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The Tension Cosmology, Largest Cosmic Structures and Explosions of Supernovae from SST

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Abstract

Here, using the Scale-Symmetric Theory (SST) we explain the cosmological tension and the origin of the largest cosmic structures. We show that a change in value of strong coupling constant for cold baryonic matter leads to the disagreement in the galaxy clustering amplitude, quantified by the parameter S_8. Within the same model we described the Hubble tension. We described also the mechanism that transforms the gravitational collapse into an explosion—it concerns the dynamics of virtual fields that lead to dark energy. Our calculations concern the Type Ia supernovae and the core-collapse supernovae. We calculated the quantized masses of the progenitors of supernovae, emitted total energy during explosion, and we calculated how much of the released energy was transferred to neutrinos. Value of the speed of sound in the strongly interacting matter measured at the LHC confirms that presented here model is correct. Our calculations show that the Universe is cyclic.

Keywords

Scale-Symmetric Theory, Tension Cosmology, Coupling Constants, Parameters σ_8 and S_8, Largest Cosmic Structures, Dark Energy, Supernova Explosion, Cyclic Universe

1. Introduction

Here we try to explain why the distribution of galaxies and matter in the late Universe is smoother than expected from the evolution of the fluctuations observed in the cosmic microwave background (CMB). We claim that it is a result of a change in value of the coupling constant for the nuclear strong interactions at low energies.

We also described the dynamics of virtual fields that transform a collapse into an explosion.

1.1. The Mechanism of Matter Clustering and Hubble Tension (the Cosmological-Tension Mechanism)

To describe the mechanism of matter clustering and Hubble tension we need long-distance interactions that follow from short-distance interactions in nuclear matter.

In the Scale-Symmetric Theory (SST), outside the nuclear strong fields, the produced virtual/real gluon-loops/gluons behave as virtual/real photon-loops/photons—it follows from the fact that contrary to the nuclear strong fields, the electromagnetic fields have not internal helicity [1]. Moreover, each gluon has three helicities/colours [1], so we have 8 types of gluons and one type of photons.

In nucleons, at low energies, there are the virtual fundamental gluon loops (FGLs) produced on the circular axis inside the core of baryons—their spin speed is $v_{spin,FGL} = c$, where $c \approx 3 \times 10^{8}\ \mathrm{m} \cdot \mathrm{s}^{-1}$, and we have the virtual gluon loops overlapping with the d = 1 state (there is the relativistic pion)—their spin speed is $v_{spin,d=1} = 0.7626c$ [1]. But the resultant speed of the components of the gluons must be equal to c, so the virtual gluon loops produced in the d = 1 state are forced to move in direction perpendicular to plane of the loop (or the loops must expand)—the velocity of such gluon-loop (or expansion rate) is 0.6469c. Outside the nuclear strong fields, such virtual gluon loop transforms into virtual photon loop and next, in distant nuclear matter, again behaves as gluon. Such virtual gluon/photon loops are responsible for the matter clustering and Hubble tension. Within SST we can show that such a leaking of virtual information from nucleons leads to the chaos theory.

In SST, the coupling constant for nuclear strong interactions of gluon loops is defined as [1]

$$\alpha_{s,d} = \frac{v_{spin,d}}{c}, \tag{1}$$

So for the FGLs we have $\alpha_s = 1$ (it is valid for low energies) while for the d = 1 state we have $\alpha_{s,d=1} = 0.7626$.

When components of a virtual field do not interact then resultant density of such field is equal to zero, but notice that there are the positive and negative densities.

Emphasize that there is a difference between size of clustering (it is directly proportional to the virtual-field positive density, so to coupling constant as well: $D_{clustering} \sim \alpha$) and range of virtual particles (it is inversely proportional to positive mass of virtual particle: $R_{range,particle} \sim 1/M_{particle} \sim 1/\alpha$) [1].

Bigger clustering regions mean that expansion of the Universe is slower, *i.e.* Hubble constant has lower value, *i.e.* $H_o \sim 1/\alpha$.

1.2. The Expansion of the Universe

In mainstream cosmology, it is assumed that at the beginning of the expansion of the Universe, in the quark epoch, there was the hot quark-gluon plasma. It causes that to describe evolution of the Universe we must take into account the running coupling constant for the nuclear strong interactions.

The scenario in SST is very different.

The matter-antimatter asymmetry is due to the left-handedness of the initial inflation field [1], so number density of produced neutrons (they have the left-handed internal helicity) was much higher than the righthanded antineutrons.

Our very early Universe appeared due to gravitational collapse—there appeared the metastable Protoworld (its core was built of the dark-matter (DM) tori) and there appeared two baryonic loops composed of the neutron black holes (NBHs) grouped in the protogalaxies—it looks as a production of the neutral pion by neutron [1]. Moreover, in the $d = 1$ state there appeared the cosmological photon loops. Creation of such metastable state (*i.e.* the Protoworld and two baryonic loops) during a gravitational collapse of matter, caused that both components, *i.e.* DM and baryonic matter (BM), had time to cool down. It means that to describe the stages after the gravitational collapse of the Protoworld, we need only values of the coupling constants for the nuclear strong interactions at low energies.

