Masses of Stellar Black Holes Based on the Atom-Like Structure of Baryons and Incompleteness of the Mainstream Theories

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Abstract: Incompleteness of mainstream theories narrows the scope of their applicability. We showed the origin of indestructibility of the cores of baryons described in the Scale-Symmetric Theory (SST) that leads to the true internal structures of black holes (BHs). Here we show that black holes are some associations of the neutron black holes (NBHs) with an invariant mass that is equal to 24.81 solar masses. The catalogs of binary mergers suggest that the NBHs can absorb the excited stellar black holes described in this article. Calculated here masses of such excited states are 2.68, 3.66, 4.87, 6.21, 10.16 solar masses. There also can be mergers only of the excited states. The excited stellar BHs are built of the cores of baryons packed to maximum. We showed that masses of the stellar black holes decrease when their mass density increases. We also calculated the coupling constant and involved energies in the quantum entanglement. We showed also the origin of the black hole star MoM-BH*-1 and that in the early Universe, due to the massive collisions of NBHs and created repulsive dark energy, masses of massive black holes rapidly decreased rather than increased.

Keywords: Scale-Symmetric Theory (SST), Stellar Black Holes, Mergers of Stellar Black Holes, Quantum Entanglement, MoM-BH*-1, Evaporation of Massive BHs.

1. Nomenclature

Correct estimation of the sizes of the three largest fundamental scales, the Titius-Bode numbers (0,1,2,4,8,16,…) and the values of the three fundamental physical constants (G, c, and $\hbar/2$) allowed the definition of the initial conditions for the Theory of Everything (ToE) and then the determination of the characteristics of the five fundamental scales that appear in the Scale-Symmetric Theory (SST) [1]. The third/baryonic scale leads to the atom-like structure of baryons [1].

The 5 fundamental scales in SST are as follows [1].

*Higgs-field scale or gravitational-field scale ($\sim 10^{-64}\,m$); objects: the SST tachyons with 6 degrees of freedom. In SST, the degrees of freedom define localization of an object, its structure and the internal and external motions. For tachyons we have 3 coordinates, radius, superluminal spin speed and superluminal linear speed.

*Quantum-entanglement scale ($\sim 10^{-45}\,m$); objects: the superluminal spin-1 binary-systems of closed strings (entanglons) with 10 degrees of freedom (8 degrees for the ground state). Closed strings are made of tachyons in direct contact.

*Planck scale or neutrino scale ($\sim 10^{-35}\,m$); objects: the cores of stable neutrinos with 26 degrees of freedom (24 degrees for the ground state). The Planck-scale objects are built of entanglons and are embedded in the Higgs field. Such a scenario leads to the 3 fundamental physical constants (G, c, and $\hbar/2$) that define the Planck scale. The Higgs potential for the Planck scale has a range about $4 \times 10^{-32}\,m$. In SST, the quantum gravity concerns the Higgs potential.

The Ramanujan numbers 10 and 26 (or 8 and 24 for the ground state) concern the quantum scale and Planck/neutrino scale.

*Baryonic scale ($\sim 10^{-15}\ m$); objects: the cores of baryons with 58 degrees of freedom (56 degrees for the ground state).

*Cosmological scale ($\sim 10^{25}\ m$); object: the Protoworld with 122 degrees of freedom (120 degrees for the ground state) which was built of the dark-matter (DM) tori that decayed to the DM loops.

The SST spacetime (the Cosmos) has a stable boundary so the 3 fundamental physical constants are invariant.

The Universe is expanding in the non-expanding SST spacetime (in the Cosmos) whose mean density is about 55 orders of magnitude higher than the current mean density of the Universe, so the Universe is generally flat.

2. Incompleteness of Mainstream Theories in Particle Physics and Cosmology which Affects the Scope of Their Applicability

Within the Standard Model (SM), we cannot determine the nature of dark matter, dark energy, the source of neutrino masses, or matter-antimatter asymmetry. In turn, within the Quantum Chromodynamics (QCD), we cannot obtain in theoretical calculations the precise masses, spin, and magnetic moments of protons and neutrons, which are the main components of baryonic matter. It can be said that we do not understand much more than we do understand. This suggests that the SM and QCD are significantly incomplete theories. Omitting the Scale-Symmetric Theory means that physics, especially particle physics and cosmology, cannot develop properly and this has been going on for 3-4 decades.

