Cosmic Reionization of Hydrogen and Helium and the Supermassive Black Holes in Very Distant Universe

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Abstract: Here, applying the Scale-Symmetric Theory (SST), we answered following question: What is the origin of the cosmic reionization? Presented here scenario differs radically from that described within the mainstream cosmology. Most important are masses of massive galaxies/quasars and the decays of large cosmic structures. Highest rate of reionization of hydrogen should be for redshift z(H,max) = 11.18 whereas complete reionization should occur at z(H,end) = 7.10. For reionization of helium we obtain respectively z(He,max) = 3.63 and z(He,end) = 2.70. Theoretical results are consistent with observational data. We showed that number and energy of created photons were sufficient to ionize the intergalactic medium. We answered as well the second very important question: Why there appeared the supermassive black holes so quickly?

1. Introduction

In the mainstream cosmology it is assumed [1] that the initial recombination of protons and electrons took place about 380 thousand years after the Big Bang – it created the gradually redshifting cosmic background radiation. It was the beginning of the dark ages that lasted about 0.4 Gyr. Before the reionization, the Universe was non-transparent because of the scattering of photons. Since about 0.15 Gyr up to 1 Gyr after the Big Bang matter started to condense so rate of reionization increased but due to the expansion of the Universe, matter had been diffused so with time it was more and more transparent (with time, the scattering processes were less frequent). But initially the recombination rate was higher than the reionization rate so the dark ages ended 0.4 Gyr after the Big Bang (0.4 Gyr > 0.15 Gyr).

Here we try to show that such picture is incorrect. Obtained here results within very simple model are consistent with observational data so there is very high probability that presented description is realized by the expanding Universe.

Emphasize that the reionization is still not good understood. In [1] we can read as follows: "Even with the quasar data roughly in agreement with the CMB anisotropy data, there are still a number of questions, especially concerning the energy sources of reionization and the effects on, and role of, structure formation during reionization."

The first very important question is: What is the origin of the reionization?

The second problem concerns the high abundance of supermassive black holes in the very distant observed Universe [2]. In article [2] we can read as follows (see also [3] and [4]):

“The researches also have found hints that the seeds for supermassive black holes (mass from about 10^5 to 10^{10} times the mass of the Sun) may be “heavy” with masses about 10^4 to 10^5 times that of the Sun, rather than light seeds with about 100 times the Sun’s mass. This addresses an important mystery in astrophysics about how these objects can grow so quickly to reach masses about a 10^9 times the Sun in the early Universe.”

The second very important question is: Why there appeared the supermassive black holes so quickly?

SST shows that the succeeding phase transitions of the superluminal non-gravitating Higgs field (HF) during its inflation (the initial big bang) had led to the different mass/energy scales and size scales (bigger structures consist of smaller structures) [5A]. Due to a few new symmetries and 7 parameters only, there appear the superluminal binary systems of closed strings (the spin-1 entanglons) which are responsible for the quantum entanglement (it is the quantum-entanglement scale), neutrinos and the very stable spin-1 neutrino-antineutrino pairs (NAPs) moving with the speed of light in “vacuum”, c, which are the components of the gravitating Einstein spacetime (ES) (it is the Planck scale; mass of lightest neutrino is the smallest gravitational mass; neutrinos acquire their gravitational masses due to their interactions with the Higgs field [5A]; as for electrons, we can define two different masses of a neutrino i.e. particle mass and wave mass (or their geometric mean) [6]), cores of baryons (it is the proton/electric-charge scale), and the cosmic-structure/Protoworld (it is the cosmological scale; Protoworld created the early Universe [5B]) that evolution leads to the dark-matter (DM) structures (they are built of entangled non-rotating-spin NAPs), dark energy (it consists of the additional non-rotating-spin NAPs interacting gravitationally only i.e. they are not entangled i.e. the dark energy is an infinitesimal part of the ground state of ES) and the expanding Universe (the “soft” big bang due to the inflows of the dark energy into the Protoworld) [5A], [5B]. The proton scale leads to the atom-like structure of baryons [5A].

