Stability of matter in the accelerating spacetime

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1 Introduction

In the seminal paper [1] F. Calogero described the cosmic origin of quantization. In paper [1] the tremor of the cosmic particles is the origin of the quantization and the characteristic acceleration of these particles $a \sim 10^{-10}$ m/s^2 was calculated. In our earlier paper [2] the same value of the acceleration was obtained and compared to the experimental value of the measured spacetime acceleration. In this paper we define the cosmic force –*Planck* force, $F_{Planck} = M_P a_{Planck}$ ($a_{Planck} \sim a$) and study the history of Planck force as the function of the age of the Universe.

Masses introduce a curvature in spacetime, light and matter are forced to move according to spacetime metric. Since all the matter is in motion, the geometry of space is constantly changing. A Einstein relates the curvature of space to the mass/energy density:

$$\mathbf{G} = k\mathbf{T}. \tag{1}$$

G is the Einstein curvature tensor and **T** the stress-energy tensor. The proportionality factor k follows by comparison with Newton's theory of gravity: $k = G/c^4$ where G is the Newton's gravity constant and c is the vacuum velocity of light; it amounts to about 2.10^{-43} N^{-1}, expressing the *rigidity* of spacetime.

In paper [2] the model for the acceleration of spacetime was developed. Prescribing the $-G$ for spacetime and $+G$ for matter the acceleration of spacetime was obtained:

$$a_{Planck} = -\frac{1}{2}\left(\frac{\pi}{4}\right)^{1/2}\frac{(N+\frac{3}{4})^{1/2}}{M^{3/2}}A_P, \tag{2}$$

where A_P, *Planck* acceleration equal, viz.:

$$A_P = \left(\frac{c^7}{\hbar G}\right)^{1/2} = \frac{c}{\tau_P} \cong 10^{51} ms^{-2}. \tag{3}$$

As was shown in paper [2] the a_{Planck} for $N = M = 10^{60}$ is of the order of the acceleration detected by Pioneer spacecrafts [3].

Considering A_P it is quite natural to define the *Planck* force F_{Planck},

$$F_{Planck} = M_P A_P = \frac{c^4}{G} = k^{-1}, \tag{4}$$

where

$$M_P = \left(\frac{\hbar c}{G}\right)^{1/2}.$$

From formula (4) we conclude that F^{-1}_{Planck} = rigidity of the spacetime. The *Planck* force, $F_{Planck} = c^4/G = 1.2\ 10^{44}$ N can be written in units which characterize the microspacetime, i.e. GeV and fm.

In that units

$$k^{-1} = F_{Planck} = 7.6\ 10^{38}\ \text{GeV/fm}.$$

2 The *Planck*, *Yukawa* and *Bohr* forces

As was shown in paper [2] the present value of *Planck* force equal

$$F^{Now}_{Planck}(N = M = 10^{60}) \cong -\frac{1}{2}\left(\frac{\pi}{4}\right)^{1/2} 10^{-60}\frac{c^4}{G} = -10^{-22}\frac{\text{GeV}}{\text{fm}}. \qquad (5)$$

In paper [4] the *Planck* time τ_P was defined as the relaxation time for spacetime

$$\tau_P = \frac{\hbar}{M_P c^2}. \qquad (6)$$

Considering formulae (4) and (6) F_{Planck} can be written as

$$F_{Planck} = \frac{M_P c}{\tau_P}, \qquad (7)$$

where c is the velocity for gravitation propagation. In paper [5] the velocities and relaxation times for thermal energy propagation in atomic and nuclear matter were calculated:

$$\begin{aligned} v_{atomic} &= \alpha_{em} c, \\ v_{nuclear} &= \alpha_s c, \end{aligned} \qquad (8)$$

where $\alpha_{em} = e^2/(\hbar c) = 1/137$, $\alpha_s = 0.15$. In the subsequent we define atomic and nuclear accelerations:

$$\begin{aligned} a_{atomic} &= \frac{\alpha_{em} c}{\tau_{atomic}}, \\ a_{nuclear} &= \frac{\alpha_s c}{\tau_{nuclear}}. \end{aligned} \qquad (9)$$

