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# GALAXY GROUPS IN THE STRUCTURE OF THE UNIVERSE: OBSERVATIONAL AND STATISTICAL APPROACH

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**Abstract.** In this paper, a catalog of 408 galaxy groups has been compiled. The number of galaxies in the groups ranges from 5 to 30. The physical parameters of the groups, such as right ascension, declination, luminosity, radial velocity, velocity dispersion, R magnitude, and B magnitude, are presented. The empirical relationship between each parameter has been statistically analyzed.

**Keywords:** galaxy groups, statistical analysis, empirical relationship, number of galaxies, radial velocity.

**Аннотация.** В данной работе составлен каталог из 408 групп галактик. Количество галактик в группах варьируется от 5 до 30. Представлены физические параметры групп, такие как прямое восхождение, склонение, светимость, радиальная скорость, дисперсия скоростей, R-величина и B-величина. Проведен статистический анализ эмпирической зависимости между каждым параметром.

**Ключевые слова:** группы галактик, статистический анализ, эмпирическая зависимость, количество галактик, радиальная скорость.

**Annotatsiya**. Ushbu maqolada 408 ta galaktika guruhlari katalogi tuzilgan. Guruhlardagi galaktikalar soni 5 dan 30 gacha. Guruhlarning fizik parametrlari, masalan, o'ngga ko'tarilish, og'ish, yorqinlik, radial tezlik, tezlik dispersiyasi, R kattaligi va B kattaligi keltirilgan. Har bir parametr o'rtasidagi empirik bog'liqlik statistik jihatdan tahlil qilingan.

**Kalit so'zlar:** galaktika guruhlari, statistik tahlil, empirik bog'liqlik, galaktikalar soni, radial tezlik.

Galaxies are complex astronomical objects composed of gas, dust and billions of stars. By the middle of the 20th century, astronomical observations showed that galaxies in the universe are not located in isolation, but are clustered together in groups and clusters under the influence of mutual gravitational attraction. Galaxy groups typically consist of 3 to 30 galaxies that form a system gravitationally bound over long periods of time.

Galaxy groups are smaller in mass and size compared to galaxy clusters, and the degree of gravitational interaction between galaxies within them is also relatively low. Galaxy groups are typically characterized by dark matter halos with masses of $10^{12,5}$-$10^{14}M_{\odot}$. In such systems, the average value of velocity dispersion is $\sigma \approx 250$ km/s, however, in some cases, this indicator can vary from several tens of km/s to several hundred km/s [1].

One of the most thoroughly studied galaxy groups is the "Local Group". The Milky Way galaxy, together with galaxies located close to it, is also part of this group. Structurally, the Local Group is conditionally divided into two subgroups: the first is a subgroup consisting of about 10 or more galaxies located around the Milky Way, and the second is a subgroup around the Andromeda Nebula (M31), which includes about 20 galaxies. The second subgroup is at least 1.5 times larger in mass and size than the first, a situation mainly explained by the larger size of the M31 galaxy compared to the Milky Way and the presence of its large satellite, the M31 spiral galaxy. The Local Group consists of 1 elliptical, 3 spiral, 9 irregular (Ir), 3 spheroidal, and 18 dwarf (d) galaxies, totaling 34 galaxies.

Furthermore, another extensively studied type of galaxy groups in astronomy is compact galaxy groups. Such groups consist of a tight collection of galaxies located very close to each other and having strong gravitational binding. Compact groups have a denser structure compared to other galaxy groups and typically contain 3–8 galaxies. Initial ideas about intergalactic structures began to take shape in the mid-19th century. In 1877, French astronomer Édouard Stephan identified a system consisting of five galaxies located close to each other [2]. This structure later became known as

"Stephan's Quintet" and served as the basis for the formation of the concept of gravitational interaction between galaxies. In the early 20th century, Edwin Hubble scientifically substantiated that galaxies are distributed in the universe in the form of clusters and groups. Between the 1920s and 1960s, theoretical models explaining intergalactic distances and their mutual gravitational interaction were developed. In 1982, Canadian astronomer Paul Hickson compiled a comprehensive catalog of compact galaxy groups. It was determined that these compact groups contain galaxies of elliptical, spiral, and irregular shapes.