During the inflation almost whole the non-gravitating Higgs field composed of tachyons transformed into the gravitating Einstein spacetime. The residual Higgs field causes that the ES components acquire their gravitational mass. All hadronic matter and the charged leptons consist of the ES components [5A]. At the end of the inflation there appeared boundary of the Cosmos – radius of the Cosmos is about 4 orders of magnitude bigger than the time distance to the observed most distant baryonic matter [5B]. Inside the core of the Protoworld, which was created in the centre of the Cosmos by the return shock wave (such wave was the result of the creation of the boundary of the ES [5B]), was created the very early Universe [5B]. Due to the evolution of the Protoworld, there appeared the expanding Universe [5B]. The very early Universe was the binary system of loops composed of the identical disc protogalaxies already grouped in larger structures [5B]. Our galaxy should be close to the centre of the expanding Universe so should be close as well to the centre of the Cosmos. We can refer to such a system as the Milky-Way-centric Cosmos.

Disc protogalaxies were built of the neutron black holes (NBHs) [5B]. Mass of NBH is f = 24.81 times greater than the Sun i.e. $M_{NBH} = f\, M_{Sun}$ [5B]. Single protogalaxy was built of 4^{16} NBHs [5B].

Due to the four-object symmetry, disc protogalaxies were grouped in larger structures [5B].

Number of entangled objects in a system is quantized [5B]

$$D_{n,S} = 4^{d} \text{ (for single objects),} \tag{1a}$$

$$D_{n,B} = 2 \cdot 4^{d} \text{ (for binary systems),} \tag{1b}$$

where for flat/disc-like structures is d = 0, 1, 2, 4, 8, 16… = 0, 2^n, where n = 0, 1, 2, 3, 4, 5,… whereas for chains is d = 3, 6, 12.

SST shows that we should not observe a smooth field of first stars or smooth field of first dwarf galaxies free from the massive galaxies [5B].

2. What is the origin of cosmic reionization?

According to SST, the creation and the beginning of the expansion of the Universe were separated in time from the inflation [5B]. Initially the Protoworld and the early Universe occupied volume with a radius of about 0.5 Gyr. Protogalaxies were already in the early Universe. It means that the present-day lifetime of a galaxy (the time of its evolution since the beginning of the expansion of the Universe) we can define as the sum of a period when the galaxy was carried by the expanding dark energy and a period in which the photons emitted by the galaxy reach Earth. It leads to conclusion that the most distant galaxies (they should be in time distance about 13.866 ± 0.096 Gyr) are already 7.75 Gyr old and we cannot see the initial period 7.75 Gyr of their evolution but we can see all baryonic matter [5B]. Emphasize that Ludwig et al. derived solar ages up to 22.3 Gyr (2009) [7]. On the other hand, SST shows that the Universe is about 7.75 (invisible period of evolution) + 13.866 (visible period) ≈ 21.6 Gyr old [5B].

It means that there is an impression that massive galaxies and the accompanying dwarf galaxies appear out of nowhere. Emphasize that in the most distant visible Universe there is not a smooth field of first stars or a smooth field of dwarf galaxies free from massive galaxies and supermassive black holes!

But why there are the dark ages that lasted about 0.4 Gyr and why in the very distant visible Universe we can see the reionized intergalactic medium? According to SST, the first photons were the superphotons each composed of $2 \cdot 4^{32}$ entangled elementary photons or of $2 \cdot 4^{16}$ photon galaxies [5B]. With time there were the successive decays of the superphotons and the corresponding decays of the large cosmic structures composed of massive protogalaxies [5B]. Within SST we calculated that about T = 7.54 Gyr from the beginning of expansion of the Universe, the groups of photon galaxies (each composed of 4 photon galaxies) started to decay to the binary systems of the photon galaxies (each composed of 2 photon galaxies) [5B]. At first, number density of decays increased rapidly and next gradually decreased with time. The decays of the superphotons lead to correct number of photons in the present-day CMB: approximately 391 photons per cubic centimetre [5B]. A photon composed of, say, N elementary photons was entangled as well with N protogalaxies. Due to the decays of the composite photons, there as well decayed the associations of protogalaxies so 7.54 Gyr from the beginning of expansion of the Universe (i.e. the lookback-time/light-travel-time is $21.61 - 7.54 = 14.07$ Gyr), the groups of 4 protogalaxies decayed to the binary systems of protogalaxies [5B] – it took place at the end of the unseen period of evolution of the Universe (7.54 Gyr < 7.75 Gyr).

Emphasize that SST leads to the time Hubble constant equal to $H = 70.52$ km s^{-1} Mpc^{-1}, to abundance of matter $\Omega_M = 0.3137$, and to flat Universe [5B]. Knowing these parameters and knowing the SST light travel time and applying the General Relativity (GR) calculator [8], we can calculate redshift z – in such a way we can compare the SST results with the observational data.

