Quantum and relativistic viewpoints on the origin of the universe and its evolution.

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Abstract

We examine a quantum point of view about the origin of the universe. We propose a simple approach to cosmology based on the Planck mass flow rate. We try to provide a perspective and simple model on the evolution of the universe from Planck time in accordance with the cosmological standard model.

Keywords : origin of universe, Planck time, Planck mass flow rate, evolution of universe, quantum vacuum

Introduction

The theory of quantum mechanics and the theory of general relativity always discuss the initial conditions of the universe and its evolution. Recently, Bruno Valeixo Bento and Stav Zalel in their paper « If time had no beginning », have provided new insights into this issue. We will try to add some simple considerations to this question throught the mass of universe and of its density and to develope this with a simple cosmological model based on the the Hubble time, Planck mass flow rate and a variable coefficient α_H. Finally we examin the grow processus of this model in accordance with the cosmological standard model.

1) **Quantum point of view on the origin of the universe.**

It is remarkable that the energy density of the quantum matter resulting from m_P,

$$mp\, c^2 / l_P^3 = 4{,}63 * 10^{113}\ J/m^3$$

be extremely close to the energy of the quantum vacuum of the quantum field theory :

$$l_P^{-2} \approx 3{,}83 * 10^{69}\ m^{-2}$$

Indeed, with the Planck force, F_P (=c^4/G), and the quantum vacuum energy of the quantum field theory, we obtain this quantum vacuum energy density :

$$Fp\, l_P^{-2} \approx 4{,}63 * 10^{113}\ J/m^3$$

It would thus seem that the matter of the universe seen by the observer, would emerge naturally at its instant t_P, from a fluctuation of the energy of the quantum vacuum and reciprocally in a unit of Planck sphere volume. This could be a quantum solution to the origin of the universe. We would have, in the literal and mathematical sense, a division between the "mass" of the universe and its volume, i.e. the vacuum of the universe, from the Planck time of the observer.

2) **Beginning of a toy cosmological model under ΛCDM model conditions after the recombination,**

It seems possible to obtain the total mass of the universe from the ΛCDM model otherwise. This could eventually lead to the development of a simple toy cosmologic model unknown to the author, built around the Hubble constant , the Hubble time, $t_H = 1 / H$, the Planck mass flow rate and a variable coefficient α_H.

α_H = **radius of the observable universe** (from calculation of the ΛCDM model for example) divided by the **Hubble radius** at time t_H for a flat universe :

$$\alpha_H = \frac{c}{H_0} \int_{a=0}^{a=1} \frac{da}{a^2\sqrt{\Omega_r a^{-4} + \Omega_m a^{-3} + \Omega_k a^{-2} + \Omega_\Lambda}} / \frac{c}{H_0}$$

$$\alpha_H = \int_{a=0}^{a=1} \frac{da}{a^2\sqrt{\Omega_r a^{-4} + \Omega_m a^{-3} + \Omega_k a^{-2} + \Omega_\Lambda}}$$

$\delta = \frac{c^3}{G} = \frac{m_{Pl}}{t_{Pl}}$ is the Planck mass flow rate

t_H = 1/H is the Hubble time ($\approx$ 4,56 10^{17} s = 14,45 billion light years today)

R_H = c / H = c t_H is the Hubble radius

The increase of the total "mass" (=energy) of the universe in the sense of the ΛCDM model is determined by the relation :

$$M_H = \rho_c \, V_H$$

$$M_H = \frac{3}{8\pi G \, t_H^2} \, \frac{4\pi}{3} (c \, t_H \, \alpha_H)^3$$

$$M_H = \frac{1}{2} \, \frac{c^3}{G} \, t_H \, \alpha_H^3$$

$$M_H = \frac{1}{2} \, \frac{m_{Pl}}{t_{Pl}} \, t_H \, \alpha_H^3$$

$$M_H = \frac{1}{2} \, \delta \, t_H \, \alpha_H^3$$

$\alpha_H \approx$ 46.12 billion light years / 14.45 billion light years $\approx$ 3.19 today if H_0 = 67,66 km/s/Mpc, Ω_Λ = 0,6889.

i.e. for H = 67.66 km/s/Mpc and Ω_Λ= 0.6889 :

$$M_H \approx 2{,}99 \; 10^{54} \; kg$$

in other words, the total "mass" of the universe ΛCDM today.

