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Primordial black holes as Dark matter, gravitational radiation as Dark energy (P. W. Anderson); unified approach to Planck-scale physics and Big Bang cosmology, early Large-scale structure and Two-stage accelerated expansion of the Universe

The work based on the algebraic approach bequeted by Einstein to the unification of quantum and continuum description of reality. It is devoted to multi-aspect and multi-disciplinary analysis and solution of many unsolved problems and paradoxes in physics and cosmology. Based on modern data from experimental physics and observational cosmology. Particular attention is paid to the key role of the black holes in the birth and development of observable Universe.

*To the blessed memory
of J. Bekenstein, S. Hawking and P. W. Anderson*

Introduction

*"What I cannot create, I do not understand."
(R. Feynman)*

The main goal of our work is to demonstrate the exceptional importance of primordial blackholes (PBHs) in the emergence and development of the observable Universe as well as to solve and remove numerous problems and paradoxes such as Planck-scale physics and Big Bang cosmology, baryogenesis, supermassive black holes formation, the very early "clumpiness" of the Universe, large-scale structure with supervoids and superclusters formation, two-stage accelerated expansion, "horizon" problem, "cosmological constant" problem, "information loss" paradox etc, that have accumulated in observational cosmology and astrophysics.

Ultimately we will demonstrate that the realistic black hole physics is the key to solving fundamental problems in cosmology. This is, by and large, the main content of the presented work.

In his prophetic scientific testament "Four last conjectures" (arXiv, 2018), the outstanding physicist and Nobel laureate P. W. Anderson wrote: "*IV. Dark energy as gravitational radiation ... This last point is the crux of the argumernt ... the mass is irreversible last ... therefore our expansion are accelerating ... this does not scem to be accounted in the present cosmology*". In fact, it was this great insight that was the driving force behind our research, an insight that led to the idea of a profound connection between dark matter and dark energy.

In presented study we followed the two wise methodological principles of Niels Bohr and Albert Einstein. First: "*Base your research on well-established physical laws, but push them into the most extreme conceivable domains*", second: "*We cannot solve our problem with the same thinking we used when created them*".

"*Physics thrives on crisis*" – wrote Steven Weinberg at the end of the last century in his profound article "Cosmological constant problem". It should be admitted with all sincerity that over the past quarter of century the situation has not only not improved, but has also worsened dramatically: the swarm of unsolved problems and paradoxes continues to grow in contrast to the new successful experimental and observational data.

It becomes absolutely clear, that without the unification of these two fundamental theories, we cannot further successfully and efficiently move forward along the path of space exploration and a deep understanding of the observable Universe. On what basis can this be done?

Gravitational waves, interpreted as "ripples of spacetime", and "probability waves" of quantum theory have a fundamentally different nature, but are related geometrically. For this reason further we will describe many phenomena and processes of black holes in terms of wavelengths and geodesical lengths. Secondly, it was necessary to find a quantum "background substance" in which the gravitational monstrous gravitational squeezing force must be equilibrated by quantum-mechanical repulsive one.

Fortunately, recent remarkable discoveries, such as Einstein's gravitational waves (LIGO/Virgo, 2015), "impossible" early galaxies and quasars, 2D photon Bose-Einstein condensate (Bonn University, 2010) with rest energy etc. provide a solid experimental and observational basis for "*fiery marriage of general relativity with quantum theory*" (J.Wheeler).

1. The sketches of "Einstein algebra"

Driven by his own deepest methodological principle, in his last work (1954) Einstein wrote the closing lines that sound like a testament: "*... a finite system with its finite energy can be described in full by a finite set of quantum number. Seemingly, it can not be compliant with continuum theory and require a purely algebraic theory for a reality description. However now nobody knows, how to find the basis for such a theory*". Note that the path to such a theory turned out to be much more dramatic than anyone might have to imagine.

Consecutively, in a physical logic, nature inspire us that primordial black holes (PBHs) represent 2D spherical photon condensates trapped in their own gravitational fields. Such a physical model inevitably leads to the natural geometrical equation that directly connects Compton wavelength of condensed light (quantum theory) with geodesical length (general relativity):

$$\lambda_{sm} = 2\pi R_s,$$

R_s - gravitational radius of black hole. Figuratively speaking, Spacetime tells condensed Light quanta how to curve; condensed Light quanta tells Spacetime how to quantize.

From the definition of the Compton wavelength

$$\lambda_{sm} = \frac{2\pi\hbar}{M_{sm}c} \text{ and } 2\pi R_s = 4\pi G M_s / c^2$$

we immediately find the mass and rest energy of each condensed photon:

$$M_{sm} = \frac{2\pi\hbar}{\lambda_{sm}c} = \frac{\hbar}{R_s c} \text{ and } E_{sm} = M_{sm}c^2 = \frac{\hbar c}{R_s}$$

as well as their total number

$$N_s = \frac{M_s}{M_{sm}} = 2 \frac{M_s^2 G}{\hbar c} = 2 \frac{M_s^2}{M_p^2} = 2 \frac{E_s^2}{E_p^2} = \frac{R_s^2}{2l_p^2} \text{ etc,}$$

expressed in form of the Planck mass M_p , Planck energy E_p , and Planck length l_p . As we can see, already these simplest but consistent relation open the door to the Terra Incognita of Planck-scale physics.

