第 50 卷第 12 期
2023 年 12 月

湖南大学学报（自然科学版）
Journal of Hunan University（Natural Sciences）

Vol. 50. No. 12.
December 2023

Open Access Article

FORMATION OF DISK-SHAPED AND EXOTIC GALAXIES WITH THE HELP OF BLACK HOLES

Melibayev Mukhtardjan
Associate professor of Kokand State Pedagogical Institute, Uzbekistan

Kuchkarov Mavzurjan
Associate professor of Kokand State Pedagogical Institute, Uzbekistan

Annotation. This work examines the structure and process of evolution of disk-shaped galaxies, as well as the question of the existence of exotic galaxies.
Keywords: Morphological sequences, regular galaxies, distributions of stars, irregular galaxies, luminosity function, exotic galaxies

INTRODUCTION

In this paper, we consider a possible variant of the formation of regular galaxies with the help of pairs or three of black holes. We will also consider the existence of exotic galaxies. With the help of pairs of black holes, it is possible to form all morphological sequences of galaxies E, So,Sa, Sb, Sc, Sd, SBa, SBb, SBc, SBd ,Ir, spherical, elliptical, spiral, barred (bar).
In order to involve the interest of a wide range of readers, we will briefly dwell on two main areas of theoretical description of galaxies. But these papers are not exhaustive but are good for an initial description of a galaxy and two black holes system.

ANALYSIS OF SCIENTIFIC SOURCES

Galaxies range widely in their sizes, shapes and masses; nevertheless, one may talk of a typical galaxy as something made out of about 10^{11} stars or so. Taking the average mass of a star to be that of the sun, the luminous mass in a galaxy is about $10^{11} M_\odot \sim 2 \times 10^{44}$ g. This mass is distributed in a region with a size of about 20 kpc. Even though most galaxies have a mass of about (10^{10} -10^{12}) $M_\odot$ and a size of (10-30) kpc, there are several exceptions at both ends of the spread. For example, 'dwarf galaxies' have masses in the range (10^5—10^7) $M_\odot$ and radii of only about (1-3) kpc. There are also some giant galaxies with masses as high as 10^{13} $M_\odot$.

Galaxies exhibit a wide variety in their shapes as well and are usually classified according to their morphology. Broadly speaking, one may divide them into 'ellipticals' and 'discs' [1,2].

Ellipticals are smooth, featureless, distributions of stars, ranging in mass from $10^8 M_\odot$ to $10^{i3} M_\odot$. The proportion of elliptical galaxies in a region depends sensitively on the environment. They contribute only about ten per cent of all galaxies in low density regions of the universe but nearly forty per cent in dense clusters of galaxies. The surface brightness of an elliptical galaxy is very well fitted by the de Vaucouleurs formula

$$I(R) = I_0 \exp(-kR^{1/4}) = I_e \exp\{-7.67 [(R/R_e)^{1/4} - 1]\} \qquad (1)$$

Received: October 04, 2023 / Revised: October 30, 2023 / Accepted: November 18, 2023 / Published: December 18, 2023
About the authors：Melibayev Mukhtardjan
Corresponding author- Email:

where R_e is the radius containing half tlic total luminosity and I_e is the brightness at R_e; R_e is about 3 kpc for bright ellipticals.

The luminosities of ellipticals vary over seven orders of magnitude. The relative number of elliptical galaxies with luminosities between L and $L + dL$ is given (approximately) by the empirical formula

$$\Phi(L)dL = \eta_*(L/L_*)^{-\alpha} exp\left(-\frac{L}{L_*}\right) dL/L_* \qquad (2)$$