According to SST, to the cold NBHs (in the first stage after the collapse of the Protoworld, the NBHs interacted with low-density DM) we must apply the nuclear strong interactions via the fundamental gluon loops (FGLs)—then the strong coupling constant is $\alpha_s = 1$. In the second stage, the cold NBHs interacted with high-density DM, so the NBHs collided, so there appeared also the cold nuclear matter, *i.e.* there were the strong interactions via the FGLs and pions [1]. In the third stage, there dominates the cold nuclear matter and DM so the strong interactions via pions are most important, so we have $\alpha_s^{NN,\pi} = 14.40076$ (it is the mean value for the proton-neutron pairs and for the alpha particles) [1].

CMB concerns the second stage. There are two components. The component α_s concerns the neutron matter and leads to the plateau in the anisotropy power (it is for the higher angular scales in the earlier moments) while the $\alpha_s^{NN,\pi}$ concerns the cold nuclear matter and leads to the maxima in the anisotropy power (it is for the lower angular scales in the later moments) [2].

Here we show that the main part of cosmological tension follows from a change in value of strong coupling constant for cold matter—generally, it is the transition from the second stage to third stage.

1.3. The Galaxy Clustering Amplitude

The disagreement (a cosmological tension) in the galaxy clustering amplitude is quantified by the parameter S_8 (or σ_8).

There are different values of S_8 and σ_8 from CMB and from galaxy weak lensing surveys—they are presented in the review article [3].

We use the SST [1] to describe the origin of the parameter S_8.

Here σ_8 denotes the amplitude of mass fluctuations on scales $8h^{-1}$ Mpc, where $h = H_o/100$.

The following formula defines the parameter S_8

$$S_8 = \sigma_8 \left(\frac{\Omega_m}{0.3} \right)^{\frac{1}{2}} = 1.0226\sigma_8, \tag{2}$$

where in SST we have $\Omega_m = 0.3137$ [2].

1.4. Virtual Fields

According to SST there is the two-component spacetime composed of the SST Higgs field (it has only inertial mass) and of the SST absolute spacetime (SST-As) that gravitational mass is equal to its inertial mass [1]. Gravitational fields are gradients in the Higgs field and they are carried by gravitational masses. Due to the properties of the Higgs field, such field has not excited states, so gravitational energy cannot be emitted or absorbed directly via excited states of gravitational fields. On the other hand, the photons, gluons, virtual and real particles and "holes" in the SST-As are the excited states of the SST-As, so energy can be emitted or absorbed directly via such excited states.

Here we describe the mechanism that leads from a collapse to an explosion. The dominant phenomenon takes place in virtual fields that are the excited states of the SST-As. We will show that there is a cold gravitational collapse that, due to the dynamics of collapsing virtual fields, transforms into an explosion.

The real particles (their gravitational mass is positive) try to equalize gravitational-mass density in their surroundings. It is realized by creating virtual fields. Such field consists of spacetime condensates and/or pairs of particles (they have positive gravitational masses), and "holes" in SST-As (they have negative gravitational masses). The virtual real particles (e.g. the electron-positron pairs or single spacetime condensates) decay to pairs of virtual photons that remove energy/gravitational-mass from the system. The created "holes" decrease local density of SST-As, so there is a constant inflow of SST-As from outside the system to its interior.

Notice that inertia of the inflows is much lower than of the outflows (it follows from the fact that mass of the SST-As components is many orders of magnitude lower than mass of the virtual particles/objects that decay to the virtual photons)—it is the reason that on the cosmological scales the negative pressure (dark energy) dominates.

By extending the general theory of relativity (GR) we can define and investigate the dark energy (DE) problems [4].

When a star collapses then the number density of the "holes" increases, so there is a moment when the "holes" are tangent (they can partially overlap as well). Then virtual photons with positive energy create negative/repulsive pressure, while the "holes" create positive/attractive pressure, but it acts only at the boundary of the virtual field composed of the tangent "holes".

In SST, we showed that total mass of the virtual particles with positive mass is two times higher than the mass of particle that creates the virtual field [1], so, when the "holes" are tangent or partially overlap, the negative pressure becomes enormous.

We see that a virtual field with a boundary for the field of the "holes" behaves as very dense dark energy [2] that leads to explosion of the system.

Our calculations concern the typical Type Ia supernovae and the typical core-collapse Type II supernovae. We calculated the quantized masses of the progenitors, emitted total energy during explosion, and we calculated how much of the released energy is transferred to neutrinos.

Consider the regions of collapsing stars in which the protons and electrons dominate. Initially, a virtual "hole" produced by the created virtual bare electron has a size approximately equal to the diameter of the equator of the bare electron, so the critical baryonic mass density that relates to creation of the boundary of the field of the tangent "holes" produced by the virtual electron-positron pairs is (one such pair is produced by the electron and second one by the proton)

$$\rho_{crit(e)} = \frac{m_{nucleon}}{4\frac{4}{3}\pi r_e^3} \approx 1.73\times10^{9}\ \mathrm{kg\cdot m^{-3}}, \tag{3}$$

where $m_{nucleon} = 1.67\times10^{-27}\ \mathrm{kg}$ is the mass of nucleon, and $r_e = 3.86607\times10^{-13}\ \mathrm{m}$ is the equatorial radius of the bare electron [1].