Considering that $\tau_{atomic} = \hbar/(m_e \alpha_{em}^2 c^2)$, $\tau_{nuclear} = \hbar/(m_N \alpha_s^2 c^2)$ one obtains from formula (9)

$$\begin{aligned} a_{atomic} &= \frac{m_e c^3 \alpha_{em}^3}{\hbar}, \\ a_{nuclear} &= \frac{m_N c^3 \alpha_s^3}{\hbar}. \end{aligned} \tag{10}$$

We define, analogously to *Planck* force the new forces: F_{Bohr}, F_{Yukawa}

$$\begin{aligned} F_{Bohr} &= m_e a_{atomic} = \frac{(m_e c^2)^2}{\hbar c} \alpha_{em}^3 = 5\ 10^{-13}\ \frac{\mathrm{GeV}}{\mathrm{fm}}, \\ F_{Yukawa} &= m_N a_{nuclear} = \frac{(m_N c^2)^2}{\hbar c} \alpha_s^3 = 1.6\ 10^{-2}\ \frac{\mathrm{GeV}}{\mathrm{fm}}. \end{aligned} \tag{11}$$

Comparing formulae (5) and (11) we conclude that gradients of *Bohr* and *Yukawa* forces are much large than F_{Planck}^{Now}, i.e.:

$$\begin{aligned} \frac{F_{Bohr}}{F_{Planck}^{Now}} &= \frac{5.10^{-13}}{10^{-22}} \sim 10^9, \\ \frac{F_{Yukawa}}{F_{Planck}^{Now}} &= \frac{10^{-2}}{10^{-22}} \sim 10^{20}. \end{aligned} \tag{12}$$

The formulae (12) guarantee present day stability of matter on the nuclear and atomic levels.

As the time dependence of F_{Bohr} and F_{Yukawa} are not well established, in the subsequent we will assumed that α_s and α_{em} do not dependent on time. Considering formulae (8) and (11) we obtain

$$\frac{F_{Yukawa}}{F_{Planck}} = \frac{1}{(\frac{\pi}{4})^{1/2}} \frac{(m_N c^2)^2}{M_P c^2} \frac{\alpha_s^3}{\hbar} T, \tag{13}$$

$$\frac{F_{Bohr}}{F_{Planck}} = \frac{1}{(\frac{\pi}{4})^{1/2}} \frac{(m_e c^2)^2}{M_P c^2} \frac{\alpha_{em}}{\hbar} T. \tag{14}$$

As can be realized from formulae (13), (14) in the past $F_{Planck} \sim F_{Yukawa}$ (for $T = 0.002$ s) and $F_{Planck} \sim F_{Bohr}$ (for $T \sim 10^8$ s), $T =$ age of universe. The calculated ages define the limits for instability of the nuclei and atoms.

3 The *Planck*, *Yukawa* and *Bohr* particles

In 1900 M. Planck [6] introduced the notion of the universal mass, later on called the *Planck* mass

$$M_P = \left(\frac{\hbar c}{G}\right)^{1/2}, \qquad F_{Planck} = \frac{M_P c}{\tau_P}. \tag{15}$$

Considering the definition of the *Yukawa* force (11)

$$F_{Yukawa} = \frac{m_N v_N}{\tau_N} = \frac{m_N \alpha_{strong} c}{\tau_N}, \tag{16}$$

the formula (16) can be written as:

$$F_{Yukawa} = \frac{m_{Yukawa} c}{\tau_N}, \tag{17}$$

where

$$m_{Yukawa} = m_N \alpha_{strong} \cong 147 \, \frac{\mathrm{MeV}}{\mathrm{c}^2} \sim m_\pi. \tag{18}$$

From the definition of the *Yukawa* force we deduced the mass of the particle which mediates the strong interaction – pion mass postulated by Yukawa in [7].

Accordingly for *Bohr* force:

$$F_{Bohr} = \frac{m_e v}{\tau_{Bohr}} = \frac{m_e \alpha_{em} c}{\tau_{Bohr}} = \frac{m_{Bohr} c}{\tau_{Bohr}}, \tag{19}$$

$$m_{Bohr} = m_e \alpha_{em} = 3.7 \, \frac{\mathrm{keV}}{\mathrm{c}^2}. \tag{20}$$

For the *Bohr* particle the range of interaction is

$$r_{Bohr} = \frac{\hbar}{m_{Bohr} c} \sim 0.1 \text{ nm}, \tag{21}$$

which is of the order of atomic radius.