It is impossible to decompose the velocity of a real or virtual physical object into four or more orthogonal components, *i.e.* simultaneously perpendicular to each other. This causes Einstein spacetime to have three spatial dimensions (x, y, z) and a fourth time dimension (ct) which is normalized by the maximum speed of experimentally measurable information carried by a photon in vacuum, c, that can produce an excited state. Such spacetime appears in general relativity (GR) and the Standard Model. In such a model of spacetime we have two unsolved problems which concern the definition of a physical object and the normalization via the speed c. We can define the way to solve these problems by quoting A. Einstein: “Everything should be made as simple as possible, but not simpler.”

The simplifications in GR and SM have caused us to lose a lot of important information and therefore we cannot solve many fundamental problems within the framework of these theories and many problems are solved incorrectly. The lack of this lost information makes it impossible to unambiguously define the internal structure and internal dynamics of such objects as the gravitational field, black holes (BHs), wavefunctions, quantum entanglement, and so on.

To build the theory of everything, we must begin with the simplest physical objects and the simplest interaction. The claim that at lower and lower levels of Nature, the structures and interactions become increasingly complex is false.

We should start building physics from pieces of spacetime without internal structure and from the interaction resulting from the viscosity of contacting pieces of spacetime, *i.e.* from the interaction without the exchange of quanta of some physical field. Such a scenario is eliminated from GR and SM.

It is a great mistake to assume that some oscillatory and rotational forms of energy do not require pieces of spacetime, *i.e.* physical volume, for their realization. Every physical object and every form of energy has a physical volume, but sometimes such volume belongs to an object that we define as the zero-energy point. Then such a volume/inertial-mass is not experimentally measurable but the information carried by fields composed of such volumes can be determined indirectly.

Fundamental physical constants such as G, c, and $\hbar/2$ define the Planck scale and are used in GR and SM. Limiting the maximum speed to c also makes GR and SM incomplete theories because there is the superluminal quantum entanglement. We know that GR is for objects which gravitational mass is equal to its inertial mass. This suggests that objects carrying the quantum entanglement do not satisfy this condition, so their scale must be smaller than the Planck length. This means that all information related to objects smaller than the Planck scale is lost, which negatively affects the initial conditions for higher scales. This in turn causes certain phase transitions and interactions occurring in an object collapsing gravitationally into a black hole to be omitted.

It is impossible to explain the origin of the three key physical constants mentioned if we neglect structures smaller than the Planck length. For example, due to the quantum entanglement, the speed c is the speed of the photon relative to the object with which it last interacted [1] – this has great significance in cosmology.

The Scale-Symmetric Theory [1], which is based on quantum fundamental scales, leads to two objects smaller than the Planck length and therefore allows for the correct definition of the internal structure and internal dynamics of the gravitational field and the BHs, for the correct interpretation of the wave functions, for the calculation of the values of physical constants, and so on, from the initial conditions applied in SST that contain only 6 + 5 = 11 initial parameters [1]. It also shows that pure gravitational fields which are composed of superluminal objects are "attached" to objects moving with the speed c in vacuum or lower.

Decades pass and the vast majority of physicists do not see that the path to the ToE leads through scales smaller than the Planck scale and that, due to the initial inflation, such scales must result from already known fundamental scales, *i.e.* the Planck scale, the baryonic scale and the cosmological scale ($\sim 10^{-35}\, m$, $\sim 10^{-15}\, m$, $\sim 10^{25}\, m$, respectively). The cosmological scale follows from the diameter of the known standard ruler in cosmology *i.e.* $2R \approx 1\, Gly \approx 10^{25}\, m$ [2].

SST shows that BHs are built of neutrons and/or of the cores of baryons packed to maximum. We describe it in details in this article. We only partially can apply the GR to black holes because it neglects the phase transition that makes the baryon core indestructible in our Universe.