Such critical density can force a weak explosions/pulsations of baryonic matter near a neutron star (NS) created in a strong supernova explosion, but it can be the origin of the pulsations of Cepheids as well. We see that the cyclically collapsing and expanding electron gas can lead to a cascade of soft explosions after the main supernova explosion.

On the other hand, the tangent virtual nuclear strong fields lead to following critical baryonic mass density

$$\rho_{crit(p)} = \frac{m_{nucleon}}{\frac{4}{3}\pi r_{strong}^3} \approx 1.48\times10^{16}\ \mathrm{kg\cdot m^{-3}}, \tag{4}$$

where $r_{strong} \approx 3\ \mathrm{fm}$ is the radius of the virtual nuclear strong field for baryons [1]. Such density, or even higher, leads to the strong supernova explosions because of the emitted virtual/real pions (they decay to photons).

We have

$$\frac{\rho_{crit(p)}}{\rho_{crit(e)}} \approx 8.6\times10^{6}. \tag{5}$$

Notice that to create a neutron star, baryonic-mass density must increase to $\rho_{NS} \approx 2.4\times10^{17}\ \mathrm{kg\cdot m^{-3}}$ [2]. Then the negative/repulsive pressure from the virtual field is $p_{DE} = -2\rho_{NS}c^2 \approx 4.3 \times 10^{34}$ Pa—it is about ten orders of magnitude lower than the kinetic pressure in the SST absolute spacetime [1], so the supernova explosions do not force an expansion of local spacetime, *i.e.* during such explosions the local Universe is still flat.

The positive/attractive pressure from the virtual nuclear strong fields appears only on the virtual-field boundary when the baryonic mass density is higher than ~1.5×10^{16} kg·m^{-3}—it is lower than the ~2.4×10^{17} kg·m^{-3} for the neutron stars, so there is possible a supernova explosion without simultaneous creation of neutron star—it is realized in the typical Type Ia supernovae.

2. Why by Using the Scale 8*h*$^{-1}$ Mpc we Obtain More Convincing Results?

This problem is not clear in the mainstream cosmology. Why we smooth the amplitude of matter perturbations over $8h^{-1}$ Mpc?

In SST, at the beginning of the expansion of the Universe, there were the protogalaxies composed of the cold neutron black holes (NBHs), *i.e.* on their equators the spin speed is equal to *c*. Such baryonic matter (BM) was surrounded by the SST cold dark matter that flowed into the cold BM.

At the beginning of the third stage, the cold baryonic matter interacted due to the nuclear strong interactions (the coupling constant is $\alpha_s^{NN,\pi}$) and due to the nuclear weak interactions (the coupling constant is $\alpha_{w(p)} = 0.0187229$ [1]). The size of the observed present-day Universe ($D_{U,strong} = 2 \times 13.80\ \text{Gly} = 8462\ \text{Mpc}$) relates to $\alpha_s^{NN,\pi}$, so the $\alpha_{w(p)}$ relates to size of the following regions of the present-day Universe, D_{weak}

$$D_{weak} = D_{U,strong} \frac{\alpha_{w(p)}}{\alpha_s^{NN,\pi}} = 11.0\ \text{Mpc} = 7.8h^{-1}\ \text{Mpc} \approx 8h^{-1}\ \text{Mpc}, \tag{6}$$

where $h \approx 0.709$ is the mean value (see formula (11)).

The initial size of the two baryonic loops was $D_{BM,initial} = 117.2\ \text{Mpc}$ [1]. At the beginning of the second stage, there were DM, BM and electrons. Electrons interacted weakly with DM, so the coupling constant was $10.77\alpha_{w(e)}$ [1], where $\alpha_{w(e)} = 0.9511182 \times 10^{-6}$, and it relates to $D_{BM,initial}$. On the other hand, the effective size of the electron vortices from the weak interactions with BM, D_{BM-e}, was defined by the coupling constant $\alpha_{w(e)}$, so we have

$D_{BM-e} = D_{BM,initial} \dfrac{\alpha_{w(e)}}{10.77\alpha_{w(e)}} = 10.9\ \text{Mpc} = 7.7h^{-1}\ \text{Mpc} \approx 8h^{-1}\ \text{Mpc}$. We see that there is a resonance in sizes of the pure electron vortices (there was the Thomson scattering of photons on such electron vortices that led to the E-modes in CMB) and the regions containing baryonic matter, both interacting due to the weak interactions defined by $\alpha_{w(e)}$ and $\alpha_{w(p)}$, respectively.

Such is the origin of the scale $8h^{-1}$ Mpc, *i.e.* size of such regions was quantized by weak interactions.

