a state of tremendous expansion, with expansion velocities exceeding half the speed of light, and very close to local thermal equilibrium at a temperature of about $100 - 120 MeV$. This characteristic feature gave rise to the name “Little Bang”. The observed explosion calls for a strong pressure in earlier collision stages” (Heinz & Jacob 2000).

The programme of creating QGP at RHIC began in summer of 2000. On June 18, 2003 a special scientific colloquium was held at the BNL to discuss the latest findings at RHIC. At the colloquium it was announced that in the detector system STAR (Solenoidal Tracker AT RHIC) head-on collision between two beams of gold nuclei of energies $130 GeV$ per nucleon resulted in the phenomenon called "jet quenching". STAR as well as three other detector experiments at RHIC, viz., PHENIX, BRAHM, and PHOBOS, detected suppression of "leading particles", highly energetic individual particles that emerge from the nuclear fireballs in gold-gold collisions. Jet quenching and leading particle suppression are signs of QGP formation. The findings of the STAR experiment were presented at the BNL colloquium by Berkeley Laboratory’s NSD (Nuclear Science Division) physicist Peter Jacobs. It was also reported by Aronson & Ludlam (2005) in April 2005. Subsequently, at the April 18, 2005 meeting of the American Physical Society at Tampa, Florida the four collaborations, viz., STAR, PHENIX, PHOBOS, and BRAHMS presented the evaluation of their experimental findings, which were later published in Nuclear Physics A757 (STAR Collaboration : Adams et al. 2005), PHENIX Collaboration : Adcox et al. (2005); PHOBOS Collaboration : Back et al. (2005); BRAHMS Collaboration : Arsene et al. (2005).

The new experiments, ALICE, ATLAS, and CMS running on CERN’s Large Hadron Collider (LHC) are continuing the study of the properties of the QGP.

5 The cause of the Big-Bang and Inflation

The standard cosmology posits that some times in the remote past, labelled as $t = 0$, a gigantic explosion,
the so called big-bang, occurred as a result of which the universe was heated to an enormously high temperature. However, it does not answer the intriguing question: What caused the big-bang? Or, what physical process heated the universe to an enormously high temperature?

Attempt is being made here to suggest the cause of the big-bang and the inflation on the basis of the experimental findings at CERN and RHIC within the framework of a singularity free Newtonian, i.e., the non-relativistic, oscillatory model of the universe in which the space does not expand. According to the proposed model, prior to the big-bang the entire matter in the universe was gravitationally collapsing continually. Consequently, with the continual collapse of the matter in the universe gravitational energy was released continually which heated the matter and raised its temperature continually and thereby increased the energy of the particles comprising the matter in the universe continually. Moreover, with the continual collapse of the matter in the universe the density of the matter in the universe also increased continually with consequent rise in energy density of the matter in the universe.

When the temperature of the matter in universe reached the transition temperature $T \sim 2 \times 10^{12}K$, which amounts to an energy of $\sim 175 MeV$ per particle and corresponds to an energy density of a little less than $1 GeV/fm^3$, the entire hadronic matter in the universe underwent a phase transition, from the hadronic phase it passed over to the QGP phase, which consisted of the asymptotically free quarks: $u,d,s,c,b,t$ and gluons. Thus, when the temperature of the collapsing matter in the universe $T \geq 2 \times 10^{12}K$, the entire matter in universe was in the form of QGP permeated by leptons, i.e., it consisted of spin $\frac{1}{2}$ quarks $u,d,s,c,b,t$ which interacted through the colour force generated by the gluons as well as through the electroweak force, and spin $\frac{1}{2}$ leptons, $e, \mu, \tau$ and their neutrons $\nu_e, \nu_\mu, \nu_\tau$ which interacted through the electroweak force only. In this way, bulk of the gravitational energy released during the gravitational collapse of the matter in the universe was utilized in deconfinement of quarks from hadrons, i.e., in disintegrating the hadrons into quarks and gluons. In other words, the gravitational energy released during the collapse liberated the quarks from the infrared slavery and delivered them asymptotic freedom. As the matter collapsed further the additional gravitational energy released during the collapse was utilized in heating the QGP permeated by leptons, i.e., in energizing the quarks and leptons in the universe. Thus, the gravitational energy released during the collapse was locked in the QGP permeated by leptons.

However, the collapse of the universe to a singularity, i.e., to a point in the 3-space (i.e., in the space) was averted; it was inhibited by Pauli’s exclusion principle. The universe could not collapse to a point otherwise all the fermions, viz., quarks and leptons, of each and every species (i.e., flavour) would have been crammed into that point which could be occupied, according to Pauli’s exclusion principle, by at most only two fermions of any species, one with, say, spin “up” and the other with spin “down”. In other words, had the universe collapsed to a singularity, Pauli’s exclusion principle would have been violated. However, Pauli’s exclusion principle is inviolable and as such the universe could not collapse to a singularity. Besides, had the entire matter in the universe collapsed to a singularity, i.e., to a point in the 3-space, the uncertainty in each component of each and every particle of the matter in the universe would have been zero. Consequently, according to Heisenberg’s Uncertainty principle, the uncertainty in the corresponding component of the momentum of each and every particle in the universe would have been infinite. This would have resulted in each and every particle of universe having infinite momentum and infinite energy. This can also be seen by the fact that had the entire matter in the universe collapsed to a singularity, the inter-particle separation $s$ between each and every pair of particles in the universe would have been zero. As the de Broglie wavelength $\lambda$ of any particle in the universe would be less than or at most equal to $s$, $\lambda = \frac{h}{p} \leq s$, where $h$ is Planck’s constant and $p$ the magnitude of the momentum of the particle. Consequently, when $s \rightarrow 0, p \rightarrow \infty$ and with it the energy of the particle $E \rightarrow \infty$. As particles of infinite energy and momentum cannot remain frozen at a point, i.e., stay put at a point forever, the collapse of the entire matter in the universe to a singularity could not occur on this count also.