SST shows that mass of the typical elliptical massive galaxies was 8 time higher than the spirals [9]. It leads to conclusion that 14.07 Gyr ago there were two different decays of associations of protogalaxies: $4 \rightarrow 2$ and $32 \rightarrow 16$. The less massive associations produced more hydrogen than helium whereas the more massive produced more helium than hydrogen. It leads to conclusion that the first decay of the lighter associations of protogalaxies can be associated with reionization of hydrogen whereas the second one with reionization of helium. First, abundance of the associations of 2 (for hydrogen) and 16 protogalaxies (for helium) increased rapidly so it should lead to the redshift with highest rate of reionization $z_{A,max}$, where $A = H$ or He. On the other hand, the associations 4 (for hydrogen) and 32 (for helium) should define redshift for the end of reionization $z_{A,end}$.

Calculate the mean time of decoupling of composite photons (the diffusion time scale) produced by accretion disc of one protogalaxy. According to SST, each protogalaxy had mass $M_{Proto} = 4^{16} f M_{Sun} = 1.0656 \cdot 10^{11} M_{Sun}$. It means that a composite photon emitted by the core of a massive galaxy with a spherical symmetry (we assume it) interacts with about $(3 \cdot 1.0656 \cdot 10^{11}/(4\pi))^{1/3} \approx 2{,}941$ Sun-like stars. It leads to conclusion that a mean photon is going via centres of about 2,941 Sun-like stars i.e. the way inside stars is about 5,882 times longer than photons covering the distance from the centre of the Sun to its surface. On the other hand, photons produced in the core of the Sun need about 0.17 Myr to appear on its surface – it is the diffusion time scale of the present Sun [10]. These remarks lead to the diffusion time scale of the protogalaxies: $T_{Proto} = 5{,}882 \cdot 0.17$ Myr ≈ 1.00 Gyr. We can see that considered herein the composite photons appeared on “surfaces” of the protogalaxies (not on “surfaces” of the associations of the protogalaxies – for them the diffusion time scale is longer) about 13.07 Gyr ago. Assuming a spherical symmetry of the Sun-like stars in an association of protogalaxies (we assume that there is one sphere), we obtain following formula for the diffusion time scale of the associations T_N

$$T_N = \mathrm{N}^{1/3}\, T_{Proto}\,, \tag{2}$$

where N = 2, 4, 16, 32.

Formula for light travel time $T_{ltt,N}$ is

$$T_{ltt,N} = 14.07 \text{ Gyr} - T_N\,, \tag{3}$$

Applying formula (3) we obtain $T_{ltt,N=2} = 12.81$ Gyr, – applying cosmology calculator [8] with the SST cosmological parameters listed above, we obtain $z_{H,max} = 11.18$. This result is consistent with the observational data [11] – an instantaneous reionization redshift for hydrogen is $z_{re} = 11.3 \pm 1.1$ (Planck + WP + highL + BAO: see Table 10 in [11]).

Applying formula (3) we obtain $T_{ltt,N=4} = 12.48$ Gyr, – it leads to $z_{H,end} = 7.10$. This result is consistent with the observational data [12] – complete reionization for hydrogen occurs at $z = 7$.

Applying formula (3) we obtain $T_{ltt,N=16} = 11.55$ Gyr, – it leads to $z_{He,max} = 3.63$. This result is close to the observational data [13] – rate of ionization of helium increases from $z = 2.7$ to $z_{re} = 3.4$.

Applying formula (3) we obtain $T_{ltt,N=32} = 10.895$ Gyr, – it leads to $z_{He,end} = 2.70$. This result is consistent with the observational data [13] – rate of ionization of helium increases from $z = 2.7$ to $z_{re} = 3.4$.

Notice as well that the SST cosmological parameters lead to the light travel time about 12.8 Gyr for the galaxy GN-z11 ($z = 11.09$) whereas the mainstream parameters lead to about 13.4 Gyr so the time for its creation was much too short (about 400 million years).