3. The Origin of the Amplitude of Mass Fluctuations on Scales $8h^{-1}$ Mpc, and the σ_8 and S_8 in Late Universe

The parameter σ_8 represents the amplitude of the matter power spectrum on the scale $8h^{-1}$ Mpc. The characteristic mass that leads to such a scale (the coupling constant must be $\alpha_{w(p)} = 0.0187229$—see formula (6)) is Y = 424.1218 MeV [1]. On the other hand, the strongly interacting nucleons were/are, first of all, in helium-4, so the involved maximum mass was/is $4\pi^{\pm} = 558.2813\ \text{MeV}$. It leads to a conclusion that we can define the parameter σ_8 for the late Universe as follows

$$\sigma_{8,late} = \frac{\text{Y}}{4\pi^{\pm}} = 0.7597\,. \tag{7}$$

From (2) and (7) we have

$$S_{8,late} = 0.7769\,. \tag{8}$$

Our result for $S_{8,late}$ is consistent with observational data: from weak lensing (WL) and galaxy clustering we have $0.775^{+0.026}_{-0.024}$ [5].

4. The σ_8 and S_8 in Early Universe

Consider the nuclear strong interactions for the transition from the second stage (it concerns the CMB) to the third stage.

During the second stage, there was a mixture of cold neutron matter, nuclear matter and dark matter while in the third stage there dominates cold nuclear matter and dark matter, so for the nuclear strong interactions we have the transition $\alpha_s^{NN,\pi} + \alpha_s \to \alpha_s^{NN,\pi}$. Such transition gives

$$\sigma_{8,early} = \sigma_{8,late} \frac{\alpha_s^{NN,\pi} + \alpha_s}{\alpha_s^{NN,\pi}} = 0.8124\,. \tag{9}$$

From (2) and (9) we obtain

$$S_{8,early} = 0.8308\,. \tag{10}$$

Our result for $S_{8,early}$ is consistent with observational data: from CMB (from ACT) we have 0.830 ± 0.043 [6]. The PDG value is $S_{8,early} = 0.832(13)$ [7].

5. The Hubble Tension

In SST, the time/spatial mean Hubble constant is (the spatial mean follows from the quantum entanglement)

$$H_o = H_{o,MEAN} = \frac{c}{L_{BM}} = 70.9\ \text{km}\cdot\text{s}^{-1}\cdot\text{Mpc}^{-1}, \tag{11}$$

where $L_{BM} = 13.8\ \text{Gly}$ is the present-day radius of the visible sphere filled with baryonic matter. From (11) we have $h = H_o/100 = 0.709$—it is the mean value. But this value was not invariant.

During the first two stages, radius of the expanding Universe was equal to the standard ruler in cosmology $R_{P,d=1} = 0.493\ \text{Gly} = 151\ \text{Mpc}$ (see Paragraph 6) but it does not mean that there was a stable state. When baryonic matter reached the $d = 1$ state (it was at the end of the second stage), the Hubble constant increased from zero to value that is characteristic for the CMB because the spin speed of the $d = 1$ photon loops decreased to $v_{spin,d=1} = 0.7626c$—such Hubble constant we denote by $H_{o,early}$. Next, during the third stage, the Hubble constant was practically invariant (a scattering should very slowly bring down the intrinsic expansion of the Universe—see Paragraph 11)—we denote it by $H_{o,late}$.

Hubble constant is inversely proportional to coupling constant ($H_o \sim 1/\alpha$), so for the transition from the second stage to third stage we have

$$\frac{H_{o,late}}{H_{o,early}} = \frac{\alpha_s^{NN,\pi} + \alpha_s}{\alpha_s^{NN,\pi}} = 1.06944\,. \tag{12}$$

Approximately there is also valid following formula

$$H_{o,late} = \frac{c}{L_{BM} - R_{P,d=1}}\,. \tag{13}$$

From (12) and (13) we obtain

$$H_{o,early} = 68.7\ \text{km}\cdot\text{s}^{-1}\cdot\text{Mpc}^{-1}\,, \tag{14}$$

$$H_{o,late} = 73.5\ \text{km}\cdot\text{s}^{-1}\cdot\text{Mpc}^{-1}\,. \tag{15}$$

The SST result $H_{o,early} = 68.7\ \text{km}\cdot\text{s}^{-1}\cdot\text{Mpc}^{-1}$ relates to the indirect measurements of the E-mode (EE) polarization power spectrum and temperature-E-mode (TE) cross-power spectrum of the CMB.

Our results are consistent with observational data: from CMB we have 68.8 ± 1.5 [8] and for SNIa-Cepheid we have 73.04 ± 1.04 [9].

The mean Hubble constant for the period 13.8 Gyr is

$$0\frac{R_{P,d=1}}{L_{BM}} + H_{o,late}\frac{L_{BM} - R_{P,d=1}}{L_{BM}} = 70.9\ \text{km}\cdot\text{s}^{-1}\cdot\text{Mpc}^{-1}\,. \tag{16}$$

As it follows from (11).

Emphasize that when we neglect the intrinsic scattering of energy of the cosmic photon loops, the mean Hubble constant for the last 13.3 Gyr is $H_{o,late} = 73.5\ \text{km}\cdot\text{s}^{-1}\cdot\text{Mpc}^{-1}$.

