Universal Law for Flat Rotation Curves of Galaxies

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Abstract: The Scale-Symmetric Theory (SST) shows that the spinning cosmic loops built of the entangled Einstein-spacetime (ES) components, with centres overlapping with centres of galaxies, are the basic dark-matter (DM) structures. Their interactions with baryonic matter via weak interactions of leptons lead to the flat rotation curves of galaxies. Here, applying such mechanism, we derived universal law that relates actual baryonic masses of galaxies with radial accelerations of stars at a critical radius (for radii bigger than such radius, there dominates the baryon-DM interaction). We calculated as well a parameter at a critical scale that is consistent with observational data. We need to change our ideas about dark matter.

1. Introduction

The Scale-Symmetric Theory (SST) shows that due to some phase transition of the Protoworld (it was a cosmological quasar), its torus and supermassive central black hole transformed into dark matter (DM) [1]. The spinning DM loops (they are built of the entangled Einstein-spacetime (ES) components moving with the speed of light in "vacuum" c – they are the spin-1 neutrino-antineutrino pairs with spins tangent to the DM loops), with centres overlapping with centres of galaxies, are the basic DM structures [1], [2].

Due to the interactions of the DM loops with baryonic vortex or stars in galaxies via weak interactions of virtual pairs containing ES condensates [3], there appears the advection, i.e. the baryonic vortex or stars outside the central stellar bulge of a galaxy acquire their unusual orbital speeds (we will call them the advection orbital speeds).

Virtual mass m^* that is the mediator of the interactions of the DM loops with the actual baryonic mass m_{bar} of a vortex, is defined by the product of the baryonic mass m_{bar} and the coupling constant that defines type of weak interactions $\alpha_{w(....)}$ i.e. $m^* = \alpha_{w(....)} m_{bar}$. It is assumed that speed of such virtual interactions is c. The inner kinetic energy of such virtual vortex is $E^* = 2\ m^*\ c^{\ 2} = 2\ \alpha_{w(....)}\ m_{bar}\ c^{\ 2}$ (the factor 2 follows from the fact that according to the SST, the sum of the absolute virtual masses (there are the virtual pairs) is two times greater than the real mass that creates such pairs [3]). On the other hand, the virtual interactions caused that the initial baryonic mass m_o, which was the source of the DM loops (number density of the DM loops depends directly proportional on the initial baryonic mass m_o), acquired the advection speed $v_{advection,orbital}$ that is the invariant for the m_{bar} also. The inner kinetic energy E_{IBV} of the initial baryonic vortex was $E_{IBV} = m_o\, v_{advection,orbital}{}^{2}$. From equality of the two inner kinetic energies, $E_{IBV} = E^*$, we obtain following main formula [2]

$$v_{advection,orbital} = c\,(2\alpha_{w(\ldots.)}\, m_{bar} / m_o)^{1/2} = const.. \qquad (1)$$

In formula (1), the m_{bar} is the actual baryonic mass of a massive spiral galaxy. The interactions of the DM loops with the actual baryonic matter are via the ES condensates in the virtual electron-positron (e^-e^+) and muon-antimuon ($\mu^-\mu^+$) pairs – according to SST, coupling constant for such interactions is [3]

$$\alpha_{w(\ldots.)} = \alpha_{w(electron\text{-}muon)} = 9.511082 \cdot 10^{-7}. \qquad (2)$$

According to SST, due to the separation in time of the SST inflation and the expansion of the Universe, formation of the protogalaxies composed of the neutron black holes (NBHs) took place already before the expansion [1]. Initially there were two loops of protogalaxies each composed of $2 \cdot 4^{32}$ neutron black holes (it follows from the pairing, the four-object symmetry and the structure of nucleons [1], [3]) grouped in $2 \cdot 4^{16}$ protogalaxies [1]. Initial baryonic mass of each protogalaxy was $M_{Protogalaxy} = 1.0656 \cdot 10^{11} M_{Sun}$, where M_{Sun} is the mass of the Sun [1].

The saturation of interactions via the quantum entanglement causes that if smaller structure is built of N parts then the next bigger one is built of N^2 parts [1] – it leads to the four-object symmetry. Due to the four-object symmetry, protogalaxies were grouped in larger structures. Number of entangled objects in a system is quantized [1]

$$D_{n,S} = 4^{d} \text{ (for single objects)}, \qquad (3a)$$

$$D_{n,B} = 2 \cdot 4^{d} \text{ (for binary systems)}, \qquad (3b)$$

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

Due to the pairing and the four-object symmetry, population of spiral binary systems composed of 8 protogalaxies, $m_o = 2(4M_{Protogalaxy}) = 8.525 \cdot 10^{11} M_{Sun}$ was highest. Such objects could transform into barred spiral galaxies or decayed to two spiral galaxies with typical mass $m_{T,S} = 4M_{Protogalaxy} = 4.263 \cdot 10^{11} M_{Sun}$. Galaxies with masses $4m_{T,S}$, $8m_{T,S}$, $16m_{T,S}$, $32m_{T,S}$, $64m_{T,S}$ or $128m_{T,S}$, appeared due to the mergers and they transformed into elliptical galaxies.

