Extrasolar Planets in Binary Systems (Statistical Analysis)

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Abstract. During the last decades, searching for extrasolar planets was growing rapidly, and about 3869 exoplanets were discovered using various detection methods. In this work, we present a statistical analysis for these known exoplanets up to date provided by NASA Exoplanet Archive. In addition, we classify them depending on the type of the host stars’ type; single star, and binary or multiple systems. Focusing on the exoplanets in binary system, we determine the common type of the stability orbit of the host binary system, and the probable mass ratio of the system to host a minimum one exoplanets. Moreover, we clarify the number of the companion planets for different systems.

Keywords: Extrasolar Planets, binary systems, Statistical Analysis, Stability

1. Introduction

Over the past years, searching for the extrasolar planets became one of the most important research areas around the world trying to study the possibility to find of a planet similar to our planet “The Earth”. The first step in this field was taken by A. Wolszczan, and D. A Frail, when they confirmed the existence of a planetary system around the PSR 1257+1 millisecond pulsar [1]. To find Earth-sized planets near the sun-liked stars many scientific planet-hunting missions were designed such as; CoRoT (Convection, Rotation and planetary Transits) [2], Kepler [3], K2 [4], Transiting Exoplanet Survey Satellite(TESS) [5], PLAnetary Transits and Oscillations of stars (PLATO)[6, 7], and CHaracterising ExOPlanet Satellite (CHEOPS)[8]. All of these missions helped to estimate a number of exoplanets around the single, double and multiple systems, and to determine their physical and orbital parameters such the masses, radius, density, age, with their orbits. The common methods to detect the extrasolar planets are Direct Imaging, Microlensing, Radial Velocity and Transit method.
Single stars have a numerous number of extrasolar planets, and the database of that can be found in helpful websites such as: The Extrasolar Planets Encyclopaedia [9], NASA Exoplanet Archive [10], and The Open Exoplanet Catalogue [11].

Binary star systems can provide a suitable environment to understand the formation and evolution of the exoplanet, it also formed about 70% our galaxy. Furthermore, about one-half of these systems consist of pre-main sequence and main sequence stars, while at least 57% of G and K dwarf stars and 30% of M dwarfs have a companion, observation present an essential way to understand the evolution of binary system. [12, 13]. Today we can determine the physical and geometrical parameters of the components of binary and multiple star systems by combining the speckle interferometry measurements with the radial velocity observations [14, 15].

Gordon Walker suggested the first exoplanet in spectroscopic binary system \( \gamma \) Cep (HD 222404, HIP 116727, and HR 8974), when he noticed a variation in the radial velocity observation [16]. In 2003, A.P. Hatzes confirmed the existence of that planet using the radial velocity method. It was a giant planet with a period of 905.57 days, 0.12 of eccentricity, and \( M_{\text{sin} i} = 1.7 \) Jupiter mass [17, 18]. Again in 2016 he discovered an Earth-like planet around a member of a multiple star the Proxima Centauri, which is the closest star to our solar system [19].

2. Exoplanets in Binary system:

In new era technology of the supercomputer astronomical simulation and adaptive optics, the exoplanetology will be one of the most important targets; by studying the exoplanets directly or by determining the interaction between the magnetic field of the star and the exoplanet.

More than a half of the stars of our galaxy are a binary and multiple star systems. Furthermore about 50% of them have main sequence types. [12, 13].

Figure 1 below shows the timeline of the host binary system, which has a 132 confirmed exoplanets. The first exoplanet HD 114762 Ab B, which has about 11 Jovian masses [20, 21], while the last one is NGTS-3Ab B, which has a mass of \( 2.38 \pm 0.26 \) M\( \text{J} \) [22].
Based on the last update of December 13, 2018, NASA’s website confirmed the numbers of the exoplanets are 3869, see website: https://exoplanetarchive.ipac.caltech.edu/index.html. Furthermore, the database of the Catalogue of exoplanets shows the binary star systems have a 132 exoplanets. While multiple systems have a 34 exoplanets [9]. Figure 2, shows that 3696 Exoplanets, which are about of 96% belongs to a Single stars, while the double systems have 3%, and Multiple systems is just 1%.

Figure 1 The timeline of the binary systems host Exoplanets.

Figure 2 The Exoplants in Single stars, double systems, and Multiple systems.
3. The exoplanets diversity in the binary system

Previously we found that the binary systems have a total of 132 exoplanets divided into five categories depending on the number of exoplanets for each host system. 68 systems have a single exoplanet, 14 systems have two exoplanets, 6 have three exoplanets, two systems have four exoplanets, and two systems have five exoplanets. Figure 3 shows the diversity of the exoplanets which belong to binary systems.

![Figure 3 The Diversity of the exoplanets in binary systems](image)

Figure 4 shows the numbers of the binary system which host a minimum one exoplanet depend on the mass ratio of the binary system $\frac{m_2}{m_1+m_2}$, where, $m_1$ and $m_2$ the mass of the first and second components of the binary star. We found 41 of 92 the host binary systems belong to mass ratio of 0.41 - 0.50 and 0.11 - 0.20, with 21 and 20 systems, respectively.

![Figure 4 The mass ratio vs the number of the binary system](image)
4. The stability

In astrophysics depending on initial conditions, various constants, and the physical and mathematical theorems, it is very difficult to determine a scientific definition of the stability. We have about 50 concepts related with stability [23].

Depending on the binary’s mass ratio \( \frac{m_2}{m_1 + m_2} \) and the eccentricity of the system, R. Dovark in 1984, classified the stability of orbits for planetary system in binary systems into three types: **The satellite-type orbits (S-type)**, which the planet orbits around one of the components of the binary system. About 107 plants belong to this type of stability, and it forms about 76 % of the confirmed exoplanets in binary system [24], see **Figure 5**. The famous example for this type is Gamma Cephei [17] and it is the only exoplanet which was discovered in spectroscopic binaries.

**Figure 5 The type of the Stability of exoplants orbit in the binary star**

**Figure 6**, shows the relation between the logarithms of the semi-major of the S – type binaries system with the number of them. And about 69 % of this type of stability has a binary semi-major axis about (90-350) AU.

**Figure 6 The number of P-type binary system vs the logarithm of the semi-major axis**
The second type: The planet-type orbits (P-type). In this case, the planet orbits around both components of the system Figure 5 and it forms about 24% of the host binary systems. Also, it is called a circumbinary planet, and 25 plants of orbits around 22 systems are belonged for this type see [25]. All confirmed exoplanets of this type which have a semi-major axis less than 0.25 AU [11]. Moreover, all catalogues of the binary system classified the exoplanets only as S-type or P-type.

![Figure 7 The number of P-type binary system vs the semi-major axis](image)

5. Conclusions

Since the first confirmation of extrasolar planet in the 1990s, searching for exoplanets field has grown tremendously. Today about 3869 exoplanets were discovered, so in this work, we present a statistical analysis for these exoplanets. Based on the information from NASA Exoplanet Archive we determined the number of binary stars that contain exoplanets during the last decades, and the number of the Exoplanets in Single stars, binary systems, and Multiple systems. Finally, we describe the diversity of the exoplanets in binary systems, and the type of the Stability of exoplanets orbit in the host stars.
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