3. Why there appeared the supermassive black holes so quickly?

We partially answered this question in Paragraph **2**. According to SST, the protogalaxies appeared already before the beginning of the expansion of the Universe and they were grouped in larger structures [5B]. They consisted of the neutron black holes without central singularities i.e. the black holes were produced by the Protoworld already before the beginning of the expansion of the Universe. The inflows of the dark energy transformed the protogalaxies into quasars (i.e. into opaque torus with central supermassive black hole composed of the neutron black holes) [5B]. It is the reason that we can see the supermassive black holes in very distant observed Universe. Notice that the superphotons and, next, the smaller but still big composite photons, which were entangled with baryonic matter, slowed the evolution of galaxies. The emission of photons by the massive protogalaxies caused that their evolution accelerated about 13 Gyr ago so there can be an illusion that cosmic objects are not older than about 13 Gyr.

4. Number and initial energy of photons produced by the associations of protogalaxies that reionized hydrogen and helium in the intergalactic medium

The energetic protons in the accretion discs produced the neutral pions. Each pion decayed to two superphotons each with energy equal to $E = 67.54441$ MeV [5A]. On the other hand, the evolution of massive galaxies accelerated about 13.07 Gyr ago at redshift $z = 24.57$. The associations of protogalaxies produced near them in the intergalactic medium the dwarf galaxies [14]. The superphotons interacted with the dwarf galaxies. Typical mass of such dwarf galaxies was $5.2 \cdot 10^7\ M_{Sun} = 2.1 \cdot 10^6$ neutron black holes i.e. typical dwarf galaxy had $N_C = 2.1 \cdot 10^6$ seeds of nuclear plasma. The interactions of the superphotons with such seeds can destroy the quantum entanglement between groups of elementary photons a superphoton consists of. It means that mean superphoton decays to N_C photons. Then mean photon has energy $E / N_C = 32$ eV. Such energy can ionize both hydrogen and helium. Moreover, number of produced photons with energy 32 eV is sufficient to reionize the intergalactic medium.

5. The horizon for the observed Universe

Obtained here results for reionization are in very good agreement with observational data so it is obscure why the cosmological horizon ($z \rightarrow \infty$) is in a light travel time about 13.2 Gyr (not in the time distance 13.866 ± 0.096 Gyr) – to obtain this result we put the SST cosmological parameters into the GR formula describing dependence between redshift and the light time travel. On the other hand, the SST time distance to the SST horizon (13.866 ± 0.096 Gyr) is consistent with the mainstream-cosmology age of the Universe. It suggests that, generally, we should not change the GR relation connecting redshift and light travel time for redshift smaller than about 25 but there should be an increasing correction for $z > 25$ in such a way that this correction should be about 0.6 Gyr for $z \rightarrow \infty$. It solves the problem. We can do it because in mainstream cosmology the primordial state is unknown.

Notice as well that there are some unsolved problems concerning the acceleration of the expansion of the Universe. In article [15] we can read as follows (see also [16]):

"A secondary criticism has focused on the way Type Ia supernovae are analyzed. When scientists found that distant Type Ia supernovae were fainter than expected, they concluded the universe is expanding at an accelerating rate. That acceleration is explained through dark energy…"

Even if we assume that the Type Ia supernovae are not in two different subclasses, there is still the unsolved problem why expanding spacetime does not change the gravitational constant that according to the Scale-Symmetric Theory (SST) [5A] is directly proportional to density of the non-gravitating Higgs field.

The gravitational constant is an invariant so spacetime cannot even expand (there must be a stable boundary of spacetime [5A], [5B]). It means that the third very important question is: Why the Type Ia supernovae are fainter than they should be?

Expansion of the two-component spacetime, so an acceleration of expansion as well, in a fruitful Cosmos is impossible. The Universe expands because there expands the dark energy but the present-day density of the dark energy in comparison with density of the Einstein spacetime is as 1 part in about 10^{55} parts [5B]. The dark energy is a part of the Einstein spacetime but it can only infinitesimally change the density of the Einstein spacetime – it is the reason that the gravitational constant is an invariant.

Assume that we calculated distance to a Type Ia supernova independently from its luminosity and next we predict its luminosity. Observed luminosities of such supernovae at redshift about $z \approx 0.5$ are lower than the predicted ones. It incorrectly leads to conclusion that the Universe accelerates its expansion. The higher rate of expansion of spacetime causes that supernova is fainter than it should be.

So why the Type Ia supernovae are fainter than they should be?

The distance between the relative recession velocities calculated within SST and General Relativity (GR) (for $H = 70.52$ km s^{-1} Mpc^{-1} and $\Omega_M = 0.3137$) for redshift $z = 0.4$ is 0.037 whereas for $z = 0.5$ is 0.059 [17]. It means that in reality the Type Ia supernovae are in distances larger than it results from GR so they are fainter than they should be.

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