Taking into account that the number N_s of condensed photons can't be less than two, we easily find a very important expression for their number, using the natural quantum number n_s :

$$N_s = 2n_s, n_s = 1, 2, 3, \dots$$

From the obvious derived quantum relations such as

$$M_s = M_p \sqrt{n_s}, E_s = E_p \sqrt{n_s}, R_s = 2l_p \sqrt{n_s}, A_s = 4\pi R_s^2 = 16\pi l_p^2 n_s \text{ etc,}$$

we find a precise characteristics of the minimal ($n_s=1$) Planck black hole:

$$M_{sp} = M_p, E_{sp} = E_p, R_{sp} = 2l_p, A_{sp} = 16\pi l_p^2, \text{ etc.}$$

Relying only on the well-established physical laws one can easily find the numerous quantized characteristics (mass M_s , rest energy E_s , size R_s , entropy S_s , temperature T_s , amount of quantum information I_s , lifetime τ_s , luminosity L_s etc.) and simple but very important laws that govern birth, growth and death of PBHs.

The first one should pay attention is that all these characteristics of PBHs are expressed only in Planck units and in the various degrees of the natural quantum number, $n_s=1, 2, 3, \dots$

$$M_s = M_p \sqrt{n_s}, E_s = E_p \sqrt{n_s}, R_s = 2l_p \sqrt{n_s}, S_s = 2k_B n_s, T_s = \frac{T_p}{4\sqrt{n_s}}, I_s = N_s = 2n_s \text{ (bit),}$$

$$\tau_s = \frac{4}{3}\pi t_p n_s^{3/2}, L_s = \frac{L_p}{4\pi n_s} \text{ etc,}$$

where $M_p, E_p, l_p, t_p, L_p, T_p$ are Planckian units of the mass, energy, time, luminosity and the temperatures consecutively, k_B - Boltzmann constant.

The more information about these results can be found in our report on MG-16 (V. Borsevici "Condensed light, quantum black holes and L-CDM cosmology..." published in World Scientific (2023), registered by DOI and NASA).

We especially note that the quantum mechanical form of describing a black hole maybe replaced using natural substitutions such as

$$n_s = M_s^2 / M_p^2 = \frac{G}{\hbar c} M_s^2 = E_s^2 / E_p = \frac{G}{\hbar c^5} E_s^2 = \frac{R_s^2}{4l_p^2} = \frac{c^3}{4\hbar G} R_s^2 \text{ etc.}$$

As example, through these substitutions one can easily compare our results with the results of Bekenstein and Hawking:

$$S_s = \frac{k_s c^3 \hbar^{-1} G^{-1}}{8\pi} A_s = S_s(\text{Bekenstein}) / \ln 2 = S_s(\text{Hawking}) / 2\pi,$$

$$T_s = \frac{\hbar c^3}{4k_B G M_s} = 2\pi T_s(\text{Hawking}).$$

As we can see our results are not very different from the results of Bekenstein and Hawking (which clearly indicates that we are on the right track), however we received them not by intuitive assumptions, but from clear and precise physical principles and relationships, as well as the experimental basis.

2. On the fundamental importance of Planck equivalences and relations

As is known, one of the sure signs of consistence of a well founded theory is that some fundamental constants, equivalences and relationships directly follow from it. In our case, we independently came up with a remarkable Planck Units System. This forces us to take very seriously the consideration of the physical meaning and of the consequences arising from it. As examples:

$$\text{Planck force: } F_p = G \frac{M_p M_p}{l_p^2} (\text{Newton}) = M_p a_p (\text{Newton}),$$

$$\text{Planck work: } W_p = F_p l_p = \frac{\hbar}{c} a_p = E_p,$$

$$\text{Planck energy: } E_p = M_p c^2 (\text{Einstein}) = \hbar \omega_p (\text{Planck}), \omega_p = 1/t_p,$$

$$g_p = G \frac{M_p}{l_p^2} = \frac{F_p}{M_p} = a_p (\text{Einstein equivalence principle}),$$

$$\text{Planck momentum: } P_p = E_p / c = M_p c = \hbar / l_p (\text{de Broglie}),$$

$$P_p l_p = E_p t_p = \hbar (\text{Heisenberg uncertainty principle}),$$

$$\text{Planck temperature: } T_p = E_p / k_B = \frac{\hbar}{c k_B} a_p (\text{Unruh relation}) \text{ etc,}$$

where a_p is Planck acceleration, g_p - Planck gravity, ω_p - Planck cyclic frequency, and so on. We'll be using them in what follow.

3. Energy and entropy radiation of black holes

Presented description of a black hole is very close to the famous 2D Kip Thorne's "membrane" taken as "stretched horizon". With two significant differences:

1) presented "membrane stretched horizon" if formed by 2D photonic condensate;

2) in our case the tremendous gravitational squeezing force $F_s = dE_s/dR_s$, equal to half the Planck force, is perfectly equilibrated by the same but repulsive quantum-mechanical one:

$$F_s(\text{quantum repulsive force}) = N_s \frac{dE_{sm}}{dR_s} = \frac{R_s^2}{2l_p^2} \frac{d(\hbar c/R_s)}{dR_s} = -F_p/2.$$

To deep understand, what opposing forces we are talking about, let us give the following example: the force of gravitational attraction between two supermassive black holes with 100 billion solar masses at a distance just 10 gravitational radii is equal to only half percent (!!)