Galaxy groups have been studied by many foreign scientists using various methods and techniques. For instance, Tago.E, Einasto.M, Suhhonenko.I, Jõeveer.M, Vennik.J, Heinämäki.P, and Tucker.D.L created a new catalog of groups and clusters using the friends-of-friends method based on the final version of the 2dF GRS. Due to the use of a limited sample size, various selection effects were examined. For this purpose, changes in group sizes and the average number density of galaxies were observed when transferring observed nearby groups to larger distances. In N-body simulations, the size distribution of dark matter halos was studied, and the properties of these halos were compared with those of 2dF groups [3].

Jeltema, Tesla E., Mulchaey, John S., Lubin, Lori M., and Fassnacht, Christopher D. examined galaxy populations in seven X-ray-selected groups at intermediate redshift ($0.2<z<0.6$). Overall, the galaxy populations in these systems resemble those in clusters at similar redshifts; they have large fractions of elliptical galaxies ($f_e \sim 70\%$) and small fractions of galaxies with significant star formation ($f_{[OII]} \sim 30\%$). A strong evolution is observed in the galaxy populations at low redshift, similar to that seen in X-ray luminous groups. Both $f_e$ and $f_{[OII]}$ correlate with radius but do not reach the field value at $\sim r_{500}$. However, significant variations in galaxy populations were found among the groups, with some groups having field-like populations. Comparisons between the morphological and spectral properties of group galaxies indicate both gas-poor mergers and a population of passive spirals. Unlike low-redshift, X-ray-emitting groups, some of these groups lack central X-ray emission from the brightest galaxy, and in several groups with a central BGG (Brightest Group Galaxy), the BGG has multiple components. These groups represent a range of evolutionary stages in BGG formation. Some groups have a relatively high central galaxy density, and one group contains a sequence of seven bright galaxies within a radius of 200 kpc, which have a lower velocity dispersion than the rest of the system. None of the central galaxies, including those with multiple components, show significant [O II] emission. These observations support a scenario where BGGs form relatively late through gas-poor mergers [4].

Based on the study of the aforementioned galaxy group catalogs, a new catalog containing 408 galaxy groups was compiled. The parameters of the galaxy groups in this catalog were obtained using the J/ApJ/776/71, VII/250, J/MNRAS/348/866 catalogs, as well as the SIMBAD and VizieR websites. The catalog includes physical parameters of the galaxy groups such as right ascension, declination, mass, luminosity, redshift, radial velocity, velocity dispersion, number of galaxies, morphological class, R magnitude, and B magnitude. They are z - redshift; MS - morphological class; L ($L_\odot$) - luminosity; M ($M_\odot$) - mass; J2000 hh mm ss - right ascension; D2000 dd mm ss - declination; σ - velocity dispersion; R (mag) - R-band magnitude of the galaxy groups; B (mag) - B-band magnitude of the galaxy groups. The number of member galaxies in the groups in the catalog ranges from 5 to 30. The statistical analysis of the empirical relationships between the given parameters is as follows:

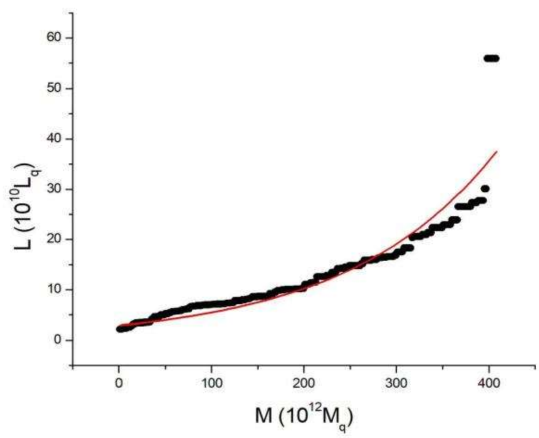

Figure-1 Mass-luminosity relation $M(10^{12}M_q)$ - mass M ($M_\odot$); $L(10^{10}L_q)$ - luminosity L ($L_\odot$)

