индекс 3624

ЕРЕВАНСКИЙ ФИЗИЧЕСКИЙ ИНСТИТУТ

ЕФИ-768(83)-84

ЦЕНТРАЛЬНЫЙ НАУЧНО-ИССЛЕДОВАТЕЛЬСКИЙ ИНСТИТУТ ИНФОРМАЦИИ И ТЕХНИКО-ЭКОНОМИЧЕСКИХ ИССЛЕДОВАНИЙ ПО АТОМНОЙ НАУКЕ И ТЕХНИКЕ

V.G.GURZADYAN

ON THE NATURE OF HIDDEN MASS

ЕРЕВАН-1984

At present there is almost no doubt on the existence of hidden (missing) mass on the scales exceeding the galactic ones. Sufficient interest to this problem was stimulated by the appearance a few years ago of experimental indication of the existence of neutrino non-zero rest mass. With massive neutrinos as well as with other weakly interacting particles (photino, gravitino, axion, etc.) were related hopes to understand the nature of hidden mass [1,2]. According to the alternative hypothesis on the baryonic nature of hidden mass, the latter consists of weak stars, cool white dwarfs, neutron stars, black holes of different mass, "jupiters", etc.

Below we discuss the possibility of obtaining constraints on the parameters of hidden mass on the example of nearby dwarf spheroidal galaxies - satellites of the Galaxy, being intensely investigated recently. According to papers [3-5], the mass-to-luminosity ratio for those galaxies exceeds on average by an order their corresponding values for globular clusters. Analysis of the nature of the hidden mass pointed out by this fact based on the considerations of maximality of neutrino phase density leads to the lower limit of their mass: $m_\nu > 500$ eV [5]. The limit on the mass of black holes obtained in the same paper is $\sim 10^2 M_\odot$. Besides these papers we will proceed from the results of investigation of statistical properties of gravitating systems from the positions of ergodic theory [6,7]. Reducing the N-body problem to the investigation of geodesic flow on a Riemannian manifold with given metric, in these papers it was shown that gravitating systems can possess strong statistical properties peculiar to Kolmogorov K-systems, in particular exponential aspiration to microcanonical equilibrium distribution. The expression for the relaxation time obtained has a form:

$$\tau = \left(\frac{15}{4}\right)^{2/3} \frac{1}{2\pi\sqrt{2c}} \frac{V}{Gmn^{2/3}} \tag{1}$$

where V, m, n are the mean velocity, mass and concentration of particles, respectively, c is a constant of order of unity.

It is known that the core of the gravitating system if other mechanisms of energy transfer are absent will collapse to a central singularity during finite time scale τ_c. Following [5] assume that both photometric and spectroscopic observations of these galaxies exclude their closeness to this phase, so that the following inequality

$$\tau_c = \alpha\tau > \tau_H$$

is fulfilled, where $\tau_H = 2\cdot 10^{10}$ yrs is the Hubble time. From that one arrives at the following upper limit to the mass of gravitating objects constituting the hidden mass:

$$m < \frac{25}{8\pi(2c)^{3/2}} \frac{\alpha^3}{\gamma^{3/2}} \frac{\tau^{9/2}}{G^{3/2} M^{1/2} \tau_H^2} \tag{2a}$$

or normalized by characteristic values

$$m < 9{,}8\ 10^{-5}\left(\frac{\tau}{100\,pc}\right)^{9/2}\left(\frac{M}{10^6 M_\odot}\right)^{-1/2}\left(\frac{\alpha}{1}\right)^3\left(\frac{\gamma}{1}\right)^{-3/2} M_\odot \tag{2b}$$

where $\gamma\tau = GM/V^2$, M is total mass of the galaxy, τ is its characteristic radius.

Numerical values for the galactic masses and adopted radii taken from [4] are listed in first three columns of the Table. In last three columns the values of upper limit of mass m obtained using Eq.(2) corresponding to radii τ_1 and τ_2 (see below) are presented.

Let us briefly discuss the adopted values of the parameters from Eq.(2) and their possible variations.

Mass M. The values of dynamical masses of galaxies obtained by means of King's expression of tidal radius

$$\tau_t = d\left[\frac{M}{(3+e)M_G}\right]^{1/3}$$

(d is perigalactic distance, M_G - the mass of the Galaxy, e - the orbital eccentricity) as well as by velocity dispersion data according to [3,4] during more thorough study (accounting for the decreasing of velocity dispersion by radius, non-point potential of the Galaxy, etc.) may only increase.

Note that for Fornax galaxy the ratio $(M/L)\sim 1$ and one has the highest upper limit for m.

