# The Evolution of Massive Galaxies

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**Abstract:** Within the lacking part of ultimate theory, i.e. the Scale-Symmetric Theory, I described the evolution of massive galaxies. Within the new cosmology, applying very simple mathematics, we can answer following questions. Why many of the oldest most massive galaxies reside in clusters? Is the gravitational redshift important for the E/S0 galaxies? What is contribution of the kinematical Doppler effect of Special Relativity to the total cosmological redshift? Is the acceleration of expansion of the Universe an illusion? Why the massive red evolved galaxies are already in place at high redshift? Why the red-sequence has a boundary at z = 0.44? When and how were produced the first-generation stars the E/S0 galaxies consist of? What was the origin of a rapid build-up of the red sequence and why it is quiescent i.e. why there do not appear numerous new stars i.e. what are the phenomena responsible for the powerful shut-down mechanism of new-star formation i.e. why E/S0 galaxies evolve in a purely passive way? Why evolution of the most massive E/S0 galaxies was quicker for lower redshift i.e. why number of massive red galaxies is greater for redshift smaller than 0.7? Why there is a significant population of massive blue galaxies at high redshift?

**1. Introduction, the answers and calculations**

The most commonly accepted mechanism of galaxy formation for redshift since z = 1 is as follows. They assembled their mass continuously through mergers of smaller units over cosmic time. The massive galaxies formed their stars within very short (at cosmic scale) periods at earlier epochs. It is known as the downsizing scenario. In top-down theories, protogalaxies form in a large-scale simultaneous collapse whereas in bottom-up theories, small structures form first, and then accrete. On the other hand, in the less-massive galaxies the stars appeared later on and period of formation was longer. The downsizing scenario for the massive galaxies is inconsistent with the standard ΛCDM cosmological model – within this model the E/S0 massive galaxies form more than half of their mass at very late epochs of redshift smaller than 1.

Consequently, there appear following questions concerning the downsizing scenario and evolution of the massive galaxies. Why many of the oldest most massive galaxies reside in clusters? Is the gravitational redshift important for the E/S0 galaxies? What is contribution of the kinematical Doppler effect of Special Relativity to the total cosmological redshift? Is the acceleration of expansion of the Universe an illusion? Why the massive red evolved galaxies are already in place at high redshift? Why the red-sequence has a boundary at z = 0.44? When and how were produced the first-generation stars the E/S0 galaxies consist of? What was the origin of a rapid build-up of the red sequence and why it is quiescent i.e. why there do not appear numerous new stars i.e. what are the phenomena responsible for the powerful shut-down mechanism of new-star formation i.e. why E/S0 galaxies evolve in a purely passive way? Why evolution of the most massive E/S0 galaxies was quicker for lower redshift i.e. why number of massive red galaxies is greater for redshift smaller than 0.7? Why there is a significant population of massive blue galaxies at high redshift?

Here, within the new cosmology that follows from the lacking part of ultimate theory, i.e. the Scale-Symmetric Theory, applying very simple mathematics, we answered the above questions.

During the inflation (the expansion of the cracked-space/Higgs-field) [1], due to the succeeding phase transitions of the Higgs field [2], there appeared the Principle-of-Equivalence Einstein spacetime [2] and its stable boundary which radius is $2.3 \cdot 10^{30}$ m [3]. In such spacetime, due to the fourth phase transition, there appeared the Protoworld and Cosmic Loop (the very early Universe) composed of nucleons [2]. Due to the phase transition of the core of the Protoworld, there appeared the dark matter (the additional Einstein-spacetime components entangled with matter) and its inflows to the very early Universe [2]. Due to the quantum entanglement, the very early Universe consisted of protogalaxies the compact cosmic structures consisted of [2]. Their parts/smaller-cosmic-structures were the direct progenitors of the massive red-sequence compact associations of the protogalaxies (such associations I will refer to as the massive red-sequence galaxies) and the direct progenitors of the massive blue compact associations of the protogalaxies (such associations I will refer to as the massive blue galaxies).