of these monstrous opposing forces. However, this tremendous equilibrium is rhythmically disrupted by quantum spontaneous V. Mukhanov-J. Bekenstein quantum transition from n_s energy level to underlying n_s-1 one (like in hydrogen atom), accompanied with mentioned above two-particle emission and gravitational radiation with quadrupolar and octupolar modes, expressed by following fundamental scheme:

$$BH_s \rightarrow BH_{s-1} + 2\gamma_s + \Gamma_s,$$

with

$$E(BH_s) = E_p \sqrt{n_s}, E(BH_{s-1}) = E_p \sqrt{n_s - 1},$$

$$\Delta E_{s,s-1}(\text{rad}) = E_p \sqrt{n_s} - E_p \sqrt{n_s - 1} = \Delta E_{s,s-1} \text{qu}(\text{rad}) + \Delta E_{s,s-1} \text{gr}(\text{rad}),$$

$$\Delta E_{s,s-1} \text{qu}(\text{rad}) = 2 \times \frac{E_p}{4\sqrt{n_s}},$$

$$\Delta E_{s,s-1} \text{gr}(\text{rad}) = \Delta E_{s,s-1}(\text{rad}) - \Delta E_{s,s-1} \text{qu}(\text{rad}) = \Delta E_{s,s-1} \text{qu} \left(\frac{1}{4n_s} + \frac{1}{8n_s^2} + \dots \right);$$

from Clausius relation:

$$\Delta S_{s,s-1} = \frac{\Delta E_{s,s-1} \text{qu}(\text{rad})}{T_s(\text{rad})} = \Delta S_{s,s-1} \text{qu}(\text{rad}) + \Delta S_{s,s-1} \text{gr}(\text{rad}), T_s(\text{rad}) = T_s,$$

$$\Delta S_{s,s-1} \text{qu}(\text{rad}) = k_s 2(\text{bit}), \Delta S_{s,s-1} \text{gr}(\text{rad}) = k_s 2(\text{bit}) \left(\frac{1}{4n_s} + \frac{1}{8n_s^2} + \dots \right),$$

where $\Delta E_{s,s-1}(\text{rad})$ – all emitted energy, $\Delta E_{s,s-1} \text{qu}(\text{rad})$ – the energy of two emitted particles, $\Delta E_{s,s-1} \text{gr}(\text{rad})$ – the energy of gravitational radiation, $\Delta S_{s,s-1}$ – the emitted entropy, that increases the total entropy of the Universe, $\Delta S_{s,s-1} \text{qu}(\text{rad})$ – two particle radiation entropy, $\Delta S_{s,s-1} \text{gr}(\text{rad})$ – gravitational radiation entropy. Typically, we are dealing with the two-photons emission, with one very important exception when it comes to baryogenesis (see below).

To clarify the deep physical meaning of the results obtained, we must "dress" the "naked" mathematical form

$$\Delta E_{s,s-1}(\text{rad}) = E_p (\sqrt{n_s} - \sqrt{n_s - 1}) = \frac{E_p}{2\sqrt{n_s}} \left(1 + \frac{1}{4n_s} + \frac{1}{8n_s^2} + \dots \right)$$

in clear physical garments.

The serious attitude towards Planck equivalences and relationships comes to our aid:

1) taking into account the simple physical expression for the acceleration a_s , associated with the dynamical process of evaporating black hole

$$a_s = \frac{F_s}{M_s} = \frac{F_p/2}{M_p \sqrt{n_s}} = \frac{a_p}{2\sqrt{n_s}}$$

and Planck equivalence $E_p = \frac{\hbar}{c} a_p$, one can easily find the very interesting accelerated physical form:

$$\Delta E_{s,s-1}(\text{rad}) = \frac{\hbar}{c} a_s + \frac{\hbar}{c} a_s \left(\frac{1}{4n_s} + \frac{1}{8n_s^2} + \dots \right),$$

where the first term express the energy of two emitted particles, the second term is related to energy of gravitational radiation, expressed by quadrupolar $1/(4n_s)$ and octupolar $1/(8n_s^2)$ terms;

$$2) \text{ from Planck equivalence } T_p = \hbar \frac{a_p}{c k_B}$$

we immediately find the amazing expression for temperature and acceleration:

$$T_s(\text{rad}) = \frac{E_p}{4 c k_B \sqrt{n_s}} = \frac{\hbar a_p}{4 c k_B \sqrt{n_s}} = \frac{\hbar}{2 c k_B} a_s = T_s,$$

which suprisingly clearly and physically convincingly confirms famous W. Unruh theorem about the connection of vacuum two-particle radiation and acceleration.

Here we must pay attention to the important historical fact that it was this Unruh theorem that allowed the remarkable physicist T. Jacobson to derive Einstein's equation from thermodynamics. Above we also used the Clausius relation, inspired by his deep statement: "*The black hole entropy without black holes*".

Note that the values of gravitational radiation energy and the emitted gravitational entropy are very significant only in the Planck-scale range, i.e. in the Planckian epoch, where quantum numbers begin with first natural numbers. But it is these first numbers, that will open the door to the Beginning of Time.

4. Lifetime and luminosity of primordial black holes, removing the "information loss" paradox

Based on the strong conditions of causality and spherical geometry we can calculate the time of transition from one state to underlying one: it is equal to half the length of the geodesic line divided by the speed of light:

$$\Delta t_{s,s-1} = \pi R_s / c = 2 \pi t_p \sqrt{n_s}.$$

A propos, from this formula we easily find the above mentioned expression for black hole lifetime

$$\tau_s = \sum_{n=1}^{N_s} 2 \pi t_p \sqrt{n} \equiv \int_0^{n_s} 2 \pi t_p \sqrt{n} dn = \frac{4 \pi}{3} t_p n_s^{3/2} = \tau_s(\text{Hawking})/3840$$

and luminosity

$$L_s = \frac{\Delta E_{s,s-1}}{\Delta t_{s,s-1}} = \frac{E_p / (2\sqrt{n_s})}{2\pi t_p \sqrt{n_s}} = \frac{l_p}{4\pi n_s} = \frac{\hbar c^6}{4\pi G^2 M_s^2} = 3840 L_s(\text{Hawking}).$$

This time we got a very significant difference from Hawking results, since he proceeded from unsubstantiated assumption, that black hole radiates like a black body and obeys the Stefan-Boltzmann law. In contrast, we find that black holes emit with much greater intensity by the way of quantum radiation.

