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Research Article

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On Origin of Primary Cosmic Rays and Kinematic Condition for Creation of Matter Structure in the Universe

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Abstract We propose some potentials depending on spacetime dimensions and satisfying Laplacian equation. These potentials allow us to introduce different forces, like Newtonian one, and to explain the Big Bang process, an origin of primary cosmic rays and kinematic condition for matter structure formation in the whole universe.

Keywords Cosmic rays, Laplacian equation

1. Possible Forms of Potentials Depending on Spacetime Dimensions

Let us introduce potential forms depending on spacetime dimensions $D = 4, \dots, 11$:

$$U_D(x_1, x_2, \dots, x_{D-1}) = -\frac{a_D}{r^{D-3}}, \tag{1}$$

where a_D is some constant and x_i are spatial variables. For example, for 4-dimensional Minkowski space: $x_i = \{x, y, z\}$, and in particular,

$$U_4(r) = -\frac{M}{r} \cdot G \tag{2}$$

is the Newtonian potential of a object with mass M. Further, we assume that all potentials (1) should be satisfied the Laplacian equation:

$$\Delta_D U_D(r) = 0, \tag{3}$$

where

$$\Delta_D = \frac{\partial^2}{\partial x_1^2} + \frac{\partial^2}{\partial x_2^2} + \dots + \frac{\partial^2}{\partial x_{D-1}^2}, \tag{4}$$

and

$$r = \sqrt{x_1^2 + x_2^2 + \dots + x_{D-1}^2}.$$

2. Different Forces

By means of appropriate choice of constants a_D which depend on spacetime dimensions one can define different forces

$$F_D(r) = \nabla_r U_D(r). \tag{5}$$

1. Let $D = 4$, then we have the Newtonian force

$$F_4 = F_N = G\frac{M_1 M_2}{r^2}, \tag{6}$$

where r is distance between two bodies with masses M_1 and M_2.

2. Let $D = 5$, then we obtain the Planck-Newtonian force [1]:

$$F_5 = \frac{G\hbar}{c}\frac{M_U}{L_{Pl}^3} = 5.241 \times 10^{105} N \quad (Newton) \tag{7}$$

for creation of the universe, where

$$M_U = 1.744 \times 10^{53} kg$$

is approximately total mass of our visible Universe and

$$L_{Pl} = \sqrt{\frac{G\hbar}{c^3}} \tag{8}$$

is the Planck length.

3. Let $D = 6$, then we obtain driven-drift (or dark-ghost) force

$$F_6 = \frac{G\hbar^2}{c^2} \cdot \frac{1}{r^4}. \tag{9}$$

If $r = L_{Pl}$ then this force is responsible at the beginning for inflation and later on accelerating expansion of the universe with acceleration rate [1]

$$F_6 = M_U \cdot a_{expan} = 1.21 \times 10^{44} N, \tag{10}$$

from which, we have:

$$a_{expan} = 6.94 \times 10^{-10} \frac{m}{sec^2}. \tag{11}$$

Last quantity gives rise accelerating expansion of our universe at large scale. For example, in future, after 13.5 billion years present volume of our universe with radius $R_P = ct_p = 1.295 \times 10^{26} m$ will be increased two times.

It means that we live in very accelerating expanding world. Here $t_p = 13.7 \times 10^9 years$.

3. Different Behaviour of Particles under Drift Force

It is well known that after Big Bang process, due to the Higgs mechanism for acquiring masses newly born all particles became mass values by means of broken symmetry of vacuum state of the universe or a phase transition from very hot radiations-photons into matter particles.

Further, all these particles should be moved, as dusts and clouds carried by fair wind, under the drift force (9).

It turns out that some stable basic particles and atoms like protons, antiprotons, electrons, positrons, alpha-particles, Hydrogen atoms etc. move differently under drift force (9) depending on their mass values and some characteristic sizes (Compton lengths) and so on. Now we calculate kinematic quantities of these particles and atoms moving in the free space due to this drift force (9).

3.1. Electrons and Positrons

Now we put the following fundamental constants:

$$G = 6.6743 \times 10^{-11} \frac{m^3}{kg \cdot sec^2},$$
$$\hbar = 1.054571817 \times 10^{-34} J \cdot sec,$$
$$c = 2.99792458 \times 10^8 \frac{m}{sec}$$

into equation (9) and taking into account that mass of an electron is

$$m_e = 9.109389 \times 10^{-28} g = 9.109 \times 10^{-31} kg,$$

and its characteristic size is the Compton length

$$\lambda_e = 3.8615 \times 10^{-13} m.$$

Then we obtain the drift force for an electron

$$F_e = \frac{G\hbar^2}{c^2} \frac{1}{\lambda_e^4} = 8.259 \times 10^{-96} \frac{N \cdot m^4}{\lambda_e^4} = 3.7145 \times 10^{-46} N, \tag{12}$$

where

$$\lambda_e^4 = 2.223 \times 10^{-50} m^4.$$

Now we use the Newtonian law for the electron

$$F_e = m_e \cdot a_e, \tag{13}$$

from which we have acceleration value for the electron

$$a_e = F_e / m_e = 4.078 \times 10^{-16} \frac{m}{sec^2}. \tag{14}$$

Due to this drift acceleration, during age of the universe the electron acquires velocity

$$v_e = a_e t_p = a_e \cdot 13.7 \times 10^9 years = a_e \times 4.32 \times 10^{17} sec = 1.76 \times 10^2 \frac{m}{sec} \tag{15}$$

