Two-level mass model of the Milky Way

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Abstract

The observed absence of a cuspy halo in the centers of galaxies implies a certain mechanism, which scatter DM. As this mechanism is considered annihilation of galactic antineutrino DM and neutrino DM of stellar origin. Annihilation intensity increases towards the center with increasing concentration of stars and density of DM, however, the scattering effect of annihilation begins to manifest mainly in the bulge. Based on such a hysteresis of scattering effect, we make up a two-level mass model of the Milky Way, where the mass distribution is regulated at two levels of concentration by one and the same law of decreasing density, inversely proportional to the distance from the center of power of 2.5. The first level starts from the surface of the central neutron collapsar and ends at the border of the bulge, and the second level extends from the bulge to the edge of the Galaxy.

1 Introduction

It is assumed that the relative constancy of the speed of rotation of spiral galaxies in a large range of distances from the bulge to the periphery is conditioned by the presence of dark matter, which is distributed in galaxies in a certain way. However, modeling of the rotation curve of galaxies identifies a cuspy halo problem, meaning that in the centers of galaxies should theoretically be achieved very high DM density, what is not actually observed. Presumably, the reason for this is the increased intensity of DM annihilation in galactic nuclei. Annihilation dissipates and pushes DM from the center to the periphery, causing the cuspy halo is reduced so that it becomes not observed. Together with DM a significant part of the gas should likewise be scattered, and this can also be regarded as one of the reasons of mass deficit in the centers of large galaxies.

A new DM model, according to which the elements of DM are nuclei consisting of only an even number of neutrinos or antineutrinos [1], is able to explain mass deficit and the lack of cuspy halo through the scattering effect of annihilation. In bulge of sufficiently large galaxies the average density of neutrino DM of stellar origin becomes comparable to the density of diffuse galactic antineutrino DM[1]. This is accompanied by increase in the intensity of annihilation, as evidenced by the radiation of Galaxy X-ray Ridge, as well as the emission line of the 511 keV of positron annihilation. As a result of annihilation, the DM density in the galactic bulge is reduced dozens of times from the level that would be obtained by direct extrapolation to the center of the law of the DM density distribution, which reproduces the observed velocities of the stars outside the bulge. Since the scattering mechanism operates over billions of years, in the nuclei of galaxies there is a balance between the accreting and dissipating DM. In this case, the part of DM that remains in the bulge, must be subject to exactly the same law of density distribution, as in the rest of the galaxy. This means that cuspy halo nevertheless exists, but is much more compact, so that it can be regarded as the outer part of the central supermassive object. And

[1]Is meant that the antineutrino DM dominates in galaxies of the Local Group, Virgo Cluster, and the filament to which they belong. It is assumed that on a larger scale galactic walls and filaments with dominance of neutrino or antineutrino DM alternate with each other.

the central object itself, covered with DM halo, will be not that other, as neutron collapsar [2]. As shown by simulation, mass of DM, concentrated in the vicinity of the central collapsar (CC) exceeds many times the mass of the collapsar itself.

2 Mass distribution of the Milky Way

Consider the density distribution of ordinary and dark matter in the Milky Way, with the objective to obtain a model that reproduces the observed orbital velocity of stars at any distance from the galactic center. We assume that in the total mass the average density of baryonic matter is about 6 times less than that of DM. With the help of a preliminary numerical simulation consisting in splitting the mass of the Galaxy into concentric layers and calculating the sum with the growth of each layer, we find that the mass distribution of the Galaxy (bulge outside) is characterized by a decrease in the average density of matter, which is inversely proportional to the distance from the center of power of 2.5. We also assume that in the bulge the average density of matter decreases as the distance from the center on exactly the same law, but with a reducing factor, which takes into account the scattering effect of DM annihilation. The corresponding expression for the average density has the form:

$$\rho_{GM}(r) = k_D(r)\,\rho_A\,(r_L/r)^{2.5}, \tag{1}$$

where ρ_A is the limiting DM density ($\rho_A = 2.72 \times 10^{14}$ kg/m$^{\mathbf{3}}$), r_L is radius of CC or radius of limiting dense DM ocean level, k_D(r) is density adjustment factor. Coefficient k_D is expressed as:

$$k_D(r) = k_{RD} + k_{DD} \cdot (r_B/r + 1)^{-1}, \tag{2}$$

where k_{RD} is dilution factor relative to density limit ($k_{RD} \leq 1$), r_B is assumed to be equal to the mean radius of the bulge border (6.79×10^{19} m or 2.2 kpc), and factor k_{DD} is chosen empirically to obtain the desired agreement between the calculated radial velocity and the observed velocities of orbital motion of stars.