In the Fig-1, the relationship between the mass of galaxy groups on the X-axis and their luminosity on the Y-axis for galaxy groups is described. The black dots in the figure represent observational data, while the continuous line correcponds to the fitted fuction. Luminosity and mass are related through the following function.

$$L_\Theta=2,94(\pm 0,15)e^{M_\Theta/160,36(\pm 3,95)} \quad (1)$$

The mass and luminosity of galaxy groups are related by an exponential function. That is, as mass increases, luminosity does not increase linearly; it can be observed to rise according to an exponential law. The values ±0.15 and ±3.95 are errors derived from statistical calculations.The correlation coefficient (relationship between luminosity and mass) is cc=0.85551. This value indicates a very strong positive correlation. **Note:** The observational data in the Fig-2, i.e., the points, show that as mass increases, luminosity initially grows slowly and then more rapidly. This characteristic is very well described precisely by an exponential function, because the error in this function is smaller compared to other functions. Additionally, relationships in other astrophysical processes are also expressed by exponential functions.

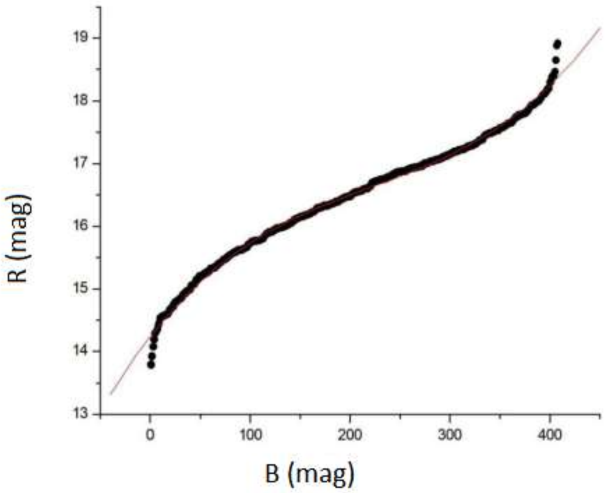


Figure-2. R mag-B mag relation

The Fig-2 depicts the relationship between B mag on the X-axis and R mag on the Y-axis. The points represent observational data, and the continuous curved line is the curve of the function fitted to the graph. The graph fits this function.

$$R=14,25(\pm 0,01)+0,02(\pm 2,8\cdot 10^{-4})\cdot B+$$
$$+(-6,62\cdot 10^{-5})(\pm 1,61\cdot 10^{-6})B^2+$$
$$+9,9\cdot 10^{-8}(\pm 2,6\cdot 10^{-9})B^3 \quad (2)$$

B mag and R mag are related by a cubic polynomial (third-degree) function. This function represents the empirical relationship between the B mag and R mag of galaxy groups. The correlation coefficient (relationship between R mag and B mag) is cc=0.99777. This value indicates a very strong positive correlation. **Note**: The third-degree polynomial function fits the observational data better than other, simpler functions. The error indicated for each coefficient is very small. The relationship between R mag and B mag depends on the characteristics of stellar spectra, atmospheric influence, and the impact of the observational instruments used.

