The Beginning and End of Time in our Universe

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In this paper we show that the origin of *spacetime* precedes the beginning of the material Universe. Thus, the Universe arises at a finite time, which defines the beginning of time itself in our Universe. In addition, it is possible to calculate the maximum scale of time between the *beginning* of the time and the *end* of the time in our Universe.

Key words: Beginning and End of Time, Gravitational Mass, Uncertainty Principle, Big Bang.

The most remarkable discovery of modern cosmology is that the Universe had a beginning, about 15 billion years ago. The Universe begins with a great explosion, the Big Bang. General Relativity predicts that at this time the density of the Universe would have been infinite. It would have been what is called, a *singularity*. At a singularity, all the laws of physics would have broken down. However, if the law of gravity is incomplete, i.e., if it can be repulsive besides attractive then the singularity can be removed. Some years ago I wrote a paper [1] where a correlation between gravitational mass and inertial mass was obtained. In the paper I pointed out that the relationship between gravitational mass, m_g, and *rest* inertial mass, m_{i0}, is given by

$$\chi = \frac{m_g}{m_{i0}} = \left\{1 - 2\left[\sqrt{1 + \left(\frac{\Delta p}{m_{i0}c}\right)^2} - 1\right]\right\} =$$
$$= \left\{1 - 2\left[\sqrt{1 + \left(\frac{Un_r}{m_{i0}c^2}\right)^2} - 1\right]\right\} =$$
$$= \left\{1 - 2\left[\sqrt{1 + \left(\frac{Wn_r}{\rho c^2}\right)^2} - 1\right]\right\} \qquad (1)$$

where Δp is the variation in the particle's *kinetic momentum*; U is the *electromagnetic energy absorbed or emitted by the particle;* n_r is the index of refraction of the particle; W is the density of energy on the particle $\left(J/m^3\right)$; ρ is the matter density $\left(kg/m^3\right)$ and c is the speed of light.

Equation (1) tells us that the gravitational mass m_g can be *negative*. This can occur, for example, in a stage of gravitational contraction of a *neutron star**, when the gravitational masses of the neutrons, in the core of the star, are progressively turned *negative*, as a consequence of the increase of the density of magnetic energy inside the neutrons, $W_n = \frac{1}{2}\mu_0 H_n^2$, reciprocally produced by the *spin* magnetic fields of the own neutrons [2],

$$\vec{H}_n = \left[\vec{M}_n \Big/ 2\pi\left(r_n^2 + r^2\right)^{\frac{3}{2}}\right] = \gamma_n\left[e\vec{S}_n \Big/ 4\pi m_n\left(r_n^2 + r^2\right)^{\frac{3}{2}}\right] \qquad (2)$$

due to the decrease of the distance between the neutrons, during the very strong compression at which they are subjected. In equation (2), $\vec{M}_n$ is the spin magnetic momentum of the neutron; $\gamma_n = -3.8256$ is

* There is a critical mass for the stable configuration of neutron stars. This limit has not been fully defined as yet, but it is known that it is located between 1.8M$_\odot$ and 2.4M$_\odot$. Thus, if the mass of the star exceeds 2.4M$_\odot$, the contraction can continue.

the gyromagnetic factor; $\vec{S}_n$ is the spin angular momentum; r_n is the radius of the neutron and r is the distance between the neutrons.

The *neutron star's* density varies from below 1×10^9 kg/m^3 in the *crust* - increasing with depth – up to 8×10^{17} kg/m^3 in the *core* [3]. From these values we can conclude that the neutrons of the core are much closer to each other than the neutrons of the crust†.

This means that the value of W_n in the crust is much smaller than the value in the core. Therefore, the gravitational mass of the core becomes negative *before* the gravitational mass of the crust. This makes the gravitational contraction culminates with an *explosion*, due to the *repulsive* gravitational forces between the core and the crust. Therefore, the contraction has a limit and, consequently, the *singularity* $(g\rightarrow\infty)$ never occur. Similarly, the Big Bang can have occurred due to the *repulsive* gravitational forces between the core and the crust of the initial Universe ‡. This means that the Universe arises at a finite time, with a finite volume. Consequently, the origin of *spacetime precedes* the beginning of our Universe.