If during this time the black hole does not receive the required dose of energy, it will begin to evaporate.

Note, that from the energy of each emitted particle

$$E_y(\text{rad}) = \Delta E_{s,s-1} qu(\text{rad}) / 2 = \frac{E_p}{4\sqrt{n_s}}$$

one can easily find that their emitted wavelength is much more than R_s :

$$\lambda_y(\text{rad}) = \frac{2\pi \hbar c}{E_y(\text{rad})} = 4\pi R_s > R_s$$

from which it clearly follow that for quantum two-particle quantum mechanical emission the tremendous gravitational field of black hole do not represents any obstacle. They both leaving the black hole by tunneling effect, taking with it exactly two bit of quantum information that the black hole loses. As we can see this completely removes so-called "information loss" paradox.

5. Accretion of free light by quantum absorption, the disks and jets origin

On the other hand, taking into account the quantum properties of black hole condensed light, it becomes clear that only free light photons with a wavelength no greater than black hole geodesic line become objects of accretion by quantum absorption.

In other words, black holes "feed" only on free light or condensed light, i.e. other black holes through colliding and merger. All "ordinary" matter is "melted" in disks and "evacuated" by jets accompanied by swirling magnetic fields by the ways of "funnel" and "slingshot" effects. In this case, we find that wavelength of the absorbed photon would not be greater than the geodesic length:

$$\lambda_y(\text{absorp}) \leq \lambda \pi R_s = \lambda_{sm},$$

which is equivalent to the energy quantum absorption condition

$$E_y(\text{absorp}) \leq \frac{2\pi \hbar c}{\lambda_{sm}} = \frac{\hbar c}{R_s}.$$

If during a mentioned above time interval

$$\Delta t_{s,s-1} = 2\pi t_p \sqrt{n_s},$$

equal to the duration of quantum transition from n_s to n_s-1 energy level, black hole does not receive the mentioned above free light quantum of energy, it continues to evaporate. If it receives, it grows according to law

$$\Delta R_{s\gamma} = \frac{2G}{c^4} E_\gamma(\text{absorp}) \geq \frac{2G\hbar}{c^3 R_s} = \frac{l_p}{\sqrt{n_s}},$$

while the absorption area A_s increases by an amount equal to

$$\Delta A_{s\gamma} \geq 16\pi l_p^2.$$

Note, that similar results led Bekenstein to his famous formula for the black hole entropy ("Black holes and Entropy", 1973).

However, for the cosmology (dark matter formation) the most important is the result that follows from presented calculation:

$$E_\gamma(\text{absorp}) \geq 2 E_\gamma(\text{rad}),$$

expressed in terms of temperature in the following striking way:

$$T_\gamma(\text{absorp}) \geq 2 T_s,$$

what means the following: when temperature of the Universe drops below the double temperature of a black hole it begins to evaporate.

This is a very important conclusion; moreover, it is the key to understanding how, in the very early Universe, the death of one generation of primordial black holes served the growth of the next generation.

We will need respect these most important cosmological conditions in our analysis of how modern dark matter, consisting of asteroid-like mass black holes, was formed.

Another most important consequence of these relations: an evaporating black hole is capable of radiative transferring of its electromagnetic radiation energy to another black hole only if the mass of the latter is twice the mass of the sourcing one.

$$M_{s_2}(\text{received}) \geq 2 M_{s_1}(\text{emitted}).$$

These are the relationships that explain how, at the very early stages of the development of the Universe, there was a cyclic transfer of energy from dying, more numerous but lighter generation of black holes to a new, much less numerous but heavier one.

This is the key to understanding not only the very early formation of the structure of dark matter, but also the key to understanding the very early "clumping" of the Universe, since these regular cycles of the generation of regular dark matter were accompanied by the hyperexponential growth of future supermassive black holes (SMBHs), as centers of formation of future galaxies.

6. Quantum information conservation law and the gravitational radiation energies of collidings and mergers black holes

We find two-particle emission (both outside blackhole) accompanied with gravitational radiation remove so-called "information loss paradox". Because, accordingly to the J.Preskill-L.Susskind definitions, each particle is the carrier of one C. Shannon bit of quantum information, corresponding to two spin states $|0\rangle$ and $|1\rangle$ in P. Dirac notation. This clearly demonstrates the inviolability of unitarity principle of quantum theory.

Based on the fundamental unitarity principle of quantum theory expressed in form of conservation information law:

$$I_{s_{1,2}} = I_{s_1} + I_{s_2} = 2n_{s_1} + 2n_{s_2},$$

we find a remarkable expression for the energy of gravitational radiation caused by colliding and merger of binary black hole system:

$$E_{s_{1,2}}(gr.rad.) = E_p \left(\sqrt{n_{s_1}} + \sqrt{n_{s_2}} - \sqrt{n_{s_1} + n_{s_2}} \right)$$

which in terms quantum numbers confirms the famous Stephen Hawking “areas theorem” for colliding and merger black holes (1971). More recently a team of Kip S. Thorne’s disciples, analyzing the LIGO collaboration data related to the “ringdown” phase of this process, convincingly confirmed the rightness of the great physicist.