3) **Value of α_H before the recombination in the cosmological toy model and consequences.**

The author hypothesises that, before the recombination, the radius of the observable universe was equal to the Hubble radius. The ratio α_H was then equal to 1.

Thus, the mass of the universe at Planck time would be determined by :

$$M_H = \frac{1}{2}\ \frac{m_{Pl}}{t_{Pl}}\ t_{Pl}$$

$$M_{\text{U at } t_{Pl}} = \frac{1}{2}\ m_{Pl}$$

This can be verified with the thermal energy :

$$E_{Th} = \frac{1}{2}\ m_{Pl}\ c^2 = \frac{1}{2}\ k_B\ T_{Pl}$$

where k_B is the Boltzmann constant with one degree of freedom assumed for the singularity and T_{Pl} the Planck temperature.

At Planck time, and at each subsequent "Planck time grain", the other half of the mass of the universe could be, as proposed in §1, the "quantum vacuum mass" from the Quantum Field Theory... equal to the mass of quantum matter, in a unit Planck sphere volume.

Indeed, the energy density of matter resulting from the mass m_{Pl} is equal to the energy density of the quantum vacuum of the QFT, which can be calculated from the inverse square of the Planck length and *c4/G*. They can therefore have an equal share in the mass of the universe at time t_P. i.e., a Planck sphere volume is composed of half a mass of Planck matter and half a mass of Planck vacuum.

Following the reasoning of figure 2 in "If time had no beginning", of Bruno Valeixo Bento and Stav Zalel , except that we consider that we have our « Planck time grain » insdead an empty set at the begining of set, with each passing unit of Planck time, the corresponding mass is added to the mass of the universe. In our cosmological toy model the "mass" of the universe at the Hubble radius, before and after decoupling, at time t_H, grows simply following the summation :

$$M_{\text{U Hubble at } t_H} = \sum_{1}^{t_H/t_p} \frac{m_{Pl}}{2}$$

i.e.

$$M_{\text{U Hubble at } t_H} = \frac{m_{Pl}}{2}\frac{t_H}{t_{Pl}}$$

$$M_{\text{U Hubble at } t_H} = (1+2+3+4+5+....+t_H) * (\frac{1}{2}\frac{m_{Pl}}{t_{Pl}})$$

$t_H = 1/H$ is the Hubble time. $H_0 \approx 67{,}66$ km/s/Mpc $\approx 4{,}56\ 10^{17}$ seconds today, so $M_{\text{U Hubble}} \approx 9{,}21\ 10^{52}$ kg

Note : … and with datas of §2 ,$M_{\text{U Observable}}$ becames $\approx 3{,}19^3$ $M_{\text{U Hubble}} \approx 2{,}99\ 10^{54}$ kg.

4) **Determination of the mass of the universe at Planck time in the ΛCDM model if it can be apply. ΛCDM**

We assume a flat universe, i.e. with zero curvature. For an observer, whose universe origin is at time t_P , the radius of its observable universe before the recombination in the ΛCDM model is = l_P (= $c\,t_P$), hence its volume V_{Pl} :

$$\frac{4\pi}{3}(l_p)^3 = 1,768\ 10^{-104}\ m^3$$

Its critical density ρ_c expressed in kg/m^3 is at time t_P :

$$\rho_c = \frac{3(Ht_P)^2}{8\pi G} = \frac{3}{8\pi G\ t_p^2} = 6,153\ 10^{95} kg/m^3$$

where $H(t_P)$ is the Hubble constant at Planck time $t_P = 1/H(t_P)$ and G the gravitational constant.

Under these conditions, the mass of the observable universe, at Planck time t_P, is also and of course, exactly 1/2 m_{Pl}. This means that half of the universe is missing. This could be a solution to the problem of the disappearance of antimatter in the formation process of the universe.

Conclusion

We have highlighted a succinct quantum approach to the origin of the universe.

We have tried to lay the foundations of a simple toy cosmology model allowing the calculation of a total "mass" of the universe that exactly matches that of the ΛCDM model at the same time $t_H = 1 / H$. This toy model is characterised by time, creating, at each Planck time of an observer, a specific observable universe, itself probably included in a larger infinite and eternal universe, which could have no beginning and no end, as proposed by Bruno Valeixo Bento and Stav Zalel.

We proposed a determination of the mass of the universe at Planck time in the framework of general relativity in agreement with the quantum density of matter and vacuum [$= 1 / (G\ t_p^2)$ kg/m^3]. Then we proposed a solution to the problem of the disappearance of antimatter in the formation process of the universe.

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