The biggest mistake of the mainstream theories is to ignore in the initial conditions superluminal pieces of spacetime (the tachyons) carrying infinitesimal spin and to ignore the direct interactions of tachyons resulting from the smoothness of their surfaces. Fluid dynamics applied to tachyons with infinitesimal spin, spin invariance for different scales and saturation of interactions lead to the ToE [1], and therefore to the correct internal structure of BHs as well.

Internal structure of the baryonic cores affects the behaviour of spacetime in a rotating black hole and also affects its shape. Surface density on the torus/electric-charge in the core of baryons is about 300,000 times higher than in the SST absolute spacetime (SST-As) [1]. Moreover, for higher surface densities than on the torus, the quantum entanglement is repulsive. It causes that in the excited stellar BHs but also in the ground-state NBHs with a mass of 24.81 solar masses, the spacetime inside them has angular momentum the same as the BHs, *i.e.* the inner spacetime is in the rest in relation to such rotating BHs. It causes that shape of such BHs is always spherical which greatly simplifies the calculation of the masses of the BHs under consideration.

3. Short-Distance Quantum Entanglement as the Origin of Indestructibility of the Cores of Baryons

One of the SST definitions of coupling constants looks as follows [1]

$$\alpha = \frac{v_{spin}}{c}\,, \tag{1}$$

where v_{spin} is the spin speed of emitted loop. Linear speed of open loop is equal to its spin speed. For example, at low energies the spin speed of the fundamental gluon loop (FGL) is $v_{spin} = c$ so the coupling constant for the nuclear strong interactions via the FGLs is $\alpha_s(low\ energy) = 1$ [1]. Spin speed of the FGLs decreases with increasing velocity/energy of colliding nucleons so value of the strong coupling constant decreases as well, but to find the relationship we must calculate the effective increases in energy of the interacting components.

For the quantum entanglement are responsible the entanglons which linear speed is superluminal and is $v_1 = 0.7269252749 \times 10^{68}\ m\ s^{-1}$ [1], so from (1) for $v_{spin} = v_1$, *i.e.* for open loop built of entanglons, we obtain the coupling constant for the quantum entanglement

$$\alpha_{entanglement} = \frac{v_1}{c} = 2.425 \times 10^{59}\ . \tag{2}$$

Energy involved in quantum entanglement can be calculated from following formula

$$E\ [J] = \frac{G_i M m}{L} = \frac{\alpha_{entanglement} c \hbar}{L} = \frac{7.666 \times 10^{33}}{L\ [m]}\ , \tag{3}$$

where L is the distance between the entangled objects.

For an equivalence of the energy in kilograms we have

$$m\ [kg] = \frac{\alpha_{entanglement} \hbar}{Lc} = \frac{8.53 \times 10^{16}}{L\ [m]}\ . \tag{4}$$

From (4) for the Planck scale we have about $10^{52}\ kg$ which is close to the mass of our Universe.

From (4) for the baryonic scale we have about $10^{32}\ kg$.

From (4) for the cosmological scale we have about $10^{-8}\ kg$ which is close to the Planck mass, *i.e.* the interaction energy is equivalent to a mass of the order of the Planck mass.

Speed of the SST tachyons is about three orders of magnitude higher than the carriers of quantum entanglement [1], so stability of the cores of neutrinos is much higher than the cores of baryons. Just the tachyons, entanglons and the stable neutrinos are indestructible in our Universe.

Notice that contrary to a classical loop, a virtual quantum loop oscillates from the closed state to open state, next to closed state, and so on [1]. It causes that quantum loop behaves as a classical loop with a radius 2π times higher. We see that instead the classical definition $mcR = \hbar$, there appears the quantum definition $ET_{period} = \hbar$ – for the radius $2A/3$ that is the radius of FGL, where A is the equatorial radius of the core of baryons, we obtain $E = m_{FGL} = 67.544413\ MeV$ [1].