Also we have shown in [1] that *time* and *space* are *quantized* and given by§

$$t = \frac{t_{\max}}{n} \qquad n = 1,2,3,... \tag{3}$$

$$l_x = \frac{l_{\max}}{n_x} \qquad l_y = \frac{l_{\max}}{n_y} \qquad l_z = \frac{l_{\max}}{n_z} \tag{4}$$

where n_x, n_y, and n_z are positive integers. The *elementary quantum of length*, $l_{\min}$, was obtained and is given by**

$$l_{\min} = \tilde{k} l_{planck}, \text{ where } \quad 5.6 < \tilde{k} < 14.9 \tag{5}$$

† The density 1×10^9 kg/m^3 in the *crust* shows that the radius of a neutron in the crust has the normal value (1.4×10^{-15}m). However, the density 8×10^{17} kg/m^3 shows that the radius of a neutron in the *core* should be approximately the *half* of the normal value.

‡ This phenomenon has been deeply detailed in [1]

§ Equations (37) and (28) of [1].

** Equation (100) of [1].

In the system of natural units known as Planck units, the time required for *light* to travel, in a vacuum, a distance of 1 *Planck length* is known as *Planck time*, t_{planck}, i.e.,

$$l_{planck} / t_{planck} = c \tag{6}$$

The Planck length (the length scale on which quantum fluctuations of the metric of the spacetime are expected to be of order unity) and the Planck time (the time scale on which quantum fluctuations of the metric of the spacetime are expected to be of order unity) are, respectively defined as:

$$\begin{aligned} l_{planck} &= \sqrt{\frac{G\hbar}{c^3}} = 1.61\times10^{-35}\, m \\ t_{planck} &= \sqrt{\frac{\hbar G}{c^5}} \cong 5.39106 \times 10^{-44}\, s \end{aligned} \tag{7}$$

The *elementary quantum of time*, $t_{\min}$, can be obtained, considering Eqs. (5) and (6), and the fact that $l_{\min}/t_{\min}=c$. The result is

$$t_{\min} = \tilde{k}\, t_{planck} \tag{8}$$

In this context, there is no a shorter time interval than $t_{\min}$. Consequently, the Planck time does not exists really. It is only a fictitious value related with the occurrence of quantum fluctuations of order unity, in the metric of the spacetime.

When $t=t_{\min}$ or $l=l_{\min}$ equations (3) and (4) point to the existence of a $n_{\max}$, given by

$$n_{\max} = t_{\max}/t_{\min} = l_{\max}/l_{\min} \tag{9}$$

Assuming that the initial Universe arises at a finite time $t_0 = n_0 t_{\min}$, as a sphere with diameter $d_{\min} = n_0 l_{\min}$, where n_0 is a positive integer number, and disappears at $t = t_{\max}$ when its diameter is $d_{\max} = n_{\max} l_{\min}$, then we can write that

$$d_{max}/d_{min} = n_{max}/n_0 \quad (10)$$

The value of d_{max} can be obtained from the expression of the *quantization of charge* [1] ††:

$$Q_{min} = \sqrt{\pi\varepsilon_0 hc\sqrt{24}\left(d_c/d_{max}\right)} =$$
$$= \sqrt{\left(\pi\varepsilon_0 hc^2\sqrt{96}\tilde{H}^{-1}/d_{max}\right)} = \tfrac{1}{3}e$$

where h is the Planck constant; $\tilde{H}$ is the Hubble constant; e is the elementary charge.