The total mass of matter bounded by current radius, will be:

$$M_{GM}(r) = M_{CC} + M_{OL} + \int_{r_L}^{r} 4\pi r^2\,\rho_{GM}(r)\,dr, \tag{3}$$

where M_{CC} is mass of CC, M_{OL} is mass of the ocean of limiting dense DM, if any.

Determine the mass bounded by current radius, we can calculate the velocity of the stars on the circular galactic orbit:

$$v_{GM}(r) = \sqrt{GM_{GM}(r)/r}\,, \tag{4}$$

Assume first that the mass of Sgr A* is distributed within a sphere with radius equal to pericenter distance of star S0-2, and consists of the mass of neutron matter concentrated in CC, and the mass of DM distributed around CC. Taking into account the latest research [20], [21], we accept the mass of Sgr A* as equal to 4.2×10^6 $M_\odot$. The required mass would be achieved with next parameters:

- $M_{CC} = 2.62 \times 10^{35}$ kg (1.35×10^5 $M_\odot$), diameter 1000 km;
- the depth of the ocean of limiting dense DM is 100 km, $M_{OL} = 52$ $M_\odot$, $k_{RD} = 1$;
- the mass of DM distributed from the ocean level to the sphere with radius of 120 au is 8.09×10^{36} kg (4.065×10^6 $M_\odot$).

Orbital period of the star S0-2 with orbital eccentricity 0.88 will be 15.74 years, estimated speed at the pericenter 7630 km/s, at apocenter 487 km/s.

Now we will correct calculation, taking into account that the central mass is not limited to a sphere with radius of 120 au, but distributed in accordance with the law of density distribution (1). In this case, the calculated velocity of the star S0-2 in apocenter will increase by 2 times, and the period will be reduced. Correspondingly, we need to reduce the mass of Sgr A* approximately 4 times. After correction we get:

- $M_{CC} = 0.99 \times 10^{35}$ kg (4.51×10^4 $M_\odot$), diameter 700 km;
- $k_{RD} = 0.97$, and the mass of DM distributed from the surface of CC to the sphere with radius of 1880 au (apocenter of S0-2) is 8.07×10^{36} kg (4.056×10^6 $M_\odot$).

Now we choose appropriate value of the coefficient k_{DD}. Acceptable agreement between the calculated and the observed orbital velocity of the stars is achieved with $k_{DD} = 56$. Fig. 1 shows the calculated rotation curve of the Milky Way.

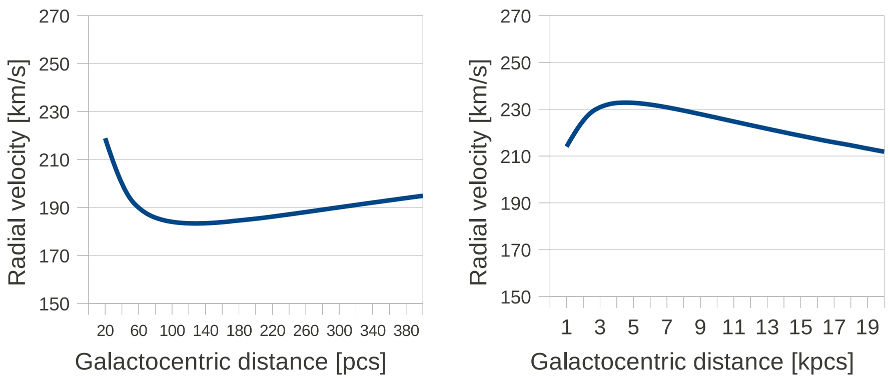

Figure 1: Calculated rotation curve of the Milky Way. Orbital velocity at a radius of 0.16 to 2.2 kpc is characterized by growth from the center to the periphery. This is consistent with observations that indicate the possible presence of a bar in the Galactic bulge.

Calculated density of the baryonic and dark matter at the galactic radius of 8.1 kpc will be about 0.50 $\mathrm{Gev/s^2/cm^3}$. Accordingly, the local DM density would be 0.43 $\mathrm{Gev/s^2/cm^3}$. Calculated mass of the Galaxy bounded by radius of 50 kpc would be about 4.0×10^{11} $M_\odot$.

3 Conclusions

Our modeling of the mass of the Milky Way was based on the assumption of the existence of neutron collapsars and neutrino dark matter model. Assuming that the scattering action of annihilation is characterized by hysteresis, we made a two-level density distribution, with the first level from the center to the borders of the bulge, the second level from the bulge to the edge of the Galaxy. By choosing parameters, we sought to reproduce the observed rotation speed of the star S0-2, and stars outsides the bulge. Introduction of the scattering factor of DM annihilation allowed us to see that the cuspy halo exists, but is concentrated near the central collapsar. Thus, dark matter manifests itself not only as a factor of the gravitational retention but it has a multilateral impact on the dynamics and evolution of galaxies.

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