where η_*= 1.2 x $10^{-2}/z^3$ Mpc^{-3}, $\boldsymbol{\alpha}$ = (1.1- 1.25), and L_*= 1.0 X 10^{10} $h^{-2}L_\odot$ in the V band. (This is called the Scliectcr luminosity function). The parameter h which occurs here has a value between 0.5 and 1; it is related to the Hubble constant which we will discuss later. The integral of $\Phi(L)$ over all L diverges in the lower limit; so clearly, this formula breaks down at very small L and needs to be truncated at some L_{min}. However, observations do suggest that the number of galaxies increases significantly at low values of luminosity which is correctly reflected in the formula. From this luminosity function, we can *formally* calculate the mean number density of galaxies

$$n = \int_0^\infty \Phi(L)dL = \eta_*\Gamma(1 - \alpha) \sim 1.2 \text{ x } 10^{-2}h^3 \ \Gamma(1 - \alpha) \ Mpc^{-3}, \quad (3)$$

which, of course, diverges for $\alpha > 1$; nevertheless, η_* often provides a rough estimate of the number density of bright galaxies. This number density of η_* corresponds to the mean intergalactic separation of $\eta_*^{-1/3}$Mpc. The mean luminosity

$$<L> = \int_0^\infty \Phi(L)LdL = \eta_* L_* \Gamma(2 - \alpha) = 1.2 \text{ x } 10^8 \ \Gamma(2 - \alpha) \text{ h } M_\odot \ Mpc^{-3}, \quad (4)$$

is, however, finite. Taking the mass of a galaxy to be $M_g \sim 10^{11}M_\odot$ the average mass density in the form of galaxies is

$$\rho_{gal} = — nMg \simeq I0^{-31} h^3 \text{ g cm}^{-3}. \qquad (5)$$

It may be noted that the luminosity function Φ(L) is essentially determined from the density of galaxies in the nearby region. The actual counts of faint galaxies show some crucial disparities with respect to Φ(L).

Another relevant parameter characterising a galaxy is its angular momentum. The angular momentum of any galaxy can be expressed conveniently in the following way: Consider a galaxy with mass M, radius R, angular momentum L and energy $E = —| E | \sim —(GM^2)/R$. The angular velocity of such a system will be about

$$\omega \simeq (L/MR^2). \qquad (6)$$

On the other hand, the angular velocity ω_{sup} needed for the system to be rotationallv supported against gravity is determined by the equation

$$\omega_{sup}^2 R \simeq GM/R^2 \qquad (7)$$

or $\omega_{\text{sup}} \sim (GM / R^3)^{1/2}$. The ratio $(\omega/\omega_{;\text{sup}})$ between the actual angular velocity ω and the angular velocity ω_{sup} needed to provide rotational support represents the degree of rotational support available in the system.

$$\boldsymbol{\lambda}=(\omega/\omega_{\text{sup}})=(\text{L/M } R^2))(\frac{R^{\frac{3}{2}}}{(G^{\frac{3}{2}}M^{\frac{1}{2}}})=\frac{LE}{GM^{5/2}} \quad (8)$$

and serves as a convenient dimensionless parameter characterizing the angular momentum of the system. For elliptical galaxies $\boldsymbol{\lambda} \sim 0.05$, showing very little systematic rotation and insignificant rotational support. Most ellipticals do show a certain degree of oblateness. The rotation of the ellipticals, however, is too small to account for this feature; it is more likely that the oblateness is due to the anisotropy of the velocity dispersion. In virial equilibrium, gravitational potential energy of the galaxy must be comparable to the kinetic energy of the constituents. This equality can arise either due to steady rotational motion or due to random motion of the stars. The stars in ellipticals have large random velocities which support them against the mean gravitational pull. Assuming that the foundations of disk-shaped galaxies consist of pairs of black holes, let's consider the laws of motion of such systems. If the distance between the black holes greatly exceeds their gravitational radii and the holes move with respect to each other at a velocity much lower than the speed of light, the corresponding equations of motion of such interacting black holes were obtained by D'Eath , Thorne and Hartle [6]. The gravitational field in the neighborhood of each black hole is described by a perturbed Kerr metric [4]. The metric far from the black holes is found using the post-Newtonian approximation to the required order of accuracy. Matching these expansions yields the following system of equations of motion for one of the black holes and of the precession of its angular momentuin in the field of the other black hole:

$$m_1\frac{d^2x_i}{dt^2}=F_1^{(!)}+F_1^{2!)}+\text{O}(\varepsilon^4) \quad (9)$$

$$\frac{dJ_1}{dt}=\left[\ (\Omega_1^{(!)}\ +\Omega_1^{(2)}+\ \Omega_1^{(3)}\ )\text{x}J_1\ \right] \quad (10)$$

