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Never there would have been a cosmic big-bang without the action of a vacuum pressure!

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Abstract
The fundamental and always resurrecting question of mankind, how this universe could ever have started its existence, is answered by most cosmologists with the standard dogmatic answer: By the Big-Bang! - that initial explosion of the world matter system! Perhaps this standard paradigm of a general and global explosion creating the world, especially in these days of wars and weapons all around, seems to be highly suggestive. Nevertheless such an event unexpectedly turns out to be extremely hard to explain as based on purely physical grounds. It indeed seems easy to imagine a granate explosion causing matter to fly apart in all directions, but it is extremely hard to explain which pressures might be responsible to drive the initially highly compacted cosmic matter apart of eachother. If the explosion forces are imagined as due to pressure forces then these pressures cannot be due to extremely high temperatures of matter, because relativistically hot matter will be just an additional source of gravity, hence just impeding matter to fly apart. As we shall show in the following article the explosive BB- event can only physically be explained, if the necessary pressure is not manifested by the gravitating matter, but by the cosmic vacuum. In fact without the cosmic vacuuum pressure, the so-called Big-Bang never could have happened. Vacuum pressure, however, up to the present days of cosmology, still is a fully speculative subject, but it will become evident in the following article, that without this highly speculative quantity there could not have happened a Big-Bang at all.

1. Introduction

At a first view one may agree upon the so-called cosmic Big-Bang - certainly being a highly suggestive cosmologic paradigm. We all belong to that generation of mankind who has seen photos of a nuclear bomb explosion, and such an event easily can support the suggestion that, similar to such a bomb, once upon a past time the highly concentrated, whole matter content of the universe could have exploded at once as a global act in the past. While this aspect appears highly suggestive in a first view, for the present times, however, equipped with the theory of matter and relativity, it nevertheless becomes extremely hard to explain this explosive event on a physical basis, as we shall demonstrate further down here. Of course, one may assume that at the initial event matter was created at an incredibly high density and temperature driving with the inherent incredibly high pressure this matter apart into all directions, more or less opening up thereby the well known big global Hubble expansion still seen in the present universe.

But astonishingly enough just the initial explosive event is the genuine physical secret and mystery, since relativistic material pressure namely not only acts explosively, but also does effectively gravitate, and hence just does impede an explosion. This problem as we shall show here might have an astonishing solution: The initial explosion only could happen by a pressure of an unusual type - that is not connected with hot matter, but with a pressurized, cosmic vacuum.

2. A critical look onto the standard cosmological Big-Bang Paradigm

The standard cosmologic paradigm starts from the assumption that the origin of the universe consists in the initial event of the cosmic Big-Bang. The general belief hereby is that about 13.7 Gigayears ahead of our present time an initial explosive matter event happened from which all cosmic structures and all cosmic dynamics ultimately emerged.

This cosmic genesis up to now is naively well believed up to the present epoch and astonishingly has not been critically questioned till now, though this standard answer is not at all satisfying in itself, as we shall show further below. Well: The so-called Big-Bang may have presented the prime physical condition for the cosmic matter to explosively fly apart. It thereby may also have initiated the early Hubble expansion of the universe. But should one not ask for the responsible physical terms and forces which must have caused this initial explosion to happen? Matter, when it is assumed to be highly condensed at this BB-begin, evidently organizes a strong gravitational field which effectively opposes the explosive fly-off of cosmic matter. One evidently needs in addition an overcompensating "antigravitational", explosive force, similar to the pressure manifested at a granate explosion.

As such a requested force physicists immediately will identify pressure forces in this cosmic game. - The Big-Bang-matter not only is infinitely dense and hot, it also, being such hot, evidently is highly pressurized. And hence this at first makes it evident that this necessarily may create an explosive scenario! - This, however, unfortunately and astonishingly enough, is simply not true, because the pressure connected with the relativistic Big-Bang matter also contributes to strengthen the internal gravitational field, due to the presence of countable proportions of equivalent relativistic masses, as it is well descibed by the theory of general relativity.

