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

Stéphane Wojnow

wojnow.stephane@gmail.com

19 October 2021
revised 10 December 2022

Abstract

The theory of quantum mechanics and the theory of general relativity always discuss the initial conditions of the universe and its evolution. We will try to add some simple considerations to this question throught a simple cosmological alternative model based on the the Hubble time, Planck mass flow rate and a variable coefficient α_H*. We estimate the number of atoms in universe with the Planck mass flow rate and the Hubble time. We also examin the grow processus of this model in accordance with the cosmological standard model for "the total mass of universe" and of its energy density.*

Keywords : cosmology, origin of universe, number of atoms in universe, Hubble constant, Planck mass flow rate, evolution of universe, quantum mechanics, general relativity, critical density, multiverses.

Introduction

The ΛCDM model based on Einstein's theory of general relativity and on observations is today the most satisfactory theoretical proposal to describe the universe. On the other hand, no quantum description of the universe has reached consensus today. It can be noted that the Planck mass flow is both a relativistic quantity (c^3/G) and a quantum quantity (m_{Pl}/t_{Pl}). We will use this quantity associated to the Hubble time to propose an alternative complete theoretical framework, i.e. relativistic and quantum, of the universe. This alternative theoretical framework that follows from the ΛCDM model recovers the estimates of the number of atoms in the universe from the latter model and explains the non conservation of the energy of the universe.

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,

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

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 :

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

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. In both cases, it is the Planck energy density.

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.

3.a) **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.

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 a « Planck time grain », the singularity of the Big bang, 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.

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

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.

3.b) **The Hubble radius of the universe at t_H would be determined by :**

$$R_{\text{U Hubble at } t_H} = \sum_{1}^{t_H/t_p} l_{pl}$$

$$R_{\text{U Hubble at } t_H} = l_{Pl}\frac{t_H}{t_{Pl}}$$

In a flat space time 4D where l = c t and t = l / c , see conclusion and annex, this model allows multiverses starting by "Planck time grains", the singularity in the Big bang theory, of mass 1/2 m_{Pl} which grows over the time continuum with adding a quanta of 1 t_{Pl}. It is in the time interval between 2 quantas t_{Pl} that quantum mechanics operates everywhere and all the time in the universe.

3.c) **Energy density at the Hubble radius in this cosmological toy model.**

We assume, for the Hubble volume Vt_H, a Hubble sphere with radius RU Hubble at radius t_H (t_H : Hubble time = 1 / H, with H Hubble constant):

$$R_{\text{U Hubble at } t_H} = l_{Pl}\frac{t_H}{t_{Pl}}$$

$$\text{V}t_H = 4\pi/3(l_{Pl}\tfrac{t_H}{t_{Pl}})^3$$

In addition we calculated the "total mass" of the universe ($M_{\text{U Hubble}}$ ...) contained in this volume:

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

The volume density ρ_{t_H} being the mass divided by the volume, we obtain :

$$\rho_{t_H} = \frac{m_{Pl}}{2}\frac{t_H}{t_{Pl}}\frac{3}{4\pi l_{Pl}^3}\frac{t_{Pl}^3}{t_H^3}$$

$$\rho_{t_H} = \frac{3}{8\pi\ t_H^2}\frac{m_{Pl}}{l_{Pl}}\ \frac{t_{Pl}^2}{l_{Pl}^2}$$

as $\frac{1}{t_H^2} = H^2$, $\frac{t_{Pl}^2}{l_{Pl}^2} = 1/c^2$ and $\frac{m_{Pl}}{l_{Pl}\ c^2} = \frac{1}{G}$

We have :

$$\rho_{t_H}\ c^2 = \frac{3\ H^2\ c^2}{8\pi G}$$

We obtain with this model, at any time $t_H > 1{,}348\ 10^{15}$ s, the critical energy density of the standard cosmological model for a flat universe.

This is valid, without recourse to cosmic inflation, from Planck time to the Hubble radius of the universe at the time of decoupling in the standard model (42 million light years) but also beyond. This is made possible by writing the "total mass" and the Hubble radius as sigma summations. This also has the consequence of limiting quantum phenomena in the universe to dimensions of the order of Planck units between t_H and t_H+t_{Pl}.

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

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}, and $\rho_c c^2 = 4,63 * 10^{113} J/m^3$, i.e. the Planck energy density that we saw at the beginning of this article.

Discussion and conclusion

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

We can see that Hubble time includes the expansion and acceleration of the expansion of the universe, without explaining it, in this toy model as in the ΛCDM model.

In this alternative model, the mass of the universe at the Hubble radius ($M_{\text{U Hubble at } t_H} = \sum_1^{t_H/t_p} \frac{m_{Pl}}{2}$), appears as a "stacking" of Planck half masses on a Hubble timeline instead of an energy density multiplied by a spherical volume in the ΛCDM model. This stacking of masses is compatible with the observed apparent isotropy and homogeneity of the universe. One may also note that this alternative model perfectly accounts for the passage from half Planck mass at the beginning of the Big bang to the mass of the universe at the chosen time t_H, thus explaining the observed non-conservation of energy in the universe described by the ΛCDM model. Finally we recall that this toy model does not use cosmic inflation.