For N successive collisions and mergers of N black holes we obtain the general expression for total gravitational radiation energy:

$$E_{sn}(gr.rad.) = E_p \left(\sum_{i=1}^N \sqrt{n_{si}} - \sqrt{\sum_{i=1}^N n_{si}} \right) = \left(\sum_{i=1}^n M_{si} - \sqrt{\sum_{i=1}^n M_{si}^2} \right) c^2,$$

where $M_{sn} = \sqrt{\sum_{i=1}^N M_{si}^2}$ is the mass of the “resulting” black hole (an amazing case of the famous Pythagorean theorem!)

The last two formulas are extremally important solving key problems of cosmology:

1) When the mass of the one of N black holes, for example, a mass of supermassive black hole (SMBH) in the centers of galaxies is immeasurably greater than the asteroid-like mass of dark matter PBHs, than as results of their mergers, almost all of their mass/energy is converted into the energy of gravitational waves, that is, the irreversible dark energy of the Universe. Note, that this is a remarkable confirmation of P. W. Anderson last prophetic conjecture.

Moreover, as will be shown later, it is these processes that are the cause of the current, second stage of the accelerated expansion of the Universe.

2) On the other hand, from these formulas is quite obvious, that during N-fold collisions and merges of approximately equal massive black holes, a supermassive one can not be formed - the overwhelming majority of their total energy would be converted into gravitational radiation. Therefore, SMBHs could only have formed due to tremendous light energy of the very early Universe.

As we will show below, without these important results it is impossible to describe and understand the most important role of PBHs and their gravitational radiation in the cosmogenesis.

7. Planck-scale physics, hot Big Bang and first stage of accelerated expansion of the Universe

Perhaps the most surprising thing in the presented approach is the logical and natural appearance of Planck units system without any additional unreasonable and unfounded assumptions and hypothesis. Moreover, from this unexpected emergence we find the very realistic principles, laws and relationships that governed the observable Universe in its primordial state. This directly opens the door to the Terra Incognita of Planck-scale physics and Beginning of Time.

Moving backwards along the "arrow of times" we find the "graininess" spacetime consisting of 3D Planck condensed photons with a tremendous Planck energy and mass densities. These condensed photons are "incapsulated" in its own non-Euclidean spacetime in which the ratio of the circumference to the radius is equal to one, which is confirmed by the tremendous value of Planck gravitational potential $\phi_p=c^2$. But this homogeneous and "graininess" 3D Planck photon condensate as whole represents extremely dense spherical package characterized by "ordinary" Euclidean metric.

From Planck-Heisenberg uncertainty relation $E_p t_p = \hbar$ it follows that the lifetime of such an extremely unstable initial state of observable Universe is equal to the Planck time. Due to its extreme instability this initial state "explodes" exactly with assumption of the hot Big Bang theory. The most questions arise: what happens during this explosion, what is its duration, and what happens next during Big Bang?

It is not difficult to see that among all the homogeneous "granular" spacetime with its dense spherical packing, each condensed Planck photon is surrounded by twelve other condensed Planck photons. What is probability after the explosion this surrounded photon will become free? Exactly as the probability that all the remaining twelve do not form Planck binary systems among themselves and with other nearest neighbors. Solving the simplest equation of the twelfth degree:

$$\aleph = (1 - \aleph)^{12},$$

we give the desired probability: $\aleph = 0.1474492855... \approx 0.14745$

Taking into account the exceptional importance of this cosmological number, we have designated it with the symbol \aleph , "alef", which means "first", "most important".

Why are we talking about Planck binaries? Because during the Big Bang their merger gives rise to Planck primordial black holes accompanied with Planck gravitational waves. According to the law of energy conservation each Planck binary system, equal to two Planck mass-energy units inevitably converted into the mass-energy of Planck black hole, while the Planck work, associated with the merger process necessarily entails Planck gravitational radiation.

Mathematically the whole process is expressed as follow:

1) with probability \aleph , condensed Planck photons turns into free ones:

$$(\gamma_p) \rightarrow \gamma_p(\text{free}),$$

the average value of energy density of free Planck light

$$\Omega_L = \aleph \approx 0.14745;$$

2) with probability $1 - \aleph$, the following transformation of Planck binaries (γ_p, γ_p) into Planck black holes (BH_p) occur accompanied by Planck gravitational waves:

$$(\gamma_p, \gamma_p) \rightarrow BH_p + \Gamma_p,$$

where the energy of the gravitational radiation is caused by Planck work w_p :

$$E(\Gamma_p) = W_p = F_p l_p = G \frac{(M_p M_p)}{l_p^2} l_p = E_p,$$

$$E(BH_p) = E(\gamma_p, \gamma_p) - E(\Gamma_p) = 2E_p - E_p = E_p,$$

we find the average value of Planck dark energy density

$$\Omega_{DE} = \frac{1 - \aleph}{2} \approx 0.42628,$$

the average value of mass/energy density of Planck dark matter

$$\Omega_{DM} = \frac{1 - \aleph}{2} \approx 0.42628.$$

In other words, we find that the energy densities of primary free light, dark matter and dark energy are distributed accordingly following proportion:

$$\Omega_L : \Omega_{DM} : \Omega_{DE} = \aleph : \frac{1 - \aleph}{2} : \frac{1 - \aleph}{2} \approx 0.14745 : 0.42628 : 0.42628.$$

Note, if we take the primary 3D Planck photon condensate as the "dark" initial matter, then this process of the hot Big Bang amazingly corresponds to the biblical tale of Genesis: "...and the Creator separated Light from Darkness, and there was the First Day (\aleph)..."