This has to be concluded, because energy in all its mass-equivalent forms, evidently including kinetic energy, acts as source of gravity. And the relativistic thermal kinetic energy of the Big-Bang matter can not at all be neglected relative to its rest mass energy. If, however, the mass energy $\varepsilon_M = \varrho_M \bullet c^2$, seen from its order of magnitude, competes with the energy equivalent of the material pressure p_M, then immediately its pressure-induced effects are showing up in the field-relevant energy-momentum tensor Π_{ik} of the GR-field equations. When we first give them here without taking into account vacuum energy Λ, then these equations are given in the form [1]:

$$\Psi_{ik} - \frac{\Psi \bullet g_{ik}}{2} = 8\pi G \bullet \frac{\Pi_{ik}}{c^4}$$

where ψ_{ik} denotes the Riemannian curvature tensor, ψ is the curvature scalar, g_{ik} is the metric tensor, Π_{ik} is the energy-momentum tensor, and G is Newton's constant of gravitation.

The specific action of the thermal material pressure p_M becomes more evident, when one procedes from the above tensor equations to the Friedmann-Lemaître differential equations given in the form [2,3]:

$$(\dot{R}/R)^2 = \frac{8\pi G}{3}\varrho_M(t) - \frac{kc^2}{3}$$

and :

$$\frac{\ddot{R}}{R} = -\frac{4\pi G}{3}[\varrho_M(t) + \frac{3p_M(t)}{c^2}]$$

where $R = R(t)$ is the time-dependent spatial scale of the homogeneous Robertson-Walker universe [4,5], ϱ_M and p_M denote mass density and pressure of the cosmic matter, k is the curvature parameter which in this approach can only attain values of $k = +1$, $k = 0$, $k = -1$.

In the second of these above differential equations one immediately recognizes that the material pressure $p_M(t)$, as also the material density, both do contribute in the same sense to the acting gravitational field, namely to decelerate the scale expansion, and with $\ddot{R} < 0$ determine a collapsing!,- rather than an explosively expanding universe, if no other cosmic forces in addition had to be taken into account. How then under such cosmic conditions the early universe can at all have exploded? This according to present-day views is only possible, if in addition to the upper material pressure $p_M(t)$ an additional cosmic pressure $\tilde{p}(t)$ becomes active which is not of thermodynamic nature and thus is not coupled to matter, but is of an unusual, different ,i.e. "immaterial" form, such that it does not simultaneously contribute to gravity.

Such an unusual pressure $\tilde{p}(t)$ could perhaps be connected with cosmic vacuum energy which anyway nowadays is sincereously discussed in cosmology. The first who introduced vacuum energy, however, a pressure-less vacuum energy into the theory of cosmology was Einstein (1917) with his cosmologic constant Λ which helped at least for the value $\Lambda = -8\pi G\varrho/c^2$ to enable a static Euclidean (uncurved $k = 0$!) universe that Einstein was looking for [6]. Later then Friedman introduced this term [2,3], given by the cosmologic constant Λ, into the field equations, and with the use of the so-called Robertson-Walker geometry [4,5], then obtained the following set of equations:

$$\text{(F1)} \quad (\dot{R}/R)^2 + c^2k/R^2 - c^2\Lambda/3 = \frac{8\pi G\varrho}{3}$$

and :

$$\text{(F2)} \quad 2\ddot{R}/R + (\dot{R}/R)^2 + c^2k/R^2 - c^2\Lambda = -\frac{8\pi G}{c^2} \bullet (p + \tilde{p})$$