4. Introduction

The Scale-Symmetric Theory (SST) [1] shows that there are five fundamental levels of Nature that were created due to the four successive phase transitions of the initial inflation field. The third phase transition leads to the core of baryons and then, due to the dynamics of the baryonic core, to the atom-like structure of baryons.

We show that mass of the neutron black hole (NBH) in its ground state follows from the atom-like structure of baryons that leads to the effective distances of neutrons equal to $A + 4B = 2.7048\ fm$ (they are the diagonals of the faces of a cube), where $A = 0.6974425\ fm$ is the equatorial radius of the core of the baryons, and $B = 0.501835\ fm$ is the distance between the $d = 1$ state and the equator and between the $d = 2$ and $d = 1$ states [1]. Mass of the neutral core of the baryons is $M = H^o = 724.775\ MeV$ [1].

The quantized orbits around the core of baryons and around NBHs are created due to the symmetrical decays of both the virtual electroweak field and some boson [1].

We show that masses of the excited states of NBHs (they are composed of the cores of baryons and relativistic pions) decrease when mass density increases.

5. Ground State of Stellar Black Holes

The radius of NBH, R_{BH}, and mass, M_{BH}, satisfy the following formula:

$$R_{BH} = \frac{G\,M_{BH}}{c^2}\,. \tag{5}$$

If N denotes the number of neutrons in such neutron black hole then we have

$$\frac{4\pi}{3} R_{BH}^3 = NL^3\,, \tag{6}$$

where $L = \frac{A+4B}{\sqrt{2}}$, and

$$M_{BH} = Nm_{neutron}\,, \tag{7}$$

where $m_{neutron}$ denotes mass of the neutron.

Solving the set of formulae (5) – (7) we get

$N = 2.946 \times 10^{58}$,

$M_{BH,o} = 4.935 \times 10^{31}\ kg$ i.e. about 24.81 solar masses,

$R_{BH,o} = 3.664 \times 10^4\ m$, *i.e.* 36.64 km.

This is the ground state of the gravitational stellar black hole composed of neutrons – the effective distances between neutrons are $R_{eff} = A + 4B \approx 2.7\ fm$ (they are the diagonals of the faces of the cubes).

6. Excited States of Stellar Black Holes

There is the SST nuclear plasma composed of the cores of baryons packed to maximum. In such a plasma, in the $d = 0$ state, there can be relativistic pions (also quarks [3] and other particles, but with lower probabilities). For the ground state of the black holes (BHs) composed of the SST nuclear plasma, *i.e.* they are free from relativistic pions, we have as follows.

$$c^2 = \frac{G\,M_{BH}}{R_{BH}} = \frac{G\rho\frac{4\pi}{3}R_{BH}^3}{R_{BH}} = \frac{4\pi}{3} G\rho R_{BH}^2\,, \tag{8}$$

$$\rho = \frac{M}{V^3}\,, \tag{9}$$

$$R_{BH} = \frac{c}{2\sqrt{\frac{\pi}{3}G\rho}}\,, \tag{10}$$

$$M_{BH} = \frac{4\pi}{3}\rho R_{BH}^3\,. \tag{11}$$

In the cooled SST plasma, the neutral baryonic core with a mass of $M = H^o = 724.775\ MeV$ occupies a cuboid with the sides equal to $2A$, $2A$ and $\frac{2A}{3}$. Then it has a density of $\rho = 1.428 \times 10^{18}\ kg\ m^{-3}$. From (10) and (11) we obtain

$$M_{BH,excited,N_d=0} = 10.16\ M_{Sun}\ , \tag{12}$$

where M_{Sun} denotes mass of the Sun.

From the Einstein formula for relativistic mass we obtain that in the $d = 0$ state, the ratio of the relativistic mass to the rest mass is [1]

$$\frac{M_{Rel}}{M_o} = 9.003577665\ . \tag{13}$$

Relativistic mass of neutral pion in the $d = 0$ state is $M_{Rel,\pi^o} = 1215\ MeV$.

For entangled pairs, due to the four-object symmetry [1], we have

$$N_d = 2 \times 4^d\ , \tag{14}$$

where $d = 0,1,2,4,8,16,32, \ldots$ are the Titius-Bode (TB) numbers.