Therefore, kinetic energy of the electron takes the value

$$T_e = \frac{m_e v_e^2}{2} = 1.41 \times 10^{-26} J, \tag{16}$$

or

$$T_e = E_e - m_e c^2 = 1.41 \times 10^{-26} \cdot \frac{1}{1.602176} \times 10^{19} eV = 8.801 \times 10^{-8} eV. \tag{17}$$

It means that moving electron under the drift force during age of the universe is slowly down. It is very important fact, discussion of which will be given below.

3.2. Protons and Antiprotons

Same calculations as above for protons give the following results: Mass of a proton:

$$m_p = 1.6726 \times 10^{-27} kg.$$

Its the Compton length

$$\lambda_p = 2.103 \times 10^{-16} m.$$

Drift force:

$$F_p = 4.222 \times 10^{-33} N. \tag{18}$$

Acceleration value:

$$a_p = 2.5242 \times 10^{-6} \frac{m}{sec^2}. \tag{19}$$

Velocity of the proton aquiring during age of universe is

$$v_p = 1.09 \times 10^{12} \frac{m}{sec}. \tag{20}$$

Its kinetic energy is

$$T_p = E_p - m_p c^2 = 9.936 \times 10^{-4} J = 6.2 \times 10^{15} eV = 6.2 \times 10^3 TeV. \tag{21}$$

This quantity plays a vital role in primary cosmic rays.

3.3. Muons and antimuons

Mass of a muon is

$$m_\mu = 1.883 \times 10^{-28} kg,$$

and its Compton length is

$$\lambda_\mu = 1.868 \times 10^{-15} m.$$

Therefore, drift force for the muon is

$$F_\mu = 6.783 \times 10^{-37} N. \tag{22}$$

Then drift acceleration a_μ and velocity v_μ take the quantities:

$$a_\mu = 3.6 \times 10^{-9} \frac{m}{sec^2}, \tag{23}$$

$$v_\mu = 1.556 \times 10^9 \frac{m}{sec}. \tag{24}$$

Its kinetic energy acquiring during age of universe is

$$T_\mu = E_\mu - m_\mu c^2 = 2.279 \times 10^{-10} J = 1.422 \times 10^9 eV = 1.4 GeV. \tag{25}$$

As protons and antiprotons, muons and their antiparticles may be played important role in primary cosmic rays.

3.4. α -alpha particles

Approximately its mass and the Compton length are

$$m_\alpha \sim 4m_p,$$

$$\lambda_\alpha = \frac{\hbar}{4m_p c} = 5.258 \times 10^{-17} m.$$

Therefore, we obtain following quantities for α-particles:

$$F_\alpha = 1.081 \times 10^{-33} N. \tag{26}$$

$$a_\alpha = 1.616 \times 10^{-7} \frac{m}{sec^2} \tag{27}$$

$$v_\alpha = 6.98 \times 10^{10} \frac{m}{sec}. \tag{28}$$

and its kinetic energy is

$$T_\alpha = E_\alpha - m_\alpha c^2 = 2m_p v_\alpha^2 = 1.63 \times 10^{-5} J = 1.017 \times 10^{14} eV = 100 TeV. \tag{29}$$

It means that α-particles may be presented in primary cosmic rays.

3.5. Hydrogen Atoms

For this atom we have

$$M_H \sim m_p,$$

and its size is

$$\lambda_H = 5.3 \times 10^{-11} m. \tag{30}$$

Therefore one can get the following quantities for a hydrogen atom. Its drift force is

$$F_H = 1.0468 \times 10^{-54} N. \tag{31}$$

Drift acceleration and velocity take the forms

$$a_H = 6.259 \times 10^{-28} \frac{m}{sec^2}, \tag{32}$$

$$v_H = 2.7 \times 10^{-10} \frac{m}{sec}. \tag{33}$$

Drift kinetic energy of the hydrogen atom is very small

$$T_H = E_H - m_H c^2 = 6.0966 \times 10^{-47} J = 3.8 \times 10^{-28} eV. \tag{34}$$

It means that hydrogen like atoms are almost at rest in universe.