*Why many of the oldest most massive galaxies reside in clusters?*

The duality of evolution of the massive galaxies (the red, passive early-type E/S0 galaxies, and blue, star forming late-type ones) follows from location of them in the compact cosmic structures. Just the inflows of the dark matter into the massive galaxies placed on surface of the compact cosmic structures were more massive than into the massive galaxies placed in centres of the compact cosmic structures. The inflows of the dark matter caused the partial exist (greater for surface and smaller for centre) of the massive galaxies from their black-hole state. It leads to conclusion that evolution of the massive galaxies placed in centre should be passive (there were only inflows of the created plasma; they transformed into the quiescent massive red-sequence galaxies) whereas of the placed on surface should be active (there were the inflows and out flows of the created plasma; they transformed into the blue massive galaxies). We can see that in centres of many present-day galaxy clusters should be a massive E/S0 galaxy surrounded by the other types of active galaxies such as spiral, barred spiral galaxies and irregular ones.

The blue massive galaxies, via the quasars, active galactic nuclei (AGN) and starburst galaxies transformed into the spiral, barred spiral and irregular galaxies. The starburst galaxies, which often are associated with merging or/and interacting galaxies, produce regions filled with large amount of ionized atomic hydrogen (H II regions). Next, the massive stars produce supernova explosions.

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All protogalaxies looked the same – they consisted of the neutron black holes (the mass of NBH is $M_{NBH} = 4.94 \cdot 10^{31}$ kg) which mass is 24.8 times greater than the mass of the Sun (the solar mass is $M_{Sun} = 1.99 \cdot 10^{30}$ kg) and which Schwarzschild radius is approximately $R = 7.4 \cdot 10^4$ m [2]. Each protogalaxy consisted of $4^{16}$ NBH i.e. its mass was about $M_P = 2.1 \cdot 10^{41}$ kg [2].

The compact associations of the protogalaxies contained following number of binary systems of protogalaxies [2]:

$$D = 4^d, \tag{1}$$

where d = 0, 1, 2, 4, 8, 16 for a flattened spheroid-like structures, and d = 3, 6, 12 for a chain-like structures.

According to the Scale-Symmetric Theory there was the decomposition of the Double Cosmic Loop on the groups of protogalaxies (d = 1; each group consisted of 8 protogalaxies) after 1.89 Gyr from the transition of the core of the Protoworld which transformed it into the dark matter [2]. Mass of such direct progenitor of the numerous most luminous blue and red galaxies was $M_G \approx 1.7 \cdot 10^{42}$ kg. Since mass of the Universe is about $3.6382 \cdot 10^{51}$ kg [2] so the 2 Gyr old Universe should contain about $2 \cdot 10^9$ progenitors of the massive galaxies. In reality, the mean lifetime is the time after which there appears 1 – 1/e = 0.632 of the smaller structures. After the strictly defined lifetimes, there are the succeeding decompositions of the Double Cosmic Loop (the very early Universe) on smaller cosmic structures [2] but due to the four succeeding inflows of the dark matter [2] the lifetimes can be shorter than the calculated.

Calculate following expression for the direct progenitors of the massive red-sequence galaxies

$$\log(M_G / M_{Sun}) = 11.9. \tag{2}$$

It is consistent with the observational facts presented here [4]. For the protogalaxy we obtain $\log(M_P / M_{Sun}) = 11.0$. It is as well consistent with the data.