When one now only is interested in the uncurved Euklidean universe with $k = 0$!, then one obtains the following two differential equations:

$$\text{(F1)} \quad (\dot{R}/R)^2 = \frac{c^2\Lambda + 8\pi G\varrho}{3}$$

and :

$$\text{(F2)} \quad 2\ddot{R}/R + (\dot{R}/R)^2 - c^2\Lambda = -\frac{8\pi G}{c^2} \bullet (p + \tilde{p})$$

and replacing now the term $(\dot{R}/R)^2$ in (F2) by (F1) delivers:

$$2\ddot{R}/R + \frac{-2c^2\Lambda + 8\pi G\varrho}{3} = -\frac{8\pi G}{c^2} \cdot (p + \tilde{p})$$

or expressed in the following form:

$$\ddot{R}/R = \frac{c^2\Lambda}{3} - \frac{4\pi G}{c^2}[\frac{1}{3}\varrho c^2 + (p + \tilde{p})]$$

This indicates, however, for the first time here and now, the possibility of getting an explosive Big-Bang event for the case:

$$\frac{c^2\Lambda}{3} > \frac{4\pi G}{c^2}[\frac{1}{3}\varrho c^2 + (p + \tilde{p})]$$

For a further analysis we have to study the unusual form of the vacuum pressure $\tilde{p}$ which is connected with the vacuum energy density ϵ_{vac} and anyway, in these days, is strongly instrumentalized for cosmological purposes, but its physical nature and its relation to other physical quantities, even nowadays, is strongly obscure and under discussion. Nevertheless as has been shown by Fahr [7], vacuum energy density only is a conserved quantity of cosmic spacetime when it is introduced like Einstein did it with $\Lambda = const$, - namely only -, if the proper energy of the comoving space time volume is conserved [6]. This invariance, however, can only be expected when this vacuum proper energy or its energy density does not perform work at the expansion or upon the dynamics of cosmic space time. If to the contrary such a work is in fact performed by the vacuum energy, then as an unavoidable thermodynamical consequence it can not be constant!

This is because in that case the thermodynamic relations between the cosmic vacuum energy density ϵ_{vac} and the associated vacuum pressure $\tilde{p} = p_{vac}$ do require that the following thermodynamical relation be fulfilled:

$$\frac{d}{dR}(\epsilon_{vac}R^3) = -p_{vac}\frac{d}{dR}R^3$$

This relation can mathematically only be satisfied, when the following functional relation between these two quantities holds:

$$p_{vac} = -\frac{3-\xi}{3}\epsilon_{vac}$$

where ξ is the polytropic vacuum index, i.e. a pure number which for the specific case $\xi = 3$ describes the case of a pressure-less vacuum which in fact Friedman (1924) did consider [3]. In all other cases ξ (_>^<) 3 vacuum energy ϵ_{vac} is associated with a pressurized vacuum and evidently then does unavoidably perform work at the expansion of space.

Under these latter conditions, however, vacuum energy density єvac as shown by the upper equation, can not be constant, which, however, in contrast once was formulated by Einstein (1917) with his $\Lambda = 8\pi G\epsilon_{vac}/c^4 = 8\pi G\varrho_E/c^2 =$ const., where ϱ_E is equivalent of the Einstein´ían mass density stabilizing the universe against a gravitational collapse [6].

Looking back upon the earlier problem raised in this article, that the thermal pressure p_M of relativistic matter can not help to let the Big-Bang matter explode, we therefore for a Big-Bang genesis would need a vacuum with a non-vanishing, positive pressure p_{vac}, i.e.given for the cases $\xi > 3$, with the consequence, however, that this kind of pressure then unavoidably performs thermodynamic work at the expansion of the universe (i.e. with growing scale $R = R(t)$). This unavoidably also would mean that ϵ_{vac} in that case can not be constant, but, also, and even in the interest of a Big-Bang genesis of the universe, has to fall off with the scale R of the universe!

This as such would not be a desastrous solution for a Big-Bang universe. One only has to see the consequence that this result were contrary to what was thought by many cosmologists of these days, especially by Perlmutter et al.(1999), Schmidt et al. (1998), or Riess et al.(1998) - namely that this actual universe, in view of its observed redshift-luminosity relations, can well and best! be explained by a constant vacuum energy density with $\Lambda = 8\pi G\varrho_{vac}/c^2 =$ const according to the idea once created by Einstein [8-10, 6].