In a more speculative register, we note that if the hypothesis of Bruno Valeixo Bento and Stav Zalel in their article "If time had no beginning" is correct, we can suppose that multiverses could exist everywhere in a flat and infinite 4D space-time, as proposed in the annex. This at each passing Planck time unit, but also before Planck time. In this model, quantum phenomena occur between t_H and t_H+t_{Pl}.

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

However, this cosmological toy model is so far incomplete : it does not permit to find simply the density parameters of the ΛCDM model.

References :

Bruno Valeixo Bento and Stav Zalel, If time had no beginning, Sept 27, 2021 https://arxiv.org/pdf/2109.11953.pdf

For the value $l_p^{-2} = 3,83 * 10^{69}$ m^{-2} from the Quantum Field Theory,
Lucas Lombriser, université de Genève, communiqué de presse ,
https://www.unige.ch/communication/communiques/2019/cosmologie-une-solution-a-la-pire-prediction-en-physique/

David W. Hogg , Distance measures in cosmology (14) and (15), 2000 December,
https://arxiv.org/pdf/astro-ph/9905116v4.pdf

https://www.dcode.fr/summation-calculator

ANNEX : Expansion of the visible universe.

time = 1/H , It can exist before t_{Pl} or t = 0.

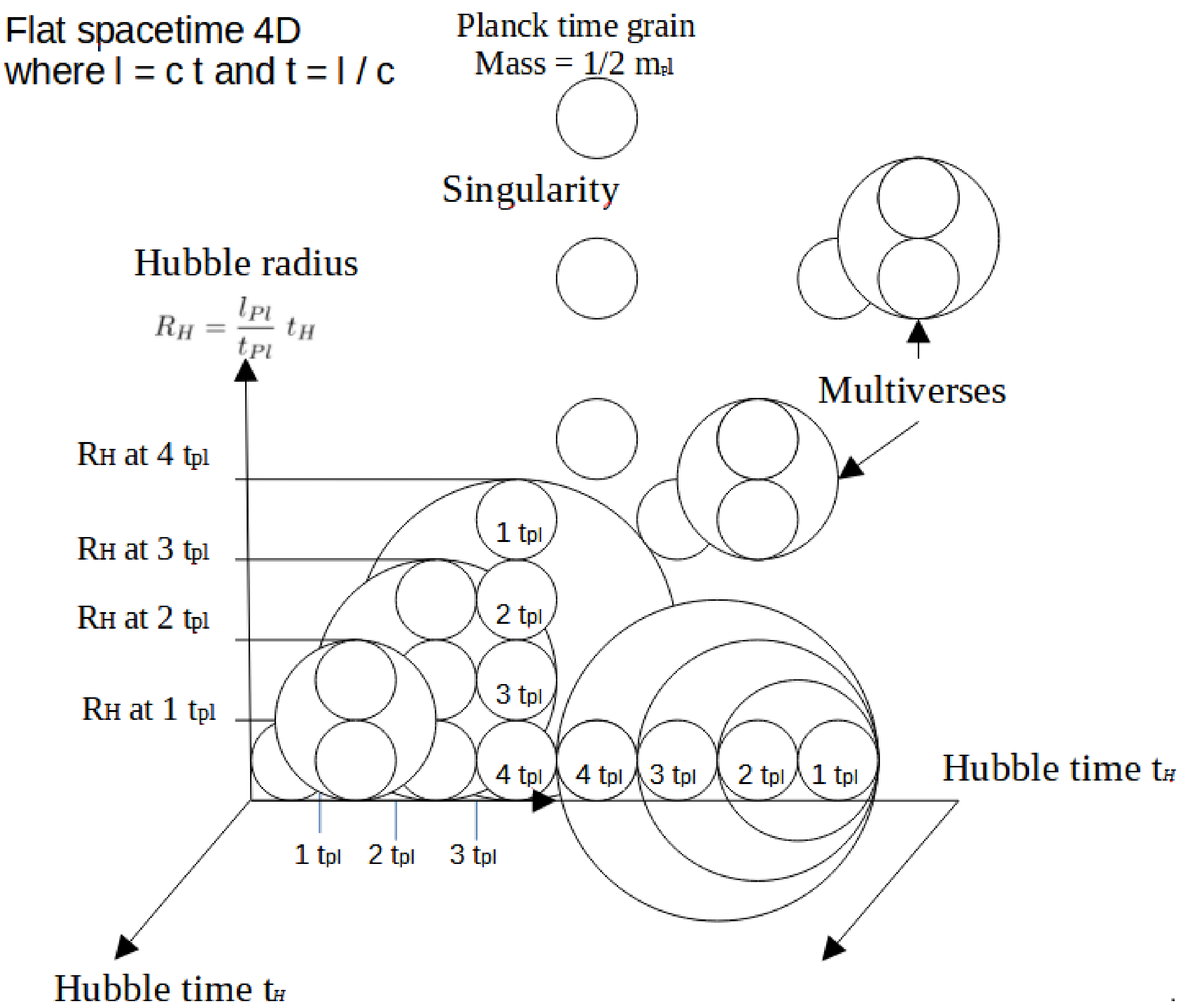

Figure 1: The length and time axes merge to form a flat 4D space.