Notice as well that galaxies with a mass of $m_{T,S} = m_o/2$ can decay to 2 or 4 parts. But it can decay to more parts also but then the initial baryonic mass can be lower than $m_{T,S}$ – it causes that the same actual baryonic mass, m_{bar}, can lead to different advection speeds so to different critical radial accelerations for the same radius and the same actual baryonic mass also – just the function describing dependence of the critical radial acceleration on actual baryonic mass is broadened for $m_{bar} < m_{T,S} = m_o/2$. We can see that the universal law for flat rotation curves of galaxies concerns the massive elliptical galaxies and the most massive spiral galaxies i.e. is valid for $m_{bar} \geq m_{T,S} = m_o/2$.

Here we calculated the critical radial acceleration (parameter) for the threshold actual baryonic mass (at the critical scale) i.e. for $m_{bar} = m_{T,S} = m_o/2$.

2. The critical radial-acceleration parameter at the critical scale

Radial acceleration of a star encircling the centre of a galaxy is defined as follows

$$g_{obs} = v_{orbital}{}^2 / R \,, \tag{4}$$

where $v_{orbital}{}^2 = G\, m_{bar} / R$, whereas R is a radius of an orbit.

For radii R greater than a critical radius, $R_{critical}$, the baryon-DM interactions start to dominate over the gravitational interactions, i.e. for $R \geq R_{critical}$ is $v_{orbital} = v_{advection,orbital} = const.$. Constancy of $v_{orbital}$ for $R \geq R_{critical}$ follows from formula (1).

Using formulae (1), (2) and (4), we can calculate observed radial acceleration, g_{obs}, for the critical radius

$$g_{obs} = [2\, c^4\, \alpha_{w(electron\text{-}muon)}{}^2 / (G\, m_o)]\; 2\, m_{bar} / m_o = g_{\dagger}\;\; 2\, m_{bar} / m_o \,, \tag{5}$$

where $g_{\dagger} = [2\, c^4\, \alpha_{w(electron\text{-}muon)}{}^2 / (G\, m_o)] = 1.29 \cdot 10^{-10}$ m s^{-2} is the radial-acceleration parameter at the critical scale. Notice that for most massive spiral galaxy is $m_{bar} = m_{T,S} = m_o/2$ so from formula (5) results that $g_{\dagger}$ is for most massive spiral galaxy. Notice that the linear dependence of radial acceleration on actual baryonic mass of a galaxy (formula (5)) is valid for $m_{bar} \geq m_o/2$.

We can compare value of the radial-acceleration parameter at the critical scale calculated here within the SST model for the baryon-DM interactions with value obtained on the basis of observational data [4]

$$g_{\dagger,observation} = [(1.20 \pm 0.02\; (rnd) \pm 0.24\; (sys)] \cdot 10^{-10}\ \text{m s}^{-2} \,. \tag{6}$$

We can see that theoretical and observational results are consistent.

Formula (5) with the additional remarks is the universal law for the flat rotation curves of galaxies.

3. Summary

Number density of the DM loops in galaxies depends on the initial baryonic mass which created the DM loops. The critical radial accelerations of stars and gas at the regions with flat rotation curves depend on both initial and actual baryonic masses of galaxies. Such result, which is consistent with observational data, suggests that we need to change our ideas about dark matter.

We showed that the universal law for flat rotation curves concerns galaxies with actual baryonic mass equal or higher than about $4 \cdot 10^{11} M_{Sun}$ – it is because for lower and lower actual baryonic masses of galaxies, the formula relating critical radial accelerations and actual baryonic masses of galaxies is more and more broadened – such broadening we can see in observational data [4].

Calculated here the radial-acceleration parameter at the critical scale $g_{\dagger} = 1.29 \cdot 10^{-10}$ m s^{-2} is consistent with value obtained from observational data [4]
$g_{\dagger,observation} = [(1.20 \pm 0.02\; (rnd) \pm 0.24\; (sys)] \cdot 10^{-10}$ m s^{-2}.

References

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