It is necessary to clarify that the breakdown of extremely homogeneity, which broke the initial "graininess" spacetime into Planck binaries and isolated condensed Planck photons, occurred due to the actions of spontaneous Planck-fluctuation. Figuratively speaking, Planck "granules" acted as "binary explosive", while Planck fluctuations as "fuses".

It is also easy to calculate the duration process in two different ways. The wavelength of a Planck free photon is 2π times longer than that of Planck condensed one equal to Planck length. Naturally, the deployment of such a wavelength requires time equal to the $2\pi t_p$. The second similar solution follows from the time of formation of the Planck black holes. Based on principle of causality it is equal to half the length of its geodesic line divided by the speed of light, i.e., $2\pi t_p$. This amazing coincidence is far from accidental, since it proves the complete and universal synchronizations of all processes at the times of Big Bang.

Calculation shows that in this case the cosmical Λ -parameter reaches the highest value at order $1/l_p^2$, 122 decimal orders (!) of magnitude more than the recent one. Let us note that his value corresponds to the Hubble parameter of order $1/t_p$, the maximum possible one.

However what happened in the next "days of creation"? Further cosmological events begin to develop in full accordance with the premises, presented in the previous sections.

Almost all the energy of the Planckian free light is absorbed by the \aleph part of Planck black holes, that doubling their mass/energy. But this leads to a decrease in the energy of dark matter mass/energy density to the value $\Omega_{DM}=2\aleph_s$. The remaining part of Planck black holes decays into two photons $\gamma_{p,0}$ and gravitational wave $\Gamma_{p,0}$:

1) with a probability \aleph the next generation of black holes is formed by followed scheme

$$\gamma_p + BH_p \rightarrow BH_s (n_s = 4)$$

with

$$M_s = M_p \sqrt{4} = 2 M_p$$

and average (typical) dark matter mass/energy density

$$\Omega_{DM} = 2 \aleph' \approx 0.29489 ;$$

2) with a probability $\frac{1-\aleph'}{2} - \aleph' = \frac{1-3\aleph'}{2}$ the Planck black hole decay occurs:

$$BH_p \rightarrow 2\gamma_{p,0} + \Gamma_{p,0} ,$$

with

$$2E(\gamma_{p,0}) = 2 \times \frac{E_p}{4} \text{ and } E(\Gamma_{p,0}) = \frac{E_p}{2}$$

and average incremented dark energy

$$\Delta\Omega_{DE} = \frac{1-3\aleph'}{2} \times \frac{1}{2} = \frac{1-3\aleph'}{4} \approx 0.13941 ,$$

the average irreversible dark energy density

$$\Omega_{DE} = \Omega_{DE}(\text{precedent phase}) + \Delta\Omega_{DE} = \frac{1-\aleph'}{2} + \frac{1-3\aleph'}{4} = \frac{3-5\aleph'}{4} \approx 0.56569 ,$$

the average Ω_L of emitted through the Planck BH_p decay $\gamma_{p,0}$ photons:

$$\Omega_L = 1 - \Omega_{DM} - \Omega_{DE} = \frac{1-3\aleph'}{4} \approx 0.13941 .$$

A propos, by direct calculation

$$\Omega_L = \frac{1-3\aleph'}{2} \times 2 \times \frac{1}{4} = \frac{1-3\aleph'}{4}$$

we find the same result.

If we compare this second phase ("the second day of creation") with precedent (Big Bang) one, we find dark energy density at Big Bang increasing from zero to 0.42628, but at the second phase of the Planck epoch it increases only with the value of $\Delta\Omega_{DE} \approx 0.13941$. This means considerable decrease in accelerated expansion in the "baby Universe" (when this increment stops, the Universe enters in the stage of non-accelerated expansion). We must notice that in parallel with this there dark matter density drops from the 0.42628 to the value of 0.29489.

From this moment on, the gravitational mass of the Universe represented exclusively by dark matter will constantly fall, serving as a bottomless reservoir of energy for its subsequent generation up to the formation of modern dark matter, as well as for subsequent formation of very massive and supermassive black holes and "ordinary" matter.

Let us proceed, in the analysis of the third phase (the "third day of creation") of the Planckian Era. Through the quantum absorption, the generation of typical black holes BH_s ($n_s=4$) will quickly grow to the typical generation BH_s ($n_s=8$). How do we know this?

Based on the previous phase, we find that the maximum energy reserve for the growth of a typical primordial black holes BH_s ($n_s=4$) through the quantum absorption of free light must be expressed as the sum of preceding phase

$$\Omega_{DM}(max) = \Omega_L + \Omega_{DM} = \frac{1+5 \mathcal{N}'}{4}.$$

In terms of a typical black hole, this gives the average mass

$$M_s = M_p \frac{\Omega_L + \Omega_{DM}}{\mathcal{N}'} = \frac{1+5 \mathcal{N}'}{4 \mathcal{N}'} \approx M_p 2.945498 .$$

However, this number 2.945498 is not in the series expressed in the form of $\sqrt{n_s}$. Based on the principle of maximum of black hole entropy s_s , we find that the largest number n_s that satisfies the natural condition: $\sqrt{n_s} < 2.945498$.

As result, we get $n_s=8$, the required number for a typical third generation black hole.