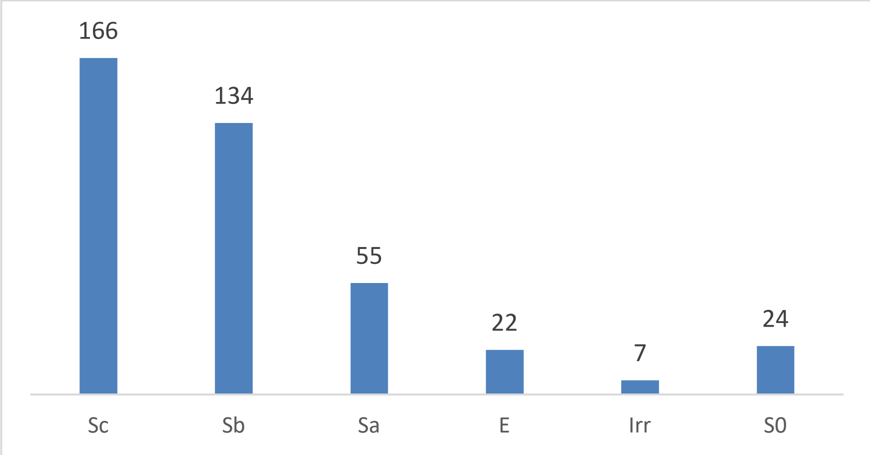


Figure-3. The relationship between morphological class and groups number

If we look at the statistical analysis of the morphological classes of the compiled special catalog groups, the number of groups belonging to the Sc class is 166, Sb is 134, Sa is 55, E is 22, Irr is 7, and S0 is 24. The maximum value is shown by groups belonging to the Sc class, while the minimum value is shown by groups in the Irr class. Spiral groups (especially Sc and Sb types) dominate among the galaxy groups. The proportion of elliptical and S0 groups is relatively low. This indicates a high number of galaxies with active star formation.

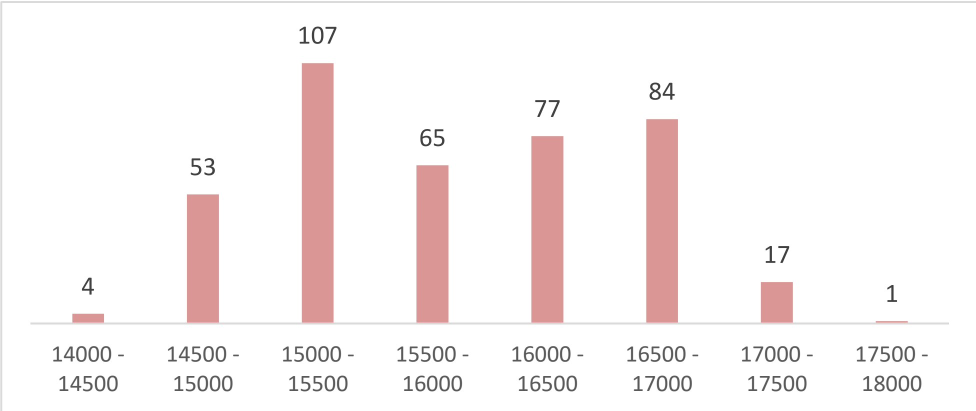


Figure-4. The relationship between radial velocity and the number of groups

The diagram shows the distribution between radial velocity (km/s) and the number of galaxy groups. It can be seen from the data that the main part of the groups is concentrated in the velocity range of 15000-17000 km/s. Particularly, the maximum value (107 groups) is observed in the interval of 15000-15500 km/s. This indicates that the average radial velocity of the galaxy groups in the compiled special catalog is concentrated precisely in this range. The sharp decrease in the number of groups at velocities above 17000 km/s indicates that high-velocity objects are rare. In the low-velocity range (14000-14500 km/s), the number of groups is also very low. The distribution has a single-peaked (unimodal) appearance.

**Conclusion.** A statistical analysis of the relationships between the parameters of the selected galaxy groups revealed strong empirical connections among them. It was found that the relationship functions are not linear but rather complex polynomial, high-degree, and exponential. The reason for the strong and complex interrelationships among the physical parameters of galaxy groups stems from their formation as cohesive objects. The obtained results are also of significant importance for understanding the dynamic properties of galaxy groups.