4. On Origin of Primary Cosmic Rays

Cosmic rays originate as primary cosmic rays, which are those originally produced in various astrophysical process, like Big Bang. Primary cosmic rays are composed primarily of protons and alpha particles (99%), with a small amount of heavier nuclei (≈ 1%) and an extremely minute proportion of positrons and antiprotrons [2-3]. Secondary cosmic rays, caused by a decay of primary cosmic rays as they impact an atmosphere, include photons, leptons and hadrons, such as electrons, positrons, muons, and pions. The latter three of these were first detected in cosmic rays.

Primary cosmic rays mostly originate from outside the Solar system and sometimes even the Milky Way. As shown above protons with very high energy about $6.2 \times 10^3 TeV$, muons with energy $1.4 GeV$, and alpha particles with around 100TeV may be originated from Big Bang process and therefore they are basic elements of primary cosmic rays. This assumption is proved by above experimental data saying that p's and α's particles are main components (99%) of primary cosmic rays.

5. Favourable Kinematic Condition for Creation Matter Structure in Universe

After Big Bang process, according to the Higgs mechanism for acquiring masses, all particles became massive and ready to form bound states. For example, protons capture slowly down electrons with energy $E_e \sim 9 \times 10^{-8} eV$ due to small drift force (12). As result hydrogen atoms are formed. Manifested hydrogen atoms become slowly down and are approximately at rest (with energy $\sim 4 \times 10^{-28} eV$) and in turn, ready to form cosmic dense objects like suns, planets, asteroids, earth and etc., even more giganic black holes with billion sun's mass.

Otherwise, if electrons will be moved with very high velocities in space then it is difficult to capture electrons by protons to form hydrogen atoms. Moreover, if formed hydrogen atoms travel also with high velocities in cosmos then it is also impossible to form dense objects in free space.

In conclusion, we notice that it is remarkable that all three forces (6), (7) and (9) are connected each other by substitutions

$$r \to \lambda = \frac{\hbar}{mc}, \quad m \to \frac{\hbar}{\lambda c}.$$

It means that in the microworld all elementary particles with characteristic length λ are freely detected into small distances and therefore they travel freely into any dimensions of spacetime.

6. Appendix 1

It turns out that the Newtonian force (6) acting in the macroworld, i.e. in the cosmic scale, quantum drift force (10) acting in the Big Bang scale are related each other and give the same acceleration value (11) for expanding universe. We see that from the Newtonian force (6) one can obtain self interaction equation for whole universe with total mass

$$M_U = 1.7438 \times 10^{53} kg,$$

$$\frac{GM_U^2}{R_p^2} = a_{expan} \cdot M_U, \tag{35}$$

where

$$R_p = ct_p = 1.2951 \times 10^{26} m.$$

Direct calculation of equation (35) gives

$$a_{expan} = \frac{GM_U}{R_p^2} = 6.94 \times 10^{-10} \frac{m}{sec^2}. \tag{36}$$

It is exactly coinciding with the quantity (11) arisen from the equation (10). Therefore, we obtain remarkable equality:

$$\frac{G\hbar^2}{c^2}\frac{1}{L_{Pl}^4} = \frac{GM_U^2}{R_p^2}, \tag{37}$$

where

$$L_{Pl} = \sqrt{G\hbar/c^3}.$$

From equation (37) we get the following relation

$$\boxed{M_U = c^2 \frac{R_p}{G}}. \tag{38}$$

Moreover, self interaction of the solar system and self interaction of the Milky Way are given by corresponding Newtonian equations:

$$\frac{GM_{ss}^2}{R_{ss}^2} = a_{expan}^{ss} \cdot M_{ss}, \tag{39}$$

$$\frac{GM_{MW}^2}{R_{MW}^2} = a_{expan}^{MW} \cdot M_{MW}, \tag{40}$$

where

$$\left.\begin{array}{l} M_{ss} \sim 2 \cdot 10^{30} kg, \\ M_{MW} \sim 1.29 \times 10^{12} M_{\odot} = 1.29 \cdot 10^{12} \times 2 \cdot 10^{30} kg, \\ R_{ss} \sim 1.437 \times 10^{14} m, \\ \text{and} \\ R_{MW} \sim 0.5265 \times 10^{10} ly, \\ ly = 9.46 \times 10^{15} m, \end{array}\right\} \tag{41}$$

where ly is the distance for which light travels during one year. Substitutions all these quantities into equations (39) and (40) give almost same results as (11) and (36):

$$a_{expan}^{ss} = 64.64 \times 10^{-10} \frac{m}{sec^2} \tag{42}$$

$$a_{expan}^{MW} = 6.94 \times 10^{-10} \frac{m}{sec^2}. \tag{43}$$

These results show that our whole universe including the Milky Way and the solar system are the same manner expanding with acceleration value

$$a_{expan}^{U} = 6.94 \times 10^{-10} \frac{m}{sec^2} \tag{44}$$

Thus in our universe accelerating expansion process is dominated.

Notice that mass of the solar system is much small with respect to mass of the Milky Way and therefore the solar system tends to move faster into periphery of the Milky Way, as the moon is moving away from earth at about 4 cm per year.

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