Using previously obtained results, we find the lifetime

$$\tau_s = \sum_{n=1} 2 \pi t_p \sqrt{n} \approx 32.6 \pi t_p$$

and emitted free light density

$$\Omega_L = \mathcal{N}' \sum_{n=1}^{n_s=8} \frac{1}{2\sqrt{n}} \approx 0.32228 .$$

The first result tells us that, taking into account the previous phases, the total duration of the Planckian Era does not exceed the value $50\pi t_p \approx 8.46e-42$ sec.

From the second result it follows that entire dead generation of primordial black holes emitted the enormous light energy, which was spent on the development of new generation.

According to previous results related to the laws of quantum absorption, we already know, we already know that for radiative transfer from a black hole to another one, the mass of latter must be not less than twice of the first one. But where do the last ones come from?

We were worked only with average, typical values of generations of black holes until now. In fact according to the laws of probability theory, we must take in account a relatively very small, but very important amount amount of black holes capable to form a new generation with mass/energy density

$$\Omega_{DM} \approx \Omega_{DE} \approx 0.32228 .$$

Since practically all light energy was absorbed by this generation of primordial black holes, we come to a remarkable conclusion: at the end of the Planckian Era dark energy reaches almost it's maximum value:

$$\Omega_{DE} \approx 1 - \Omega_{DM} \approx 0.67771 ,$$

and it's last increment:

$$\Delta\Omega_{DE} \approx 0.67771 - 0.56569 \approx 0.11202 .$$

The latter means that with the end of the Planckian Era the first stage of the accelerated expansion of the Universe ends, and, the stage of non-accelerated but very rapid expansion begins, what we will show below.

If we compare the obtained value of dark energy density 0.67771 with the modern data from 0.685 and above, then we will get that over the five to six billion years the Universe has accelerated in accordance with the increment

$$\Delta\Omega_{\Lambda} \geq 0.0073 \text{ (i.e. 0.73\% and more)}$$

depending of the significant recent discrepancy in the results of different approaches to the measurements.

8. Between the Planckian Era and the Baryogenesis Epoch: solving the problem of supermassive black holes formation and the very early "clumping" of the Universe

As it was established above, the development of generations of black holes proceeded precisely through radiative transfer of light energy from one much more numerous generation, but much "lighter", to a much less numerous, but much "heavier" one.

All this can be expressed in a simple and clear form with far-reaching consequences:

$$\#_{sj} E_p \sqrt{n_{sj}} = \#_{sj-1} E_p \sqrt{n_{sj-1}} = \Omega_{DM} E_u ,$$

where $\#_{sj}$ and $\#_{sj-1}$ represent the average numbers of the black holes in a given and previous generations respectively, while n_{sj} and n_{sj-1} refer to the typical quantum numbers representing these generations, E_u - the all energy of the observable Universe. It is not difficult to understand, that the time lag between generations is equal to the lifetime of the previous generations.

$$\Delta t_{sj, sj-1} = \frac{4\pi}{3} t_p (\sqrt{n_{sj-1}})^3 ,$$

It is easy to see the direct relationship between the $\sqrt{n_s}$ and the time:

$$\sqrt{n_s} \propto t^{1/3} .$$

Taking into account that the cosmological scale factor a is proportional to $\sqrt{n_s}$, we find that

$$a \propto \sqrt{n_s} \propto t^{1/3} ,$$

Hubble parameter

$$H(t) = \frac{\dot{a}}{a} = \frac{dt^{1/3}/dt}{t^{1/3}} = \frac{1}{3t} ,$$

and Hubble radius

$$R_H(t) = \frac{c}{H(t)} = 3ct .$$

Let's check our results, knowing that the age of the Universe and its observable radius are respectively

$$\text{Age}_U = 8.08 \times 10^{60} t_p \text{ and } R_U = 2.7 \times 10^{61} l_p .$$

We find

$$R_H(\text{Age}) = 3c \times 8.08 \times 10^{60} t_p = 4.424 \times 10^{61} l_p .$$

What do these surprising results mean?

Firstly, that the proposed approach copes well with the difficult problems of cosmology.

Secondly, this confirms the very rapid non-accelerated expansion of the very early Universe.

The difference of only minus 10% between the obtained Hubble radius and the radius of the modern Universe clearly indicates that the latter has increased significantly due to the second stage of the accelerated expansion.

Having understood the development of generations of the dark matter over time, we are ready to solve the puzzling problem of the birth and hyperexponential growth of supermassive black holes (SMBHs).

Immediately after the end of the Planckian Era an incredibly rare event will begin to occur: some very rare primordial black holes acquire masses much greater than the masses of typical black holes. Each death of the next generation led to the colossal emission of light energy, which was absorbed by the rapidly growing accreted surface of these future monsters.

Based on the fact, that both the quantum information of the growing black hole and its accretion area are proportional to the quantum number, in accordance with Bohr's correspondence principle, it is not difficult to write an equation describing $n_s(t)$ growth:

$$\frac{dn_s(t)}{dt} = B_s(t)n_s(t) ,$$

where $B_s(t)$ is accretion (light absorption) function, expressing the dependence on the radiation of each generation of typical black holes evaporation

$$n_s(t) = \exp \left\{ \int B_s(t) dt \right\} .$$

As the result we obtain hyperexponential growth of the mass of a supermassive black hole:

$$M_{SMBHs}(t) = M_p \exp \left\{ \frac{1}{2} \int B_s(t) dt \right\} .$$

Note that cumulative integral of a function $B_s(t)$ expresses the hyperexponential growth of SMBHs.