For single objects we have

$$N_d = 4^d\ . \tag{15}$$

Probabilities of the two lowest modes, *i.e.* for $d = 0,1$, should be highest, *i.e.* for $N_d = 1,2,4,8$.

For the two lowest modes for the relativistic neutral pions in the $d = 0$ state we obtain following quantized masses of the stellar BHs. The repeatable mass contained in cuboids with sides ($2A$, $2A$ and $\frac{2A}{3}$) is calculated using the following formula

$$M_d = H^o + N_d M_{Rel,\pi^o}\ , \tag{16}$$

where $N_d = 0,1,2,4,8$.

For $N_d = 0$ we already obtained $M_{BH,excited,N_d=0} = 10.16\ M_{Sun}$ (see (12)).

From (9) – (11) and (15), for the cuboid ($2A$, $2A$ and $\frac{2A}{3}$) and for $M_d = H^o + M_{Rel,\pi^o}$ we obtain

$$M_{BH,excited,N_d=1} = 6.21\ M_{Sun}\ . \tag{17}$$

For the cuboid ($2A$, $2A$ and $\frac{2A}{3}$) and for $M_d = H^o + 2M_{Rel,\pi^o}$ we obtain

$$M_{BH,excited,N_d=2} = 4.87\ M_{Sun}\ . \tag{18}$$

For the cuboid ($2A$, $2A$ and $\frac{2A}{3}$) and for $M_d = H^o + 4M_{Rel,\pi^o}$ we obtain

$$M_{BH,excited,N_d=4} = 3.66\ M_{Sun}\ . \tag{19}$$

For the cuboid ($2A$, $2A$ and $\frac{2A}{3}$) and for $M_d = H^o + 8M_{Rel,\pi^o}$ we obtain

$$M_{BH,excited,N_d=8} = 2.68\ M_{Sun}\ . \tag{20}$$

The stellar black hole in the ground state (24.81 solar masses) can interact with or absorb one or many the excited stellar black holes. Then we obtain the masses of black holes that appear in the catalogs [4-5]. Consider the BHs that before the observed mergers have had central masses from 5 up to 41 solar masses. Then in the interval from 27 up to 29 solar masses (width of such an interval is about 5.6%, *i.e.* 2 from the 5 up to 41 solar masses) we have about 11% of BHs whereas in the interval from 34 up to 36 solar masses (interval width is also about 5.6%) we have about 10% of BHs. This leads to a conclusion that the numbers of stellar BHs in the intervals from 27 up to 29 and from 34 up to 36 solar masses are about 2 times higher than it should be for a random distribution. The first interval relates to $M_{BH,o} + M_{BH,excited,N_d=4} \approx 28.5$ solar masses or to $M_{BH,o} + M_{BH,excited,N_d=8} \approx 27.5$ solar masses (the mean is 28 solar masses). The second interval relates to $M_{BH,o} + M_{BH,excited,N_d=0} \approx 35$ solar masses. There are many BHs with masses from 40 up to 60 solar masses that probably have evolved from the binary systems $2M_{BH,o} \approx 50$ solar masses, and so on.

7. The Composite Black Holes and Origin of the MoM-BH*-1

The Titius-Bode number $d = 32$ is the only possible value that leads to a non-trivial baryonic mass of our Universe. The number of the ground-state neutron black holes in the early Universe (the double-loop composed of the NBHs – there is an analogy to the two fundamental gluon loops in neutral pion [1]) was $2\ (loops) \times 2 \times 4^{32} = 4^{33}$ (see (14)), so the baryonic mass of the Universe (*i.e.* without dark matter and dark energy) is about $3.64 \times 10^{51}\ kg$. The upper limit for number of neutron black holes in one cosmological loop is 2×4^{32}.