Considering the electromagnetic origin of the mass of the *Bohr* particle, the planned sources of hard electromagnetic field, e.g. free electron laser (FEL)at TESLA accelerator (DESY) [8] are best suited to the investigation of the properties of the *Bohr* particles.

4 Possible interpretation of F_{Planck}, F_{Yukawa} and F_{Bohr}.

In an important work, published already in 1951 J. Schwinger [9] demonstrated that in the background of a static uniform electric field, the QED vacuum is unstable and decayed with spontaneous emission of e^+e^- pairs. In the paper [9] Schwinger calculated the critical field strengths E_S:

$$E_S = \frac{m_e^2 c^3}{e\hbar}. \tag{22}$$

Considering formula (22) we define the *Schwinger* force:

$$F^e_{Schwinger} = eE_S = \frac{m_e^2 c^3}{\hbar}. \tag{23}$$

Formula (23) can be written as:

$$F^e_{Schwinger} = \frac{m_e c}{\tau_{Sch}}, \tag{24}$$

where

$$\tau_{Sch} = \frac{\hbar}{m_e c^2} \tag{25}$$

is *Schwinger* relaxation time for the creation of e^+e^- pair. Considering formulae (11) the relation of F_{Yukawa} and F_{Bohr} to the *Schwinger* force can be established

$$\begin{aligned} F_{Yukawa} &= \alpha_s^3 \left(\frac{m_N}{m_e}\right)^2 F^e_{Schwinger}, \qquad \alpha_s = 0.15, \qquad (26)\\ F_{Bohr} &= \alpha_{em}^3 F^e_{Schwinger}, \qquad \alpha_{em} = \frac{1}{137}, \end{aligned}$$

and for *Planck* force

$$F_{Planck} = \left(\frac{M_P}{m_e}\right)^2 F^e_{Schwinger}. \tag{27}$$

In Table 1 the values of the $F^e_{Schwinger}$, F_{Planck}, F_{Yukawa} and F_{Bohr} are presented, all in the same units GeV/fm. As in those units the forces span the range 10^{-13} to 10^{38} it is valuable to recalculate the *Yukawa* and *Bohr* forces in the units natural to nuclear and atomic level. In that case one obtains:

$$F_{Yukawa} \sim \frac{16 \text{ MeV}}{\text{fm}}. \tag{28}$$

It is quite interesting that $a_v \sim 16$ MeV is the volume part of the binding energy of the nuclei (droplet model).

Table 1: Schwinger, *Planck*, *Yukawa* and *Bohr* forces

$F^e_{Schwinger}$	F_{Planck}	F_{Yukawa}	F_{Bohr}
[GeV/fm]	[GeV/fm]	[GeV/fm]	[GeV/fm]
$\sim 10^{-6}$	$\sim 10^{38}$	$\sim 10^{-2}$	$\sim 10^{-13}$

For the *Bohr* force considering formula (11) one obtains:

$$F_{Bohr} \sim \frac{50 \text{ eV}}{0.1 \text{ nm}}. \tag{29}$$

Considering that the Rydberg energy ~ 27 eV and *Bohr* radius ~ 0.1 nm formula (29) can be written as

$$F_{Bohr} \sim \frac{\text{Rydberg energy}}{\text{Bohr radius}} \tag{30}$$

5 Concluding remarks

In this paper the forces: *Planck*, *Yukawa* and *Bohr* were defined. It was shown that the present value of the *Planck* force (which is the source of the universe acceleration) $\sim 10^{-22}$ GeV/fm is much smaller than the *Yukawa* ($\sim 10^{-2}$ GeV/fm) and *Bohr* (10^{-13} GeV/fm) forces respectively. This fact guarantees the stability of the matter in the present. However in the past for T (age of the universe), $T < 0.002$ s, $F_{Yukawa} < F_{Planck}$ (0.002 s) and $F_{Bohr} < F_{Planck}$ (10^8 s). In this paper the relation of the *Schwinger* force (for the vacuum creation of the e^+e^- pairs) to the *Planck*, *Yukawa* and *Bohr* force was obtained.

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