Here we denote by x_i, the position and by v_i, the velocity of the ith black hole haviug a mass M , and an angular momentum J_i ,; $\mathbf{r}_{21} = \mathbf{x}_2 - \mathbf{x}_1$, $\mathbf{v}_{21} = \mathbf{v}_2 - \mathbf{v}_1$ are the positiou aud velocity of the second black hole with respect to the first; $r = |\ \mathbf{r}_{21}|$, and $\text{n} = \mathbf{r}_{21}/\text{r}$. Quantities

$$J_i = |\boldsymbol{J}_i\ | \quad \textbf{and j,} = \boldsymbol{J}_i\ /J,$$

are the magnitude and the unit vector in the direction of angular momentum of the i th black hole. The smallness parameter $\boldsymbol{\varepsilon}$ is equal to the ratio of the larger of the two gravitational radii to the characteristic distance between black holes. The value of the force $\mathbf{F^1}$ corresponding to the geodesic law of motion of one body in the gravitatioual field created by the second body [it was found by Einstein, lnfeld, and Hoffman is [7].

$$F_1^{(!)}=\frac{M_1\ M_2}{r^3}\{\mathbf{n}(1-\frac{\boldsymbol{4M_2+5M_1}}{r}+v_1^2+v_2^2-4\boldsymbol{v_1v_2}-\frac{3}{2}(\boldsymbol{v}_2\mathbf{n}\ )\ (\boldsymbol{v}_2\mathbf{n}\ ))\ -v_2[\mathbf{n}(\ 3\boldsymbol{v}_2\text{-}\ 4v_1)\ ]\ \} \quad (11)$$

The term in (9)

$$F_2^{(2)} = \frac{M_1 J_2}{r^3}\{6\mathbf{n}([\boldsymbol{j}_1 \text{x } \mathbf{n}\ ]\ \boldsymbol{v}_{12}) + 4[\boldsymbol{j}_2 \text{x } \boldsymbol{v}_{12}] - 6\ ([\boldsymbol{j}_2 \text{x } \mathbf{n}\ ](\ \boldsymbol{v}_{12}\boldsymbol{n})\ \}$$
$$+ \frac{M_2 J_1}{R^3}\{6\mathbf{n}([\boldsymbol{j}_1 \text{x } \mathbf{n}\ ]\ \boldsymbol{v}_{12} + 3\ [\boldsymbol{j}_1 \text{x } \boldsymbol{v}_{12}]\ -3[\boldsymbol{j}_1 \text{x } \mathbf{n}\ ](\ \boldsymbol{v}_{12}\ \mathbf{n})\ \}, \qquad (12\ )$$

describes the additional force due to spin-orbital interaction. The term O(ε^4) in the same equation corresponds to the spin-spin interaction and to the interactiou of the quadrupole moment of the black hole with the curvature: Both are of order $\boldsymbol{\varepsilon}^4$.

Equation (10) describes the precession of the angular momentum of a black hole with respect to a comoving orthogonal reference frame that does not rotate with respect to an infinitely distant observer. The gravimagnetic $\Omega_1^{(!)}$, and the geodesic, $\Omega_1^{(2)}$, components of the angular velocity of this precession and the component $\Omega_1^{(3)}$ due to the coupling of the quadrupole moment of the black hole to curvature are,

$$\Omega_1^{(!)} = \frac{I}{r^3}\ [-\boldsymbol{J}_2 + 3\mathbf{n}(\mathbf{n}\ \boldsymbol{J}_2)\ ] \qquad (13)$$

$$\Omega_1^{(2)} = \frac{M_2}{r^2}[(\frac{3}{2}\boldsymbol{v}_1\ -2\boldsymbol{v}_2)\ \text{x}\ \mathbf{n}\ \_ \qquad (14)$$

$$\Omega_1^{(3)} = \frac{3M_2}{M_1 r^3}\ \mathbf{n}\ (\mathbf{n}\ \boldsymbol{J}_1) \qquad (15)$$

respectively [8,9,10].