The theory of the solar system described within the Scale-Symmetric Theory (it describes correctly mean radii of planets and perihelion precession of Venus [2]) leads to conclusion that around groups composed of 256 neutron black holes is valid the Titius-Bode law for gravitational black holes i.e. there appear states which mean radii define following formula [2]

$$R = A + dB, \tag{3}$$

where 2A is the radius of the Schwarzschild surface, A/B ≈ 1.39 whereas d = 0, 1, 2, 4, 8, 16, 32, … We can notice that the d = 2 and d = 4 are the two lowest states above the Schwarzschild surface. The massive galaxies consist of big number of such groups. It leads to conclusion that the gravitational redshift is very important to describe correctly the evolution of the massive red-sequence and blue galaxies. The dark matter inflowing into a massive red-sequence galaxy transform the neutron black holes placed on surface of the galaxy into plasma composed of nucleons and electrons. This plasma gathered especially in the d = 2 and d = 4 states but due to the massive inflows of the plasma it creates a layer of plasma above the Schwarzschild surface and thickness of the plasma layer depends on volume and density of the inflowing plasma. Very thin plasma layer just above the Schwarzschild surface causes that gravitational redshift of such specific “star” is much greater than 1 but such objects are very dark. On the other hand, there was the upper limit for mass of produced plasma so there is the upper limit for thickness of the plasma layer. Assume that the plasma gathered especially in the d = 2 and d = 4 states and between them. Then radius of the surface of the plasma in different massive red-sequence galaxies is defined by following dominating interval <A + 2B, A + 4B>. Calculate the gravitational redshift for the boundaries of the interval. The gravitational redshift of a photon can be calculated in the framework of General Relativity, for the Schwarzschild metric, as

$$\lim z(r) = -1 + 1/\mathrm{sqrt}(1 - R_S / R), \quad (4)$$

where $R_S = 2A$ whereas R is respectively $R_{lower} = A + 2B$ and $R_{upper} = A + 4B$. Calculated gravitational redshift is $z_{lower} \approx 1.357 \approx 1.36$ and $z_{upper} \approx 0.437 \approx 0.44$. We can see that the gravitational redshift is very important in correct description of evolution of the Universe so of the massive red-sequence galaxies as well. Notice that for radius of the surface of the plasma smaller than A + 2B, the gravitational redshift is higher than 1.36.

The new cosmology described within the Scale-Symmetric Theory leads to the kinematical Hubble constant equal to $H_{K,ET} = 45.24$ [2] i.e. the h in the formula for luminosity L is h = 0.4524

$$L = M_V - 5 \log h. \quad (5)$$

On the other hand, the h applied here [4] is h = 0.7. It is easy to explain the apparent discrepancy. In the mainstream cosmology it is assumed that the kinematical redshift for distance 13.8 Gyr is $z_{k,M} = 1$ ($v/c = (z^2 + 2z)/(z^2 + 2z + 2)$, where z is the observed redshift). Since in the Scale-Symmetric Theory the maximum kinematical redshift for about 13.866 Gyr is $z_{k,ET} = 0.6415$ [2] so to obtain within the Scale-Symmetric Theory the Hubble constant associated with the gravitational redshift $H_{G,ET}$, we must divide the $H_{K,ET}$ by $z_k$

$$H_{G,ET} = H_{K,ET} \cdot z_{k,M} / z_{k,ET} = 70.5, \quad (6)$$

i.e. h ≈ 0.7 as it is in the mainstream cosmology.

Now we can formulate the very important conclusion: the cosmology is in fact not the pure kinematical cosmology. There appear both the kinematical and gravitational redshift. It is not true that the protogalaxies formed in a large-scale simultaneous collapse. In reality, at beginning of the observed expansion of the Universe there was the Double Cosmic Loop which diameter was $0.382 \cdot 10^9$ light-years [2].