Notice that when we take into account also the earlier nuclear weak interactions of the cold nucleons then we obtain lower value of the Hubble constant that is the Particle-Data-Group (PDG) central value: 67.4 ± 0.5 [7]

$$H_{o,early,SW} = H_{o,early}\frac{\alpha_s}{\alpha_s + \alpha_{w(p)}} = 67.4\ \text{km}\cdot\text{s}^{-1}\cdot\text{Mpc}^{-1}. \tag{17}$$

6. The Largest Cosmic Structures

Here we show that sizes of the largest cosmic structures follow from the geometry of the Protoworld and from the circle-diameter oscillations of the characteristic rings.

In the Protoworld, there were created rings composed of the photon/gluon/baryonic loops with the radii of $R_{P,d} = A_{Protoworld} + dB_{Protoworld}$, where $d = 0$, 1, and we have $A_{Protoworld} = 0.2867\,\text{Gly}$ and $B_{Protoworld} = 0.2063\,\text{Gly}$ [1]. Initially, the baryonic protogalaxies were on the circular axis with a radius of $\frac{2A_{Protoworld}}{3} = 0.1911\,\text{Gly}$. At the beginning of the expansion of the Universe, the rings attracted galaxies and DM.

For $d = 1$ we have $R_{P,d=1} = 0.493\,\text{Gly} = 151\,\text{Mpc}$—it is the standard ruler in cosmology.

Due to the $\alpha_s^{NN,\pi} + \alpha_s \to \alpha_s^{NN,\pi}$ transition that leads to the cosmological tension, circumferences of the three characteristic rings increased $\frac{\alpha_s^{NN,\pi} + \alpha_s}{\alpha_s^{NN,\pi}} \approx 1.07$ times, so the initial diameters were

$D_{P,n}$ = 0.38 up to 0.41 Gly,
0.57 up to 0.61 Gly, and
0.99 up to 1.05 Gly.

Due to the circle → diameter baryonic oscillations, the initial diameters increased π times to

$\pi D_{P,n}$ = 1.2 up to 1.3 Gly,
1.8 up to 1.9 Gly, and
3.1 up to 3.3 Gly.

The second transformation, due to the circle → diameter baryonic oscillations, increased the initial diameters π^2 times to

$\pi^2 D_{P,n}$ = 3.8 up to 4.0 Gly,
5.7 up to 6.0 Gly, and
9.7 up to 10.4 Gly.

The circle-diameter baryonic oscillations can transform a ring into a bubble, a wall, an arc, a filament, a group of quasars or into new ring. Such cosmic structures were stabilized by the inflowing dark-matter loops during the gravitational collapse of the core of the Protoworld [2].

We see a perfect consistency of the SST results with the observational data [10]-[12]:

for the Herkules-Corona Borealis Great Wall we have 9.7 - 10 Gly,
for the Giant GRB Ring we have 5.6 Gly,
for the Huge-LQG we have 4.0 Gly,
for the Giant Arc we have 3.3 Gly,
for the Clowes-Campusano LQG we have ~2 Gly,
for the Big Ring we have 1.3 Gly,
for the Ho'oleilana Bubble we have ~1 Gly,
for the Boötes Supercluster we have 0.62 Gly,
for the Great Attractor we have 0.4 Gly.

Due to the diameter → circle baryonic oscillations, the initial diameters decreased π times to

$D_{P,n}/\pi$ = 0.12 up to 0.13 Gly,
0.18 up to 0.20 Gly, and
0.31 up to 0.34 Gly.

There are many structures with diameters close to ~0.2 Gly and ~0.34 Gly.

The second transformation, due to the diameter → circle baryonic oscillations, decreased the initial diameters π^2 times to

$D_{P,n}/\pi^2$ = $\underline{0.0387}$ (lower limit) up to 0.0414 Gly,
0.0581 up to 0.0621 Gly, and
0.100 up to 0.107 Gly.

The lower limit for the second order of the diameter → circle transition/oscillations (*i.e.* 0.0387 Gly) is very close to the scale obtained by using the coupling constants (see formula (6)): $0.0387\text{ Gly} = 8.4h^{-1}\text{ Mpc} \approx 8h^{-1}\text{ Mpc}$, so there is a coupling-oscillations resonance.

Our very simple model suggests that the center of the Ho'oleilana Bubble is the initial center of the Protoworld, so of the expanding Universe as well. In center of the Ho'oleilana Bubble, there is the Boötes Supercluster, so it is in the centre of the expanding Universe. Notice that the Milky Way (MW) Galaxy is in distance 0.82 Gyr from the centre of the expanding Universe, so MW is close to the centre.

7. Quantized Masses of the Progenitors of Supernovae

In the centre of the bare muon there is a spacetime condensate and two energetic neutrinos that are a part of the spacetime condensate, so it is a three-body system. On the other hand, the muon is the electron-like object, so according to SST, the masses of both the electric charge and the three-body system are the same. It leads to a conclusion that energy of each neutrino is about 17.6 MeV while the total mass of the spacetime condensate is $M_{C,muon} \approx 52.8\text{ MeV}$.

