CORRECTION OF THE ORBITAL MASS OF DOUBLE GALAXIES ESTIMATION

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ABSTRACT

We obtain a more accurate statistical estimation of the mass of double galaxies moving in circular orbits, including confidence intervals for different confidence levels.

Keywords: extragalactic astronomy, mass of galaxies, double galaxies

1. INTRODUCTION

Determination of the mass of galaxies is one of the most difficult problems in extragalactic astronomy. One of the methods of estimating the mass of double galaxies is associated with the assumption of the motion of galaxies in a closed Keplerian orbit. The method of determining the mass of double galaxies was developed by Page (Page 1952, 1960, 1961, 1962). Later this approach was improved in the works of Holmberg (Holmberg 1954), Karachentsev and Shcherbanovsky (Karachentsev 1970, Norellinger (Noerdlinger 1975), Karachentsev (Karachentsev 1987).

2. DETERMINATION OF THE ORBITAL MASS

Karachentsev I.D. (Karachentsev 1987) considers the physical pair of galaxies that carry orbital motion around a common center of mass. In the simplest case, we are dealing with a circular orbit for which according to Kepler’s third law the total mass of galaxies is determined by the formula:

\[ M = \frac{R_p (ΔV_r)^2}{G} \]  

where \( R_p \) – projection of the distance between galaxies on the picture plane, \( ΔV_r \) – relative radial velocity, \( η \) – a geometrical projection factor that has the form:

\[ η = \sin^2 i \cos^2 Ω (1 - \sin^2 i \sin^2 Ω) \frac{1}{2} \]  

\( R_p \), \( ΔV_r \) determined from observation but for an individual galaxy the geometric factor \( η \) cannot be determined, therefore, statistical method of evaluation is used. An assumption is made about the random position of galaxies in relation to the line of sight. Then, the simultaneous distribution of the random quantities \( i \) and \( Ω \) in this case has the form:

\[ p_k(i, Ω) = \frac{2}{π} \sin i \quad 0 < i < \frac{π}{2}, 0 < Ω < \frac{π}{2} \]  

Further in the work (Karachentsev 1987) Karachentsev proposed to use the expected value of a geometrical projection factor \( < η > = \frac{3π}{32} \). Therefore, we get an estimate of the coefficient that is being used at the moment:

\[ K_0 = \frac{3π}{32} \]

\[ M = \frac{32}{3πG} R_p (ΔV_r)^2 \]

3. CHANGING THE EXISTING ESTIMATION OF THE ORBITAL MASS

Generally speaking, \( < \frac{1}{η} > = \frac{1}{<η>} \), so it is interesting to investigate the distribution of \( K \). If we try to calculate the expected value of \( K \), we can see that the integral diverges and therefore no expected value exists. In such cases, the median is used as an estimate of the central distribution tendency (Demidenko 1981). The median is considered a robust estimate (Demidenko 1981) and can be quantified numerically.

Using computer simulation, a median of the distribution was calculated, which is proposed to be used to estimate the total mass of galaxies. Then the new estimation is 1.54 times more than (1) and looks like (2) with

\[ K = 1.54K_0 \]

Of course, estimation is still quite rough. For some orbits, we can get a mass much less than the real one. In view of this, other quantiles of distribution were also calculated (results are shown in Table 1). Table 1 contains confidence intervals for different confidence probabilities and clearly illustrates in what limits the mass of double galaxies can vary.

| Probability q, % | Quantile αq |
|-----------------|-------------|
| 50              | 1.54        |
| 84.13           | 20.26       |
| 15.87           | 0.45        |
| 97.72           | 1227        |
| 2.28            | 0.31        |
| 9              | 238         |
| 5               | 0.33        |
| 97.5            | 1015        |
| 2.5             | 0.31        |

So, the lower and upper limits of the 1σ confidence interval are 0.45 and 20.26 respectively and we propose to use the factor \( K = 1.54^{±18.7} \) in the equation (2). This

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confidence interval is very asymmetrical, so an estimation of its boundary based on the statistical distribution of $K$ is very useful. Estimation of the confidence intervals limits for some popular confidence levels one can find in Tab. 1.

4. CONCLUSION

The method of measuring the mass of double galaxies was considered. The use of the mass distribution median is proposed instead of the inversed expected value of a geometrical projection factor. As a result, we propose some corrections to the formula that was used for years. In addition, the confidence intervals for different confidence probabilities were calculated to estimate its accuracy.

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