Analysis and results

The color, gas content and many other physical properties of galaxies vary systematically along the morphological sequence of types E-SO-Sa-Sb-Sc-Sd-Ir.

We assume that the formation of disk-shaped galaxies requires two black holes instead of their surrounding stars. A large galaxy is formed when two black holes come together. Apparently, the formation of disc-shaped galaxies, in particular spiral galaxies, is formed in an evolutionary manner according to the following scheme:

1. Existence of the pre-galactic state of two black holes with stars.
2. As two black holes come closer together, a single bar galaxy with shoulders is formed.
3. Further approaching a spiral galaxy is formed with two black holes in the disk-shaped center.
4. Further convergence of black holes leads to eleptic and spherical galaxy.
5. A spherical galaxy, due to its large symmetry, has a single merge black hole.

This schematic evolution of the constituent disc-shaped galaxies naturally corresponds to the age of the galaxies. Spherical and eleptic galaxies have a large age. This is consistent with astrophysical data. Accurately calculating the stage of the evolutionary process with two black holes and a huge number of stars is quite a difficult task. More than 50 universities around the world have begun to study the problem of merging two black holes. The author of this work does not have an exact algorithm or digital program for calculating this complex problem. We are ready to work together within the framework of an international conference or collaboration within the framework of an astrophysical project to solve this interesting problem.

Exotic galaxies are the type of galaxies that have a lower level of symmetry structure that can be explained using the constituent massive black holes. According to the author, a linearly constructed chain of black holes should exist in nature. The existence of cylinder-like structural black holes cannot be ruled out.

They should form cylinder-like galactic structures. Perhaps the origin of ulta high-energy cosmic rays (shalls) and their acceleration in space are connected precisely by cylindrical galactic objects [11]. The author would like to thank in advance the sincere physicists who share these opinions.

References:

1.Sattorov I. Astrofizika. Vol. 2., Tashkent, Turon –Iqbol, 2007. -350 p.

2.Padmanabhan T. Theoretical astrophysics. Cambridge University press. 2010. Vol. -456 p., Vol.2, -570 p., Vol.3, -620 p.

3.V.P. Frolov, I.D. Novikov, Black Hole Physics ,Copenhagen, 1977.

4. C.M. Baugh, S.Cole and C.S. Frenk. THE EPOCH OF GALAXY FORMATION, The Astrophysical Journal · March 1997.

5.M.Melibaev, M.Khuchkarov, Comparative Analyses of the Stellar and Galactic Processes in Different Spectrum of Electromagnet Radiation at Space Laboratories, Texas Journal of Engineering and Technology. 20-12-2022.

6. D'Eath P.D. Phys.Rev.**D11** 1387, **D18** ,990

7. Einstein A., Infeld L. Hoffman B. 1938. Ann. Math. **39**,65.

8. Thorne K.,Price R., Macdonald, Black Holees, Yale Univ., New Haven.

9. Misner C.W., Thorue K.S,. Wheeler,1973, Gravitation, Freeman, San Francisco.

10.Misner C.W,, 1978, Phys. Rev.,**D18**, 4510

11. Abreu, P., Aglietta, M., Ahlers, M., Ahn, E., Albuquerque, I., Allekotte, I., et al. (2013). Bounds on the density of sources of ultra-high energy cosmic rays from the Pierre Auger Observatory. *J. Cosmol. Astropart. Phys.* 1305:009. doi: 10.1088/1475-7516/2013/05/009