The collapse rate of a star depends on the energetic conductivity for the flows of energy from the interior of the star to its surface. SST shows that its value is highest when energy is transported by the spacetime condensates placed in centres of the muons ($M_{C,muon}$) or in centres of baryons ($Y = 424.1\text{ MeV}$). Due to the nuclear weak interactions (the coupling constant is $\alpha_{w(p)} = 0.0187229$ [1]), there can be the following virtual transition $Y \to 8M_{C,muon}$. The virtual spacetime condensates can decay to pairs of virtual photons—then negative pressure rapidly increases.

The mass of neutron ($M_{neutron} \approx 939.6\text{ MeV}$) relates to mass of the NBH, *i.e.* to 24.81 solar masses [2]. It leads to a conclusion that the ~52.8 MeV relates to $M_{Ch} = 1.4M_{Sun}$ (where M_{Sun} is the mass of the Sun) that is the Chandrasekhar limit for the Type Ia supernovae while the ~424.1 MeV relates to
$M_{t-II} = 11.2M_{Sun}$ that is a progenitor for the typical Type II supernovae.

Notice that the typical Type II supernovae can collapse in many different ways, so they can explode in many different ways as well. The collapses can be symmetrical or there can be 1 up to 8 the Type Ia collapses in the same progenitor, so masses of the resultant core can be different—it leads to different light-curves and spectra of the same progenitor. Moreover, we can observe an expansion asymmetry. The same concerns progenitors with masses higher than 11.2 solar masses.

We see that due to the emitted spacetime condensates, there is an efficient emission of energy by central part of a gravitationally collapsing star. In the cooling region can be created a neutron star that must be cool.

Notice that the progenitors of the Type IIP supernovae should have particular properties. According to SST, their mass should relate to the mass of the charged core of baryons $H^{\pm} = 727.44\ \text{MeV}$—it leads to a mass of $M_{IIP} = 19.21 M_{Sun}$ for the Type IIP supernova progenitor. In center of such progenitors is produced the SST nuclear plasma composed of the $H^{\pm}$ cores and the $H^{+}H^{-}$ pairs packed to maximum. The annihilations of the $H^{+}H^{-}$ pairs lead to a big explosion of the progenitor after its gravitational collapse. This is a reason that practically we should not observe a remnant (a neutron star or a black hole) in center of such explosion. This concerns, e.g., the SN 1987A. Notice that in such a big explosion appear relativistic energies.

8. Total Energy Emitted During Explosion of Supernova

Consider the typical Type Ia supernovae. We assume that the nuclear weak mass of the condensate in centre of the muon appears on the equator of a nucleon, *i.e.* in distance A = 0.6974425 fm from the nucleon centre, but it is emitted from the d = 1 state that has a radius of $A + B$ = 1.19928 fm [1]. From constancy of both the angular momentum and spin speed we obtain that the mass/energy decreases $\frac{A+B}{A}$ times. Then the emitted total energy is

$$E_{t-Ia} = \frac{M_{Ch}}{m_{nucleon}} M_{C,muon} \alpha_{w(p)} \frac{A}{A+B} = 9.6 \times 10^{56}\ \text{MeV} = 1.5\ \text{foe}, \tag{18}$$

where "foe" means "ten to power fifty-one ergs", *i.e.* $1\ \text{foe} = 10^{44}\ \text{J}$.

The same assumptions for the typical core-collapse Type II supernovae lead to (we assume that whole mass of a progenitor undergoes the core phase)

$$E_{t-II} = \frac{M_{t-II}}{m_{nucleon}} Y \alpha_{w(p)} \frac{A}{A+B} = 98\ \text{foe}. \tag{19}$$

9. Energy Transferred to Neutrinos

In the typical Type Ia explosion, initially there is the nuclear plasma/matter, *i.e.* the coupling constant is

$$\alpha_s^{NN,\pi} + \alpha_s, \tag{20}$$

where $\alpha_s^{NN,\pi} = 14.40$ is the coupling constant for the nuclear matter (interactions are via pions) while $\alpha_s = 1$ is the strong coupling constant for interactions via the fundamental gluon loops (FGLs) [1]. The emitted neutrinos are from decays of the FGLs, so energy transferred to neutrinos is

$$E_{t-Ia,neutrinos} = \frac{\alpha_s}{\alpha_s^{NN,\pi} + \alpha_s} E_{t-Ia} = 0.10 \text{ foe}. \tag{21}$$

The rest, *i.e.* ~1.4 foe, is the kinetic energy.

On the other hand, the core collapse causes that initially there are nucleons, so the coupling constant is

$$\alpha_{w(p)} + \alpha_s. \tag{22}$$

The emitted neutrinos are from decays of the FGLs, so energy transferred to neutrinos is

$$E_{t-II,neutrinos} = \frac{\alpha_s}{\alpha_{w(p)} + \alpha_s} E_{t-II} = 96 \text{ foe}. \tag{23}$$

The rest, *i.e.* ~2 foe, is the kinetic energy.