In SST, the protogalaxies composed of the neutron black holes (NBHs) were created already before the expansion of the Universe from collapsing matter. Their invariant mass was (it is only the baryonic mass)

$$M_{Proto,BM} = 4^{16}\ M_{BH,o} = 1.066 \times 10^{11} M_{Sun}\ . \tag{21}$$

Similar scenario, *i.e.* associations of BHs, is presented in [6-7] but it is based on the solution of the black hole Schrödinger equation with the "gravitational fine structure constant".

According to SST, just before the observed expansion of the Universe there was collapse of the Protoworld which was composed of dark matter. Due to the collision of dark matter with the protogalaxies which were composed of the neutron black holes, there appeared massive collisions of NBHs. The main source of repulsive dark energy in the baryonic gas surrounding a massive black hole were the photons from annihilations of the virtual particle-antiparticle pairs produced in large quantities by electrically charged particles mainly from the beta/weak decays of free neutrons released in collisions of NBHs [2], [8]. There are the dark-energy photons and the averaging rapidly reduced spacetime density, but also there are the annihilations of the dark-energy photons and the local regions in spacetime with reduced density, i.e. the local returns to the initial state of spacetime.

Mass of the nucleons was enhanced due to the interactions of them with dark matter [8]. The repulsive energy was about 2.2 times higher than the enhanced mass of the electrically charged baryons in the baryonic gas surrounding the black hole [8]. The quieter central regions of massive black holes did not produce dark energy, so they are remnants of more massive black holes. We see that in the early Universe the masses of massive black holes rapidly decreased rather than increased.

From (15) and (21) we obtain that due to the repulsive dark energy, Protogalaxies could emit dwarf galaxies with baryonic mass 4^4 times lower, i.e. their mass was about $10^{8.6}$ solar masses. On the other hand, the same mechanism caused that the dwarf galaxies emitted black hole stars with baryonic mass 4^4 times lower, i.e. their baryonic mass was about $10^{6.2}$ solar masses. Such a mass has the black hole star MoM-BH*-1 [9].

Emphasize that the massive collisions of NBHs and the repulsive dark energy caused the complex BHs to evaporate intensively [2].

8. Summary

The catalogs of binary mergers suggest that the NBHs can absorb the excited stellar black holes described in this article, *i.e.* BHs are the composite objects. Masses of the excited states are 2.68, 3.66, 4.87, 6.21, 10.16 solar masses. The observational data suggest that probability of absorption of the excited state that does not contain relativistic pions, *i.e.* BHs with a mass of 10.16 solar masses, is very high.

The catalogs show also that there can be mergers only of the excited states.

We showed that higher mass density of the SST nuclear plasma leads to lower mass of black hole. Volume of the core of baryons is practically invariant so for increasing mass density the mass of BH asymptotically approaches zero.

There are no forces in the Universe that can destroy the core of baryons – it follows from the very strong short-distance quantum entanglement [1]. The core-anticore baryonic asymmetry that had led to the observed matter-antimatter asymmetry was realized at the end of the initial inflation due to the gravitational collapse of the outer layer of the supercooled expanding SST spacetime. The resulting constant spacetime boundary ensures the invariance of the three fundamental physical constants discussed in this article. We believe that our expanding Universe is expanding matter, dark matter and dark energy in the invariant ground state of the SST spacetime.

Number of the baryonic cores can change only in the processes of creation and annihilation of the core-anticore pairs.

Before the expansion of the Universe there were practically only the associations of the SST NBHs (their invariant mass is $M_{BH,o} = 24.81\ M_{Sun}$) and dark matter [1], [8]. In collisions of the NBHs, there were produced the excited stellar black holes and there appeared dark energy that is a virtual field [8]. Probability of creation of the excited stellar black holes with lower mass is lower because then in the $d = 0$ state there is more the relativistic pions with relativistic masses equal to 1215 MeV. The catalogs suggest that when we take into account only the excited BHs then initially abundance of the excited BHs with the highest mass of 10.16 solar masses was highest. The exception to the described rule should be the excited BHs with a mass of 3.66 solar masses because of the 4-object symmetry that increased the abundance of such BHs.

We showed that in the early Universe, due to the created repulsive dark energy, masses of massive black holes rapidly decreased rather than increased.

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