From the equation above, we get ‡‡

$$d_{max} = 3.4\times 10^{30}\, m \quad (11)$$

Equations (9), (8), (5) and (10), shows that

$$t_{max} = n_{max}\tilde{k}t_{planck} = \left(\frac{n_0 d_{max}}{d_{min}}\right)\tilde{k}t_{planck} \quad (12)$$

Since the *grand-unification era* begins at $\sim 10^{-43}s$ [4,5], then we can conclude that the Big bang must have occurred before $10^{-42}s$. This means that $t_0 = n_0 t_{min} < 10^{-42}s$. Thus, it follows that $n_0 = t_0/t_{min} = t_0/\tilde{k}t_{planck}$ must be equal to 1. Thus, the time scale in our Universe *begins* at $t_0 = t_{min} = \tilde{k}t_{planck}$ and, according to Eq.(12) ($d_{min} = l_{min}$), *ends* at

$$t_{max} = \left(\frac{n_0 d_{max}}{l_{min}}\right)\tilde{k}t_{planck} = \left(\frac{d_{max}}{\tilde{k}l_{planck}}\right)\tilde{k}t_{planck} =$$
$$= \frac{d_{max}}{c} \cong 1.1\times 10^{22} s \quad (13)$$

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†† Equation (91) of [1].

‡‡ This is the maximum "diameter" that the Universe will reach.

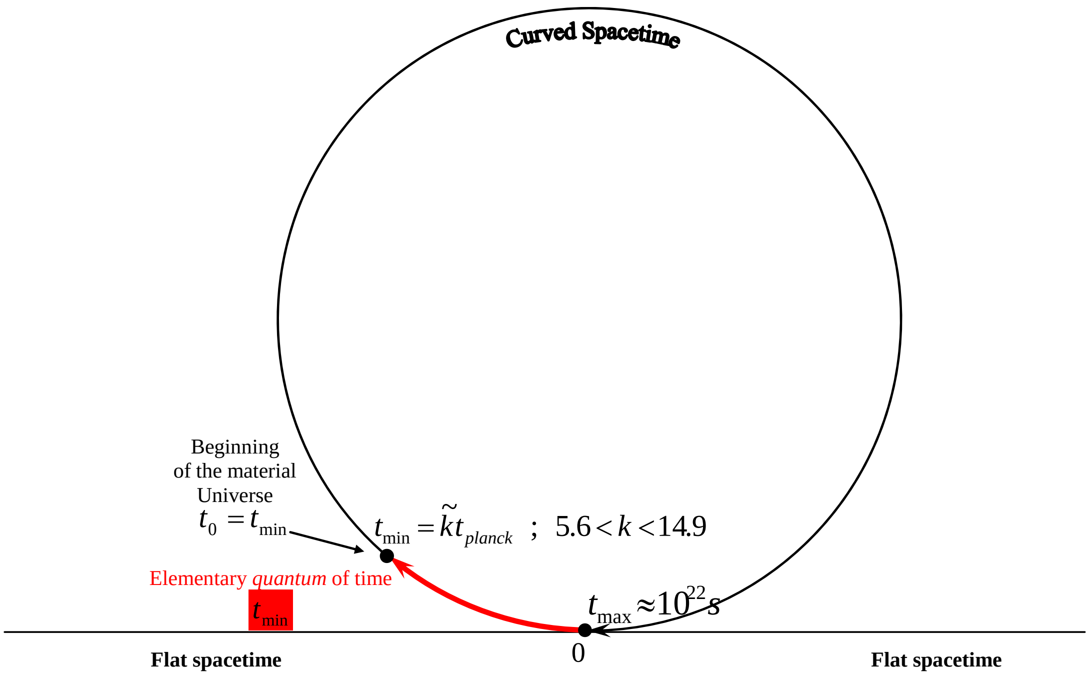

Fig.1 – Schematic Diagram of the Beginning $(t_0 = t_{\min})$, and End $(t_{\max} = n_{\max} t_{\min})$ of Time in the material Universe. In this context, there is no a shorter time interval than $t_{\min}$. Consequently, the Planck time does not exists really. It is only a fictitious value related with the occurrence of quantum fluctuations of order unity, in the metric of the spacetime.

References

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