Why the kinematical correction was relatively small i.e. why the mainstream cosmology almost correctly describes the luminosity-redshift relation? The Scale-Symmetric Theory shows that the present-day radius of the sphere filled with baryonic matter is about $13.866 \cdot 10^9$ light-years, of the CMB about $R_{CMB} = 21.614 \cdot 10^9$ light-years whereas mass of the Universe is about $3.6382 \cdot 10^{51}$ kg [2]. Consequently, it leads to the correct present-day mean temperature of the Universe and correct abundance of the visible matter, dark matter and dark energy [2]. The compact cosmic structures have the radial speeds the same as the expanding local dark matter i.e. they are in the rest in relation to the expanding dark matter. It causes that the Doppler redshift is the non-relativistic redshift, not the kinematical Doppler effect of Special Relativity [2], [5]. It causes that the relativistic formula for redshift $v/c = (z^2 + 2z)/(z^2 + 2z + 2)$, where z is the observed redshift, cannot be applied to the galaxy clusters. In reality, there should be $v/c = z_K$, where the $z_K$ is the kinematical redshift in the Scale-Symmetric Theory. The Scale-Symmetric Theory shows that the radial speed of the front of the baryonic matter is $v_B = 0.6415c$ whereas relative speed of light emitted by the front is $v_L = c - v_B = 0.3585c$. It means that the kinematical redshift is zero for the near galaxies and increases to the upper limit 0.64 for the most distant galaxies. The detected present-day light was emitted by the front when it was in following distance X

$$X / v_B + X / v_L = R_{CMB} . \quad (7)$$

It gives $X \approx 4.97 \cdot 10^9$ light-years (here, we neglect the very quickly damped protuberances of the dark matter [2]). We can see that there appears the correction for total cosmological redshift $z_T$

$$z_T = z_G + z_K . \quad (8)$$

In presented here theory of gravitational redshift, the increase in radial distance for the change in the observed redshift from $z = 1.36$ to $z = 0.44$, is $X_g \approx 4.8 \cdot 10^9$ light-years. The same increase we obtain applying the mainstream theory of kinematical redshift of Special Relativity $v/c = (z^2 + 2z)/(z^2 + 2z + 2)$ – for $z = 0.44$ we obtain $0.3493 \cdot 13.8 \cdot 10^9 = 4.8 \cdot 10^9$ light-years whereas for $z = 1.36$ is $0.6956 \cdot 13.8 \cdot 10^9 = 9.6 \cdot 10^9$ light-years i.e. the distance is as well $4.8 \cdot 10^9$ light-years. It means that describing the phenomena concerning the gravitational redshift we can use the formula for the kinematical redshift of SR but we proved that the origin of this formula is very different. Within the dynamical-redshift Standard Cosmological Model, for redshift range between $0.40 < z < 1.3$ [4], we obtain the look-back times of ~ 4.2 – 8.7 Gyr so the changes are in approximation the same as in presented here theory of gravitational shift and as in the theory of relativistic redshift.

In presented here cosmology the total redshift is the sum of the gravitational and kinematical redshift (formula (8)). On the other hand, the dynamical-redshift mainstream cosmology is formulated in such a way that it is an analogy only to the presented here gravitational-redshift cosmology. The difference between presented here cosmology and the mainstream cosmology follows from the kinematical redshift that changes from zero to 0.64, where the upper limit is for most distant galaxies. This kinematical redshift has not an analogy in the mainstream cosmology. It causes that the real redshift of the Type Ia supernovae is higher than it follows from the mainstream cosmology i.e. they are in distances greater than it follows from the mainstream cosmology. The discrepancy is higher for more distant supernovae i.e. they are fainter than it follows from the mainstream cosmology. This phenomenon does not follow from an acceleration of expansion of the Universe – it follows from the incompleteness of the mainstream cosmology.

As an example, calculate within the Scale-Symmetric Theory the total redshift for a massive galaxy placed on the front of expanding baryonic matter for present-day observer in centre of the expanding dark matter. Additionally, assume that the surface of the plasma is in the d = 2 state. Since $z_G = 1.36$ whereas $z_K = 0.6415$ so the total redshift is $z_T = 1.36 + 0.64 = 2.0$. Such massive galaxy is $T = X/z_K \approx 7.75$ Gyr old i.e. about $\Delta T = R_{CMB} - T = 13.866$ Gyr $\approx X/(1 - z_K)$ from present-day. On the other hand, within the kinematical mainstream cosmology, applying the formula for the kinematical Doppler redshift of Special Relativity $v/c = (z^2 + 2z)/(z^2 + 2z + 2)$, for $z = 2$ we obtain $v/c = 0.8$ and present-day time distance $\Delta t = 13.8$ Gyr $\cdot$ 0.8 = 11.0 Gyr. We can see that the distance calculated within the Scale-Symmetric Theory (13.866 Gyr) is greater than the distance calculated within the kinematical mainstream cosmology (11.0 Gyr). This leads to conclusion that in reality a supernova placed in the considered galaxy is fainter than it follows from the kinematical mainstream cosmology and it is the observational fact. It does not result from an acceleration of expansion of the Universe.