**Appendix 1**

| J2000 hh mm ss | D2000 dd mm ss | z | Velocity dispersion (km/s) | Radial velocity (km/s) | L ($L_{\odot}$) | M( $M_{\odot}$) | Number of galaxies |
|---|---|---|---|---|---|---|---|
| 23 44 32,9076 | -26 26 37,9 | 0,05402 | 600,7 | 15752 | 4,99E+10 | 4,68E+12 | 8 |
| 23 44 31,66247 | -26 32 43,4 | 0,05452 | 600,7 | 15894 | 4,99E+10 | 4,68E+12 | 8 |
| 23 44 19,92193 | -26 25 32,797 | 0,05291 | 600,7 | 15440 | 4,99E+10 | 4,68E+12 | 8 |
| 23 43 52,60247 | -26 27 25,697 | 0,05147 | 600,7 | 15042 | 4,99E+10 | 4,68E+12 | 8 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 23 43 23,86967 | -26 32 03,199 | 0,05133 | 600,7 | 14985 | 4,99E+10 | 4,68E+12 | 8 |
| 23 40 33,09073 | -29 50 24,796 | 0,05108 | 247,6 | 14928 | 8,60E+10 | 1,20E+13 | 9 |
| 23 40 30,0732 | -29 52 13,3 | 0,05133 | 247,6 | 14985 | 8,60E+10 | 1,20E+13 | 9 |
| 23 39 52,46327 | -29 56 24,695 | 0,05018 | 247,6 | 14672 | 8,60E+10 | 1,20E+13 | 9 |
| 22 25 10,37833 | -31 04 11,201 | 0,04953 | 247,6 | 14473 | 8,60E+10 | 1,20E+13 | 9 |
| 23 39 39,17733 | -29 57 08,1 | 0,05201 | 247,6 | 15184 | 8,60E+10 | 1,20E+13 | 9 |
| 23 39 11,22793 | -29 51 41,105 | 0,05086 | 247,6 | 14872 | 8,60E+10 | 1,20E+13 | 9 |
| 23 47 01,7724 | -27 28 54,898 | 0,05024 | 148,8 | 14672 | 5,41E+10 | 5,36E+12 | 8 |
| 23 46 41,08153 | -27 27 15,3 | 0,04999 | 148,8 | 15022 | 5,41E+10 | 5,36E+12 | 8 |
| 23 46 25,99367 | -27 22 14,599 | 0,04965 | 148,8 | 14501 | 5,41E+10 | 5,36E+12 | 8 |
| 00 01 53,59993 | -35 28 04,505 | 0,05001 | 287,4 | 14615 | 4,68E+10 | 4,21E+12 | 5 |

## Appendix 2

| J2000 hh mm ss | D2000 dd mm ss | M S | R (mag) | B (mag) |
|---|---|---|---|---|
| 23 44 32,9076 | -26 26 37,9 | Sc | 17,256 | 18,088 |
| 23 44 31,66247 | -26 32 43,4 | Sc | 16,857 | 18,133 |
| 23 44 19,92193 | -26 25 32,797 | Sc | 16,392 | 17,755 |
| 23 43 52,60247 | -26 27 25,697 | Sc | 17,421 | 17,965 |
| 23 43 23,86967 | -26 32 03,199 | Sc | 16,744 | 17,812 |
| 23 40 33,09073 | -29 50 24,796 | E | 15,144 | 16,501 |
| 23 40 30,0732 | -29 52 13,3 | Sc | 17,948 | 19,221 |
| 23 39 52,46327 | -29 56 24,695 | Sb | 16,328 | 17,624 |
| 22 25 10,37833 | -31 04 11,201 | Sc | 16,943 | 17,696 |
| 23 39 39,17733 | -29 57 08,1 | Sb | 17,23 | 18,37 |
| 23 39 11,22793 | -29 51 41,105 | Sa | 16,289 | 17,625 |
| 23 47 01,7724 | -27 28 54,898 | E | 16,536 | 17,853 |
| 23 46 41,08153 | -27 27 15,3 | Sc | 15,599 | 16,72 |
| 23 46 25,99367 | -27 22 14,599 | Sc | 17,048 | 17,946 |
| 00 01 53,59993 | -35 28 04,505 | Sc | 17,322 | 18,394 |