But independent of that, let us remind here, that the only essential condition for an "explosive" BB- event is fulfilled, if the following relation holds:

$$\frac{8\pi G\varrho_{vac}}{3} > \frac{4\pi G}{c^2}[\frac{1}{3}\varrho c^2 + (p + p_{vac})]$$

which with $p_{vac} = -\frac{3-\xi}{3}\epsilon_{vac} = \frac{\xi-3}{3}\varrho_{vac}c^2$ leads to the following form of the second Friedman equation F2:

$$\frac{8\pi G\varrho_{vac}}{3} - \frac{4\pi G}{c^2}[\frac{1}{3}\varrho c^2 + (p + \frac{\xi - 3}{3}\varrho_{vac}c^2)]$$

Taking this equation serious, then let us now think positively in favour of the Big-Bang to happen in fact: To have the vacuum pressure dominant at small scales of the universe, i.e. in the young universe $R < R_0$!, and thus to have the Big-Bang happening in this early cosmologic epoch, one needs to have a dominance of the vacuum mass energy density ϱ_{vac} over cosmic mass density ϱ, the relation for instance given in the form:

$$\varrho_{vac}/\varrho = (\varrho_{vac,0}/\varrho_0) \cdot (R_0/R)^{\gamma}$$

with γ denoting a positive number and meaning that the vacuum energy density is given by:

$$\varrho_{vac}(R) = (\varrho_{vac,0}) \cdot (R_0/R)^{3+\gamma}$$

One with this information then could reduce the upper differential equation for scales $R < R_0$ by neglecting the term containing the mass density ϱ into the following simplified form:

$$\ddot{R}/R = \frac{8\pi G\varrho_{vac}}{3} - \frac{4\pi G}{c^2}[\frac{\xi - 3}{3}\varrho_{vac}c^2)] = \frac{4\pi G}{3}\varrho_{vac} \cdot [2 - (\xi - 3)]$$

Taking now for instance from the allowed range of values (i.e.$\xi > 3$!) for instance a polytropic index $\xi = 4$, one would then be led to the following relation:

$$\ddot{R}/R = \frac{4\pi G}{3}\varrho_{vac} \cdot [2 - (\xi - 3)] = \frac{4\pi G}{3}\varrho_{vac} = \frac{4\pi G}{3}\varrho_{vac,0}(R_0/R)^{3+\gamma}$$

or find the Big-Bang acceleration $\ddot{R}$ for the range $R < R_0$ with a positive scale acceleration given by:

$$\ddot{R} = \frac{4\pi G}{3}\varrho_{vac,0}R_0 \cdot (R_0/R)^{4+\gamma}$$

The above equation does not allow to calculate the exact course of the Big-Bang scale explosion due to the missing knowledge on the relevant cosmologic quantities $\varrho_{vac,0}$, ξ, and γ, but it nevertheless allows to prove that under conditions of a pressurized cosmic vacuum the event of a cosmic Big-Bang at least seems physically possible.

3. Conclusions

It thus seems from the above, as if there are only two options to understand the universe as we wish to understand it at these days: Either one accepts a variable vacuum energy density decreasing at ongoing expansion of the cosmic scale $R(t)$, i.e. with increasing scale $R(t)$. This would imply that cosmic vacuum energy density becomes less and less important in the cosmic future, and the well known SN1a-redshift fits presented by Perlmutter et al. (1999), Schmidt et al.(1998), Riess et al. (1998) can not tell us the cosmic truth [8-10]. Or alternatively when one assumes, that cosmic vacuum energy density is a constant quantity, however, with a permanently vanishing pressure, - then one can not explain the explosive Big-Bang event and the ongoing Hubble expansion of the universe due to an evident lack of cosmic pressure! The reader himself may make his own final choice!

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