Incidently, it may be pointed out that the singularity theorems of Penrose, Hawking, and Geroch do not tell what happens eventually to a gravitationally collapsing massive object, e.g., the universe, or a black-hole, after it collapses to a singularity. However, it is implicit in their theorems, that after collapse to a singularity the object stays put at the singularity forever. But can it? The above considerations show that if at all a massive object collapses to a singularity, it cannot stay put there forever, otherwise there would not have been the big-bang and we would not have been around today. However, if the singularity theorems of Penrose, Hawking, and Geroch are valid, then the pertinent question is: What happens eventually to a massive object after it collapses to a singularity? Has the GTR any answer to this question?

The snag is that while arriving at the singularity theorems the general relativists had all along given cognizance to gravitational interaction only, they ignored
the other interactions, especially the strong interaction, viz., the QCD, regarding them as negligible in comparison to the gravitational interaction. But the fact is that at ultra-high energies and ultra-high densities the QCD rules the roost, not the gravitation as is obvious from the fact that the coupling constant of the strong nuclear interaction is many orders of magnitude larger than that of the gravitational interaction. This is also obvious from the experimental findings at CERN and RHIC. Moreover, while arriving at the singularity theorems they all along treated the matter in the gravitationally collapsing object as a classical fluid, they completely ignored its microscopic structure and its quantum mechanical behaviour which have far reaching consequences at ultra-high energies and ultra-high densities. Furthermore, the GTR has been validated experimentally only in the weak field limit, it has not yet been validated experimentally in the domain of strong gravitational fields.

If the gravitationally collapsing matter in the universe could not eventually collapse to a singularity, then another intriguing question is : What happened to it in the final stages of the collapse? Hints as to the answer to this question is provided by the experimental findings at CERN and RHIC given in Section 4 above. The answer is the following:

In the final stages of the collapse innumerable collisions between the ultra-high energy nuclei in the ultradense matter in the universe occurred and at each and every collision point a fireball was created after the collision which presumably contained the QGP. Thus in the final stages of the collapse innumerable fireballs were created. These fireball were in a state of tremendous explosion and consequently each and every one of them exploded with a ”Little Bang” . The cumulative effect of the innumerable ”Little bangs” so produced was the ”Big-Bang”. And, after the explosion, each and every fireball expanded with speeds exceeding half the speed of light in vacuum resulting in the inflationary expansion of the matter in the universe, i.e., the inflation.

Subsequently, with the expansion of the fireballs inter-quark separation between quarks increased and with it the attractive force between them also increased so much so that eventually all the quarks lost their asymptotic freedom and were subjected to infrared slavery resulting in their enslavement, i.e., their confinement, in hadrons. In this way all the quarks in the QGP were hadronized. As a result of this hadronization of all the quarks in the universe tremendous amount of energy was released which was earlier locked in the QGP before the big-bang.

6 Discussion

In the oscillatory model of the universe the big-bang is preceded by the contracting phase of the matter in the universe, and after the big-bang the matter in the universe expands continually again, but its velocity of expansion is continually decelerated due to the opposing gravitational force. Eventually, the expansion comes to a halt and thereafter the matter in the universe starts contracting continually again due to the self-gravitation up to a certain minimum volume to be followed by another big-bang and expansion. The sequence of contraction, big-bang, expansion, contraction, big-bang —— is repeated ad infinitum. However, in the model proposed here singularity never occurs, the matter in the universe never collapses to a singularity. Moreover, the space neither expands nor contracts, only the matter in the universe undergoes oscillations with successive phases of contraction and expansion occurring perpetually.

The detractors of the oscillatory model of the universe have the objection that it would violate the second law of thermodynamics according to which entropy only increases, it does not decrease, in any process and as such the entropy of the universe would build up from oscillation to oscillation resulting, eventually, in the ”heat death ” of the universe. However, this objection is not valid. By definition, the universe is a closed system, there is nothing outside the universe. The cycle of contraction and expansion of the matter in the universe is an adiabatic process since heat neither enters the system from outside nor leaves the system. Moreover, it is a reversible processes. Thus, the sequence of contraction, big-bang, expansion, contraction, big-bang ..... of the matter in the universe is a reversible adiabatic process and in any reversible adiabatic process the entropy remains constant, it increases only in irreversible processes (Saha & Srivastava [1950]). Consequently, the contention that entropy of the universe would build up from oscillation to oscillation in the oscillatory model of the universe is not at all correct; oscillatory model of the universe would not violate the second law of the thermodynamics.

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