Astronomical and Astrophysical Transactions (*AApTr*), 2025, Vol. 35, Issue 3, pp. 285–290,
ISSN 1055-6796, Photocopying permitted by license only, ©Cambridge Scientific Publishers

Binary galaxies: observational data and empirical relations

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Received 27 April, 2025; accepted 31 May, 2025

This paper analyzes a compiled catalog of binary galaxies developed by the author and studies the statistical properties of their physical parameters. Additionally, based on observational data and using statistical methods, the relationships between the mass of the central black hole, the velocity dispersion of stars in the bulge, and the total luminosity of binary galaxies are investigated. The derived empirical formulas are of significant importance in understanding galaxy evolution.

Keywords: Binary galaxies, empirical relations

1 Introduction

Binary galaxies are systems composed of two galaxies that are physically bound to each other (Toomre & Toomre (1972)). Binary galaxies play an important role in understanding galactic evolution, nuclear activity, and star formation processes (Barnes & Hernquist (1992); Mihos & Hernquist (1996)). Observations show that such interactions can lead to the formation of spiral structures, the emergence of gaseous tidal streams, and even mergers between these galaxies (Conselice (2003); Lotz et al. (2008)). This study is based on observational data of binary galaxies and focuses on the interrelationships between their structural properties and physical parameters, which are key issues in astrophysics (Patton et al. (2000); Lambas et al. (2003)). Through this research, a deeper understanding of the dynamics of binary galaxies, their evolutionary stages, and the large-scale structure of the universe can be achieved (Kitzbichler & White (2008); Ellison et al. (2008)). Based on available observational catalogs and databases, a compiled catalog of binary galaxies was created. The relationships between their parameters were identified and statistically analyzed.

The aim of the study:

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- To analyze and study existing catalogs and atlases of binary systems;
- To create a general catalog of binary galaxies based on recent observational data, conduct its statistical analysis, and determine empirical correlations between their physical properties.

2 The compiled catalog of binary galaxies and its statistics

Galaxy catalogs generally contain information about their spatial positions, various parameters, and physical properties. The first statistical studies on binary galaxies were conducted by the Swedish astronomer Holmberg (Holmberg (1937)), and a smaller catalog of galaxy pairs was created by Turner (Turner (1976)). The Arp Atlas (Arp (1982)) mainly includes peculiar structures found in interacting galaxies. Among the currently available catalogs of galaxy pairs, the most complete, homogeneous and well studied is the Karachentsev catalog, which includes galaxies selected from the Local Group (Karachentsev & Makarov (2008)). In compiling the catalog, we used the catalogs of the authors mentioned above as well as recent observational data. As a result, a compiled catalog containing 613 galaxy pairs was created. The latest observational data were used in the compilation process.

Throughout the NED database, the coordinates of binary galaxies were updated to epoch 2000.0, including corrections for proper motion and redshift. Missing parameters for some galaxies, such as the central black hole mass, the velocity dispersion of stars in the bulge, morphological type, and type code, were obtained from the authors' publications (Greene et al. (2016); van den Bosch (2016); Koss et al. (2022); Williams et al. (2022); Nuritdinov et al. (2025)). The remaining quantities were derived using

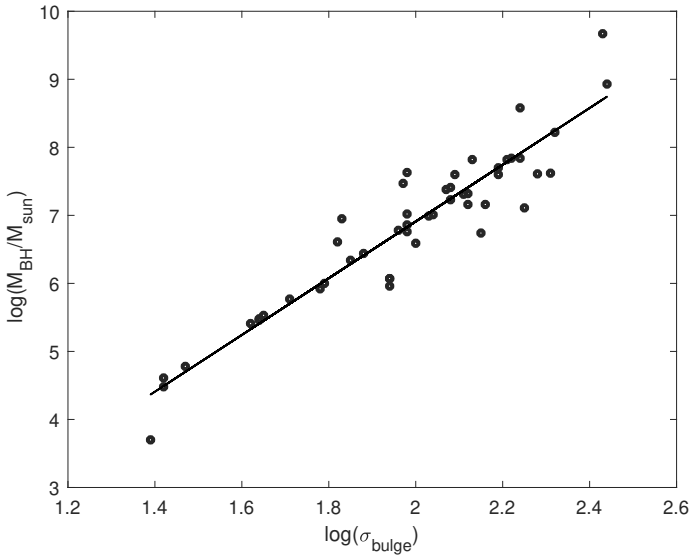


Figure 1 The relationship between the central black hole mass of each galaxy and the velocity dispersion of stars in its bulge, determined from observations.