Our results are in perfect consistency with observational data.

10. Experimental Verification of the $\alpha_s^{NN,\pi} + \alpha_s \to \alpha_s^{NN,\pi}$ Transition

The CMS Collaboration extracted the speed of sound in the strongly interacting matter created in ultrarelativistic lead-lead collisions at the LHC. The squared speed of sound in natural units is [13]

$$c_s^2 = \left(\frac{v_{sound}}{c}\right)^2 = 0.241 \pm 0.002(stat.) \pm 0.016(syst.). \tag{24}$$

On the other hand, in SST, the sound/transverse speed relates to the orbital relativistic speed of pions on the last TB orbit for the strong interactions (the peripheral interactions)—it is defined by both the radius $R_{d=4} = A + 4B = 2.70478 \text{ fm}$ and the speed $v_{d=4} = 0.507794c$ [1]. But due to the Pb-Pb collisions, in the peripheral region of the expanding plasma, there is the transition from cold nuclear plasma (*i.e.* just after the Pb-Pb collisions) to cold nuclear matter (it mimics the transition from the second stage to the third stage of the expanding Universe), so the energy $E \sim v_{d=4}^2 \sim \frac{1}{R_{d=4}}$ decreases $\frac{\alpha_s^{NN,\pi} + \alpha_s}{\alpha_s^{NN,\pi}}$ times—this leads to following SST value for the squared speed of sound

$$c_{s,SST}^2 = \left(\frac{v_{d=4}}{c}\right)^2 \frac{\alpha_s^{NN,\pi}}{\alpha_s^{NN,\pi} + \alpha_s} = \frac{A}{R_{d=4}} \frac{\alpha_s^{NN,\pi}}{\alpha_s^{NN,\pi} + \alpha_s} = 0.2411. \tag{25}$$

Notice also that the effective temperature estimated using the mean transverse momentum (219 ± 8 (syst.) MeV [13]) is very close to the relativistic mass of the virtual pions that appear in the $d = 4$ state—their rest mass is 187.57 MeV [1], so the SST value for the squared speed of sound leads to the relativistic mass ~215 MeV. Moreover, in nucleons/baryons, in the $d = 1$ state, there very frequently is the relativistic charged pion with a mass of 215.76 MeV [1]—due to the ultrarelativistic collisions, such pions are pushed to the periphery of the expanding nuclear plasma.

11. The Cyclic Universe

SST shows that in the expanding Universe, the amounts of BM, DM and DE should be practically invariant [2] but it does not mean that the ratio of the negative pressure from DE to the positive gravitational pressure from BM and DM does not depend on radius of the expanding Universe, R_U.

Denote the total mass of BM and DM by M_{BM+DM} and energy of DE by E_{DE}. Then from [2] we have $E_{DE} = 2.1878 M_{BM+DM}$.

The definition of the negative pressure exerted by DE is

$$-p_{DE} = -\frac{E_{DE} c^2}{\frac{4}{3}\pi R_U^3}. \tag{26}$$

The definition of the positive gravitational pressure from BM and DM exerted on a nucleon on surface of the expanding baryonic sphere is (radius of the virtual strong field is $\sim \frac{4\pi}{3} A = 2.92144\ \text{fm}$ [1])

$$p_{gr} = \frac{G M_{BM+DM} m_{nucleon}}{R_U^2 \pi \left(\frac{4\pi}{3} A\right)^2}, \tag{27}$$

where $m_{nucleon} \approx 939\ \text{MeV}$, and $A = 0.6974425\ \text{fm}$ is the equatorial radius of the core of baryons [1].

From (26) and (27) we obtain

$$\frac{-p_{DE}}{p_{gr}} = 1.13 \times 10^{25} \frac{1}{R_U [\text{m}]} = 1.2\ \text{Gly} \frac{1}{R_U [\text{Gly}]}. \tag{28}$$

From (28) follows that for $R_U > 1.2\ \text{Gly}$ there is $-p_{DE} < p_{gr}$. Notice that circumference of the initial baryonic loops also was 1.2 Gly [1], so there was a resonance that had led to the metastable Protoworld.

DE played very important role when the negative pressure was higher than the positive gravitational pressure—then the expanding Universe behaved as a cosmological supernova. There appeared cascading protuberances with redshift higher than 1 but they were very quickly damped.