As a result of this hyperexponential growth, the forming dark matter begins to "clumping" around the growing monster and shape dark halo formation regions of the future galaxies. As we will show below, it was the penultimate typical generation of primordial black holes that will produce baryogenesis and pass its baton to the modern generation of dark matter and "ordinary" matter. According to our estimates, the Baryogenesis Epoch began not later than a hundred years after Big Bang.

9. Baryogenesis through primordial black hole production

The problem of baryogenesis and leptogenesis is one of the most difficult unsolved problems of cosmology and particle physics.

However the key to solution is that this "ordinary matter" is always surrounded by dark matter, and it's concentration is greatest where the concentration of dark matter is greatest. That is in galaxies, clusters, superclusters - that form so-called "Cosmic Web".

Let's do what Einstein did: he accepted the experiments on the constancy of the speed of light as the postulate. We will also take the observed baryon asymmetry as a postulate and relate it to black holes production of two-particle according to the scheme:

$$BH_s \rightarrow 2n^0, 2n^0 \rightarrow 2p^+ + 2e^- \dots$$

when n^0 , p^+ , e^- referred to the neutron, proton and electron, we can easily determine the restriction imposed to the "productive" quantum numbers from

$$\frac{E_p}{4E(c-q)} \leq n_s \leq \frac{E_p}{4E(n^0)},$$

where $E(n^0) = 0.9396\text{GeV}$ is the rest energy of the neutron, $E(c-q) = 1.25\text{GeV}$ of the free "charm" quark, next in this parameter after neutron. We needed the "charm" quark rest energy in order to determine the quantum number $n_s(c-q)$ at which neutron production stops. Using a simple equation

$$\frac{[2n_s^*(n^0) - 2n_s(c-q)]E(n^0)}{E_p \sqrt{n_s^*(n^0)}} = \frac{\Omega_L}{\Omega_{DM}}$$

we can determine the boundary typical number $n_s^*(n^0)$ which characterises the generation of black holes capable of production "ordinary matter" of the observable Universe. Note, that the number of baryons in the Universe (Eddington number $=10^{80}$) is 10^{41} times more than the number of modern dark matter black holes. It is the subject to think about.

Here the expression on the left side denotes the productivity of one typical black hole, expressed as the number of neutron it produces (square brackets) times the rest energy of neutron and divided by the rest energy of typical producing black hole. This should be equal to the energy density of baryon $\Omega_B = 0.0496$ divided by the energy density of the producing black hole $\Omega_{DM} = 1-0.6777$.

Solving this equation $\sqrt{n_s^*(n^0)}$ we find that it's equal to 2.99×10^{18} .

Solving these two quantum numbers, $n_s^*(n^0)$ and $n_s(c-q)$, we find, that the duration of the production process of baryonic matter is equal to 102 thousand years, while the all process of the evaporation and death of the producing generation lasted for about 190 thousand years. It fit perfectly into half of cosmic time from Big Bang to Recombination Epoch, equal to 388 thousand years. All this was accompanied by the last process of the great reheating of the Universe.

Let us remember, that all this processes was happened "in clumps" of nascent galaxies. After cooling, all ordinary matter was restored in forms of relatively cold plasma of primary nucleosynthesis.

10. Completion of the creation of modern dark matter and large scale structure

Along with the process of baryogenesis and leptogenesis the process of radiative transfer of light energy from the last generation of dead primordial black holes to the modern ones is continued.

This process ended, when the temperature in "clumps" dropped the hard cut-off at $511\text{keV}/k_B$ (the rest energy of electron) to the typical temperature $80\text{keV}/k_B$ and the so-called Bremsstrahlung hard X-ray radiation.

Using the formulas that connect the threshold accretion temperature with the mass of black hole and it's other parameters, we find the following typical characteristics of t modern dark matter:

$$\text{typical } \sqrt{n_s} = \frac{Ep}{2 \times 80 \text{ keV}} = 7.625 \times 10^{22}, M_s = 1.659 \times 10^{18} \text{ g},$$

$$\text{minimal } \sqrt{n_s} = \frac{Ep}{2 \times 511 \text{ keV}} = 1.194 \times 10^{22}, M_s(\text{min}) = 2.598 \times 10^{17} \text{ g};$$

the parameter of emitted hard X-ray spectrum:

$$\text{the peak } E_\gamma = 30 \text{ keV}/k_B, \text{ typical } 40 \text{ keV}/k_B, \text{ hard cut - off at } 250 \text{ keV}/k_B.$$

It is this unsolved hard X-ray spectrum, that astrophysists find throughout th Universe in the active centers of galaxies, clusters and superclusters. It appears especially brightly in the coronas of supermassive black holes, even in the so-called "non-jets" events (!). The later clearly shows that these great clusters of dark matter in SMBHs corona by the process of colliding and merging are among the most powerful sources of dark energy production, that cause increasing acceleration of the modern Universe.

Regarding the exceptionally early process of clumping of "ordinary" matter and the halo of dark matter, we should not be very surprised by the galaxies discovered by JWST.

Note that in very early Universe galaxies were located very close to each other, forming one large universal "supercluster". And only ae Universe rapidly expanded, bricks and filaments appeared in it, connecting relic of clusters and sureclusters. Also note that superclusters are always confined to supervoids, resulted in the initial homogeneity only on very large scales.

Without knowing the past it is difficult to understand the present. In conclusion, there is lot to learn following the ideas and advise of our great predecessors.

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