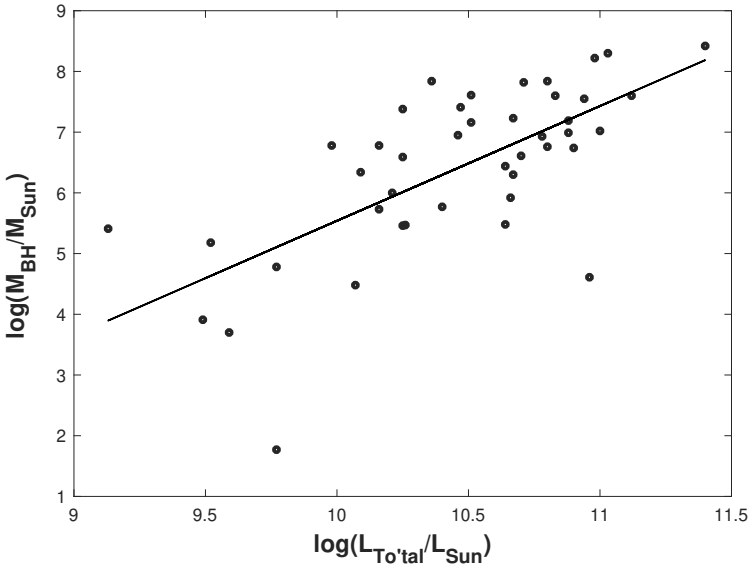


Figure 2 The relationship between the central black hole mass of a galaxy and the total luminosity of binary galaxies, determined from observations.

empirical formulas. Accordingly, total orbital masses were calculated using the formulas of Heisler and Tremaine (Heisler & Tremaine (1985)). Due to the extensive size of the complete version of this catalog, it is deemed appropriate to publish it separately. Below are presented some correlation coefficients and empirical formulas. The empirical relation between the mass of the central black hole and the velocity dispersion of stars in the bulge of galaxies was found in the following form:

$$M_{BH} = (4.17 \pm 0.22)\sigma + (-1.43 \pm 0.43), \quad \text{cc} = 0.94. \tag{1}$$

This relation indicates that the mass of black holes is closely linked to the dynamics in the central region of the galaxy (see Figure 1).

The empirical relation between the black hole mass and the total luminosity of galaxies was found in the following form:

$$M_{BH} = (1.89 \pm 0.32)\mathrm{L} + (-13.36 \pm 3.33), \quad \text{cc} = 0.68. \tag{2}$$

This indicates that galaxy luminosity has a certain degree of influence on the mass of central black holes (see Figure 2).

The empirical relation between the black hole mass and the morphological type code of galaxies was found in the following form:

$$M_{BH} = (-0.2 \pm 0.03)\mathrm{T} + (7.25 \pm 0.13), \quad \text{cc} = -0.64. \tag{3}$$

The negative value of the correlation coefficient indicates an inverse relationship between black hole mass and morphological type. These relations demonstrate that the key physical parameters in binary galaxy systems are interrelated (see Figure 3).

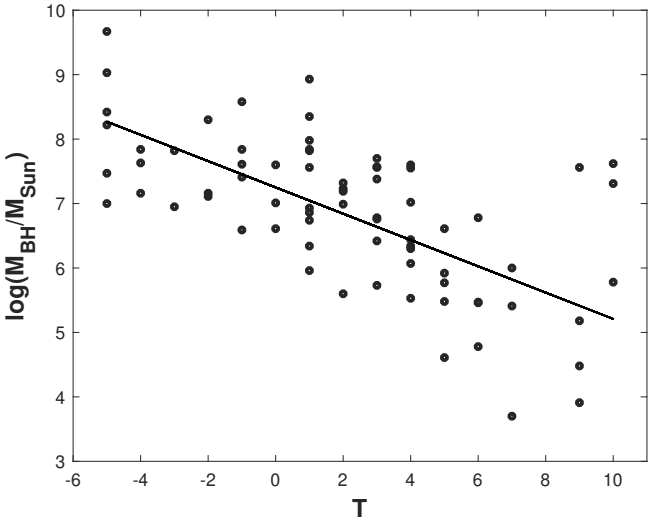


Figure 3 The relationship between the black hole mass of each galaxy and the morphological type of the corresponding galaxy, determined from observations.

In particular, the strong correlation (cc = 0.94) between black hole mass and the velocity dispersion of stars in the bulge confirms that this relationship is one of the most important indicators of galactic dynamics. Additionally, the correlation between radial velocity and distance reflects the governing laws of mutual galaxy motion.

3 Conclusion

The following results were achieved within the scope of this study:

1. A compiled catalog of 613 galaxy pairs was created within a volume of 200 Mpc in diameter, with radial velocities less than 13,500 km/s.
2. Correlation values were determined for the pairs $(M_{BH}; \sigma)$, $(M_{BH}; \mathrm{L})$ and $(M_{BH}; \mathrm{T})$.
3. Statistical analysis was carried out, and empirical formulas were derived based on the values above.

These results serve as an important resource for gaining a deeper understanding of galaxy evolution and the formation processes of black holes.

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