Radii τ_1 and τ_2. In the Table for characteristic values of radii are those at which surface brightness falls off roughly by a factor of 2 from the central value (τ_1) and beyond which we cannot confidently say that the galaxy extends (τ_2) [5]. Note that the radii at which surface brightness $\mu_V = 25^m\!.0$ is reached are sufficiently smaller than τ_2.

Parameter γ. If one uses the law $\tau^{1/4}$ which as believed fits the luminosity run of elliptical galaxies, this parameter can increase up to ~ 10.

Parameter α. Many numerical studies of the process of collapse of the core of non-homogeneous system lead to a conclusion that the collapse of, particularly, two-component system occurs during a time scale of an order of relaxation time (cf. [8] and references therein). The variation of relaxation time scale does not influence this result and leads to the changing of evolution time scale only [9]. On the other hand, the increase of the ratio of component's masses usually tends to hasten the collapse process.

Thus it follows that the variation of parameters used for estimation of m generally can lead to increasing of upper limits. Therefore it appears that the obtained mass values are strong arguments against the hypothesis that hidden mass in these galaxies may consist of weak stars or products of their evolution - white dwarfs, neutron stars and black holes.

Other arguments against the stellar nature of hidden mass are presented in papers [10,11]. So far as the picture with massive neutrino encounters certain difficulties connected with their phase density (for these galaxies), the most favourable situation appears to be for models with gravitino, photino and other collisionless particles. The latter if exceeding by an order the mass of baryonic matter, according to [2] can lead to several obs_rvable effects.

It is unclear so far whether the hidden mass has unique nature at all scales. It is not impossible that at small scales (galactic), say, baryonic matter, at the large scales (rich galaxy clusters) massive neutrinos dominate [12]. If on the other hand the hidden mass has unique nature, which seems more natural, the dwarf galaxies can be convenient objects for understanding its nature.

The author thanks the participants of the theoretical seminar under S.G.Matinyan for the interesting discussion.

Table

Object	M/L	$M/10^6 M_\odot$	r_1	r_2	$m_1/M_\odot$	$m_2/M_\odot$
Fornax	1.0	24	7'.7	30'	$1.3\ 10^{-2}$	5
Sculptor	6.8	13	6'.5	20'	$2.2\ 10^{-4}$	$3.4\ 10^{-2}$
Draco	13	2.1	4'.0	22'	$2.5\ 10^{-5}$	$4.3\ 10^{-2}$
Ursa Minor	126	22	7'.8	21'	$1.3\ 10^{-4}$	$1.2\ 10^{-2}$
Carina	54	3.4	4'.3	19'	$8.2\ 10^{-5}$	$5.6\ 10^{-2}$

REFERENCES

1. Shandarin S.F., Doroshkevich A.G., Zeldovich Ya.B. The Large-scale Structure of the Universe. - UFN, 1983, v.139, p.83-134.
2. Blumenthal G.R., Faber S.M., Primack J.R., Rees M.J. Formation of Galaxies and Large Scale Structure with Cold Dark Matter. - SLAC-PUB-3307, 1984.
3. Aaronson M. Accurate Radial Velocities for Carbon Stars in Draco and Ursa Minor: the First Hint of a Dwarf Spheroidal Mass-to-Light Ratio. - Astrophys. J., 1983, v.266, p.L11-15.
4. Lin D.N.C., Faber S.M. Some Implications of Nonluminous Matter in Dwarf Spheroidal Galaxies. - Astrophys. J., 1983, v.266, p.L21-L25.
5. Faber S.M., Lin D.N.C. Is There Nonlumionous Matter in Dwarf Spheroidal Galaxies? - Astrophys. J., 1983, v.266, p.L17-L20.
6. Gurzadyan V.G., Savvidy G.K. Collective Relaxation of Stellar Systems.- Preprint EPI-678 (68)-83, Yerevan 1983.
7. Gurzadyan V.G., Savvidy G.K. To the Problem of Relaxation of Stellar Systems. - Dokl. AN SSSR, 1984, v.277, p.69-73.
8. Lightman A.P., Fall S.M. An Approximate Theory for the Core Collapse of Two-Component Gravitating Systems. - Astrophys. J., 1978, v.221, p.567-579.
9. Spitzer L., Shull J.M. Random Gravitational Encounters of Spherical Systems. VII. Systems with Several Mass Groups. - Astrophys. J., 1975, v.201, p.773-782.
10. Hegyi D.J., Olive K.A. - Phys.Lett.B, 1983, v.126, p.28-32.
11. Carr B.J., Bond J.R., Arnett W.D. Cosmological Constraints of Population III Stars. - Astrophys. J., 1984, v.277, p.445-469.

12. Schramm D.N., Steigman G. Relic Neutrinos and the Density of the Universe. - Astrophys. J., 1981, v.243. p.1-7.

The manuscript was received 26 September 1984