Emphasize also that the virtual and real photon loops produced in the d=1 state have the radial speed equal to $v_{radial} = 0.6469c$ that sustains the expansion of the Universe. This speed decreases when spin speed of the loops increases—it is possible when energy of the loops is scattered. Scattering of energy of the photon loops should be more efficient for loops placed closer to the regions that today relate to the initial position of the cosmological baryonic loops (the loops and the $d = 1$ state lead to the "axis of evil" as well)—such regions are placed today in distance $R \approx 5.3$ Gly from the center of the expanding Universe. Such a scattering is defined by the fine structure constant that is ~1973 times lower than

$\alpha_s^{NN,\pi}$, so the scattering is a very slow process. It should very slowly bring down the intrinsic expansion of the Universe. The intrinsic deceleration practically does not concern the baryonic front of the expanding Universe. Emphasize that such a "deceleration" leads to a cyclic Universe and its collapse will start from the inner layers of the Universe. We see that due to the intrinsic deceleration, the Hubble constant should have a minimum for $R \approx 5.3$ Gly from the center of the expanding Universe

$$H_{o,late,SE} = H_{o,late} \frac{\alpha_s}{\alpha_s + \alpha_{em}} = 73.0\ \text{km} \cdot \text{s}^{-1} \cdot \text{Mpc}^{-1}, \tag{29}$$

where $\alpha_{em}^{-1} = 137.035999085$ is the fine structure constant from SST [1]. Our result (29) is the central value in [9]. Then the mean Hubble constant for the last 13.3 Gyr should be ~73.3 km·s^{-1}·Mpc^{-1}.

Moreover, within SST we showed that physical constants depend on densities of the two components of the SST spacetime [1], so there must be a stable boundary of such spacetime.

12. Summary

Within SST we showed that during gravitational collapse of big amount of matter there appeared the metastable state containing the core of the Protoworld composed of DM, the neutron protogalaxies, and the cosmological photon loops. There were three stages after the gravitational collapse of the Protoworld.

The CMB was emitted at the end of the second stage while the main part of cosmological tension is due to a change in the coupling constant for the nuclear strong interactions in cold nuclear plasma/matter during the transition from the second stage to third stage. We obtained $\frac{S_{8,early}}{S_{8,late}} = 1.06944$, $S_{8,early} = 0.8308$, and $S_{8,late} = 0.7769$.

The results concerning σ_8 and S_8 obtained within SST are consistent with observational data.

We also, by applying the same model, described the origin of the Hubble tension. For the end of the second stage (it concerns the CMB) we obtained $H_{o,early} = 68.7\ \text{km} \cdot \text{s}^{-1} \cdot \text{Mpc}^{-1}$ while for the third stage, *i.e.* for the late Universe, we obtained $H_{o,late} = 73.5\ \text{km} \cdot \text{s}^{-1} \cdot \text{Mpc}^{-1}$. We showed that when we take into account also the earlier nuclear weak interactions of the cold nucleons then we obtain lower value: $H_{o,early,SW} = 67.4\ \text{km} \cdot \text{s}^{-1} \cdot \text{Mpc}^{-1}$ that is the PDG central value from CMB anisotropies (Planck). On the other hand, our result when we take into account also the intrinsic deceleration is $H_{o,late,SE} = 73.0\ \text{km} \cdot \text{s}^{-1} \cdot \text{Mpc}^{-1}$—it is the central value for the present-day Hubble expansion rate from the distance ladder (SH0ES). Emphasize that for the cosmic bubbles in distant Universe ($R <$ 13.3 Gly) we obtained a value 73.5 km s^{-1}·Mpc^{-1} while for the cosmic bubbles placed in distances ~5.3 Gly from the center of the expanding Universe, we obtained a minimum 73.0 km·s^{-1}·Mpc^{-1} that should decrease with time. Then the SST mean Hubble constant for the last 13.3 Gyr is ~73.3 km·s^{-1}·Mpc^{-1}. The SST results are in perfect agreement with the latest observational results, so our simple model based on the coupling constants describes correctly the matter clustering and solves the Hubble-tension problem. We showed that our Universe is cyclic.

Our results are the mean values because the inhomogeneous inflows of dark matter and changes in density of dark energy caused that we observe a dispersion of observational data.

The regions with the scale $8h^{-1}$ Mpc we can call the bubbles in the expanding Universe—they were quantized by the weak interactions. The main part of cosmological tension is due to the $\alpha_s^{NN,\pi} + \alpha_s \rightarrow \alpha_s^{NN,\pi}$ transition. After the SST inflation, there was created the metastable Protoworld that evolved into the expanding Universe composed of the bubbles (it was the SST soft-big-bang/explosion). We see that the creation of the Protoworld was separated in time from the SST inflation (*i.e.* from the SST big bang).

Virtual/real energy can leak from nuclear matter and such exchanged energy is responsible for attraction of matter in clustering region and leads to the chaos theory.

SST shows that sizes of the largest cosmic structures follow from the geometry of the Protoworld and from the circle-diameter oscillations of the characteristic rings.

We showed also that the center of the Ho'oleilana Bubble (there is the Boötes Supercluster) is a centre of the expanding Universe, so Milky Way is close to such a centre.

Here we also described the role of the SST dark energy in explosions of the supernovae. We described the typical Type Ia supernovae, typical core-collapse Type II supernovae and Type IIP supernovae. In other progenitors we should observe some mixtures of the three fundamental explosions. It can lead to different light-curves and spectra of the same progenitors, and it can lead to expansion asymmetry.

Full interpretation of the general theory of relativity (GR) is impossible if we neglect the quantum entanglement (most important are the quantum entanglement between emitted photon and its source and the complex quantum entanglement inside nucleons), the other Standard-Model (SM) interactions, and the structures below the Planck scale.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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