**References**

1. Jennifer Lynn Connelly // Optically and X-ray Selected Galaxy Groups at Intermediate Redshift // Munchen, den 18. Mai 2012
2. Rao, J. “Explore the Archer’s Realm”. Space.com (2005 year September 2).
3. Tago.E, Eynasto.J, Saar.E, Eynasto.M, Suxonenko.I, Joever.M, Vennik..J, Heinamaki.P, Taker. DL // VizieR Online Data Catalog: Clusters and groups of galaxies in 2dF // Astronomische Nachrichten, Vol.327, Issue 4, p.365 May 2006.
4. Jeltema, Tesla E, Mulchaey, Jon S, Lubin, Lori M Fassnacht, Kristofer D. // The Evolution of Galaxies in X-Ray-luminous Groups // The Astrophysical Journal, Volume 658, Issue 2, pp. 865-883. April 2007
5. Eke V.R, Baugh C.M, Cole S, Frenl C.S, Norberg P, Peacock J.A, Baldry I.K, Bland-Hawthorn J, Bridges T, Cannon R, Efstathiou G, EllisR.S, Glazebrook K, Jackson C, Colles M, Collins C, Couch W, Dalton G, de Propris R, DriverS.P //VizieR Online Data Catalog: 2dFGRS Percolation-Inferred Galaxy Group (2PIGG) (Eke+, 2004) // Monthly Notices of the Royal Astronomical Society, Volume 348, Issue 3, pp. 866-878.
6. Matthew Colless, Bruce A. Peterson, Carole Jackson, John A. Peacock, Shaun Cole, Peder Norberg, Ivan K. Baldry, Carlton M. Baugh, Joss Bland-Hawthorn, Terry Bridges, Russell Cannon, Chris Collins, Warrick Couch, Nicholas Cross, Gavin Dalton, Roberto De Propris, Simon P. Driver, George Efstathiou, Richard S. Ellis, Carlos S. Frenk, Karl Glazebrook, Ofer Lahav, Ian Lewis, Stuart Lumsden, Steve Maddox, Darren Madgwick, Will Sutherland, Keith Taylor // VizieR Online Data Catalog: The 2dF Galaxy Redshift Survey (2dFGRS) (2dFGRS Team, 1998-2003) // The Astrophysical Journal.
7. C. M. Carollo, A. Cibinel, S. J. Lilly, F. Miniati, P. Norberg, J. D. Silverman, J. van Gorkom, E. Cameron, A. Finoguenov, Y. Peng, A. Pipino, C. S. Rudick // The Zurich Environmental Study (ZENS) of Galaxies in Groups along the Cosmic Web. II. Galaxy Structural Measurements and the

Concentration of Morphologically Classified Satellites in Diverse Environments // The Astrophysical Journal, Volume 776, Issue 2, article id. 72, 49 pp. (2013).

8. Oliver Müller, Katja Fahrion, Marina Rejkuba, Michael Hilker, Federico Lelli, Katharina Lutz, Marcel S. Pawlowski, Lodovico Coccato, Gagandeep S. Anand and Helmut Jerjen // The properties of dwarf spheroidal galaxies in the Cen A group // Astronomy & Astrophysics, Volume 645, id.A92, 16 pp. January 2021.

9. Abril-Melgarejo.V, Epinat. B, Mercier. W, Contini. T, Boogaard. L, A. Brinchmann J, Finley. H, Michel-Dansac. L, Ventou. E, Amram. P, Krajnovic. D, Mahler. G, Pineda. J. C. B, Richard. J // VizieR Online Data Catalog: Tully-Fisher relation in MAGIC groups (Abril-Melgarejo+, 2021) // Astronomy & Astrophysics, February 2021.

10. Liu A., Bulbul E., Ghirardini V., Liu T., Klein M., Clerc N., Oezsoy Y., Ramos-Ceja M. E., Pacaud F., Comparat J., Okabe N., Bahar Y. E., Biffi V., Brunner H., Brueggen M., Buchner J., Ider Chitham J., Chiu I., Dolag K., Gatuzz E., Gonzalez J., Hoang D. N., Lamer G., Merloni A., Nandra K., Oguri M., Ota N., Predehl P., Reiprich T. H., Salvato M., Schrabback T., Sanders J. S., Seppi R., Thibaud Q. // The eROSITA Final Equatorial-Depth Survey (eFEDS). Catalog of galaxy clusters and groups. // Astronomy & Astrophysics, August 2022.