In the near massive galaxies, due to their long evolution, we can neglect the gravitational redshift. It causes that all galaxies in groups of galaxies have almost the same redshift.

There should be same unintelligible correlations in redshift distribution of the massive galaxies for observed redshift z = 1.14 ([4] – see Fig.1 and for distribution of bright AGN samples [7] – see Fig.2) which leads to the kinematical redshift of Special Relativity equal to the upper limit of the kinematical redshift in the Scale-Symmetric Theory z = 0.64. For such galaxies, the gravitational redshift is $z_G = 0.5$. To obtain such relativistic redshift the observed redshift must be z = 0.73. On the other hand, the z = 0.715 ≈ 0.72 is for the mean of the total redshift distribution of the massive galaxies ([4] – see Fig.2) whereas the sum 0.64 + 0.72 = 1.36 is the gravitational redshift for the plasma in the d = 2 state.

The inflows of the dark matter were very rapid so as well of the plasma (at a cosmic scale). The plasma gathering between the d = 2 and d= 4 states very quickly transformed the groups of 256 neutron black holes into the specific first-generation big stars. We can see that there was a rapid build-up of the red sequence over a very short time scale. The time distance between the first and last inflow of the dark matter was about 1 Gyr [2]. It is the powerful shut-down mechanism of star formation in the red-sequence galaxies. The massive red galaxies had formed the bulk of their stars within short periods at the earliest epoch.

Notice that due to the decomposition of the massive red-sequence galaxies on the smaller massive red-sequence galaxies defined by the mean lifetimes and accelerated by inflows of the dark matter, and due to the increasing electromagnetic pressure, in the luminosity-redshift relation there appears the so called "red envelope" or "red sequence" [4].

*Why evolution of the most massive E/S0 galaxies was quicker for lower redshift i.e. why number of massive red galaxies is greater for redshift smaller than 0.7? Why there is a significant population of massive blue galaxies at high redshift?*

The gravitational redshift is lower when there is more the plasma between the d = 2 and d = 4 states. Due to the fusion of the nucleons in the plasma, there were emitted the very high-frequency photons. The repulsive electromagnetic pressure acting on the smaller parts of the massive red-sequence galaxies increases for lower gravitational redshift. It means that decomposition of the massive red-sequence galaxies on the less-massive ones was quicker for lower gravitational redshift.

Why the luminosity ~ –23 of the bright end of the red sequence does not depend on redshift [4]? It is because it concerns only the same compact cosmological structures, i.e. the groups of protogalaxies, and the redshift is not the kinematical redshift, it is the gravitational redshift. There are the greater areas of the surfaces of the plasma layers for lower gravitational redshift but due to the gravitational interactions with the central black holes, mass density on surface of the thicker layers is lower – it causes that luminosity of all the specific first-generation stars is in approximation the same. Luminosity of the massive red-sequence galaxies can change only due to the succeeding decompositions on smaller massive red-sequence galaxies. Such processes are quicker for lower gravitational redshift. It causes that in the luminosity-redshift relation, the broadening of the luminosity increases with decreasing gravitational redshift. It is consistent with data presented here [4].

In the blue massive galaxies, due to the much more massive inflows of the dark matter, there were the inflows and outflows of the plasma whereas in the red massive galaxies, due to the less massive inflows of the dark matter, there were only the inflows of the plasma into the cores of the massive galaxies. Due to the outflows of the plasma from the massive galaxies, from the plasma were produced big normal stars – it is the reason that there is a significant population of massive blue galaxies at high redshift.

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