The Exoplanets Catalogues and Archives: An Astrostatistical Analysis

A.A Abushattal [*], A. F. Kraishan, and O. S. Alshamaseen

Department of Physics, Al-Hussein Bin Tala University, P. O. Box 20, 71111, Ma'an, Jordan.

Abstract

The discovery of more than 5000 exoplanets based on several methods will improve our understanding of the formation and evolution of the exoplanets. Due to the dramatically increases in the amount of the astronomical data in recent decades. Which can be analyzed statistically to extract scientific information and test astrophysical theories. This information is valuable to figure out if there is a life somewhere else on the universe. This work presents a statistical analysis of all these exoplanets based on three primary data sources: NASA Exoplanet Archive, Open Exoplanet Catalogue, and Exoplanet.eu catalogue. Moreover, several parameters are examined, including mass, radius, discovery method, distance, orbital period, and discovery year. As part of our analysis, we have also clarified and summarized the data in the form of graphs based on astrophysical correlations.

Keywords: *extra-solar Planets, statistical Analysis, exoplanet archive, exoplanet catalogues*

1. Introduction

The term extrasolar planet is used to describe any planet that orbits a star other than the Sun and is outside of the solar system. In 1992, extrasolar planets were discovered for the first time by the researchers Wolszczan, as well as D. A Frail, when they confirmed the existence of a planetary system around the PSR 1257+1 millisecond pulsar (Wolszczan & Frail, 1992). More than 5,000 have been identified, and almost 9,000 have yet to be identified. It has become an increasingly relevant research area around the world in recent years to study the possibility of finding a planet similar to our planet, "The Earth".

To find Earth-sized planets near sun-like stars many scientific planet-hunting missions were designed such as CoRoT (Convection, Rotation and planetary Transits), a CNES-led mission launched in 2006, was the first space telescope to detect exoplanets. The transit method was used to uncover exoplanets while focused on studying stars(Baglin et al., 2007), The Kepler mission from NASA in 2009 has been responsible for a quarter of all exoplanet discoveries. Due to the long duration of the scan, it is sensitive to even faint stars over a wide area of sky(Borucki et al., 2010), K2 (Howell et al., 2014), Transiting Exoplanet Survey Satellite (TESS) Launched in April 2018, NASA's Transiting Exoplanet Survey Satellite is a mission to search for exoplanets. As a first-of-its-kind satellite, it conducts transit surveys throughout the sky(Ricker et al., 2014), PLAnetary Transits and Oscillations of stars (PLATO) Planetary Transits and Oscillations of Stars is a mission designed for searching for planets with liquid water within the habitable zone of Sun-like stars. Moreover, it will provide insight into the evolutionary state of the entire extrasolar system by analyzing the planet's host star, including its age(Catala, 2009), and CHaracterising ExOPlanet Satellite (CHEOPS), December 2019 marked the launch of the satellite and April 2020 marked the start of operations. Any bright star, particularly one that hosts exoplanets in the Earth-to-Neptune size range, can be observed. The ability to observe the same targets repeatedly makes CHEOPS the most effective instrument for studying individual exoplanets. This is because it knows exactly where and when to look for transits. These planets will be measured precisely and combined with mass measurements calculated by other observatories, enabling a first characterization of their nature to be made. A CHEOPS mission will also identify candidates for future missions to explore further. As a result, the James Webb Space Telescope will have well-characterized targets to study more thoroughly (Abushattal et al., 2019b, Broeg et al., 2013, Hatzes, 2016).

[*]Ahmad.Abushattal@ahu.edu.jo, Corresponding author

doi:https://doi.org/10.52526/25792776-22.69.2-235

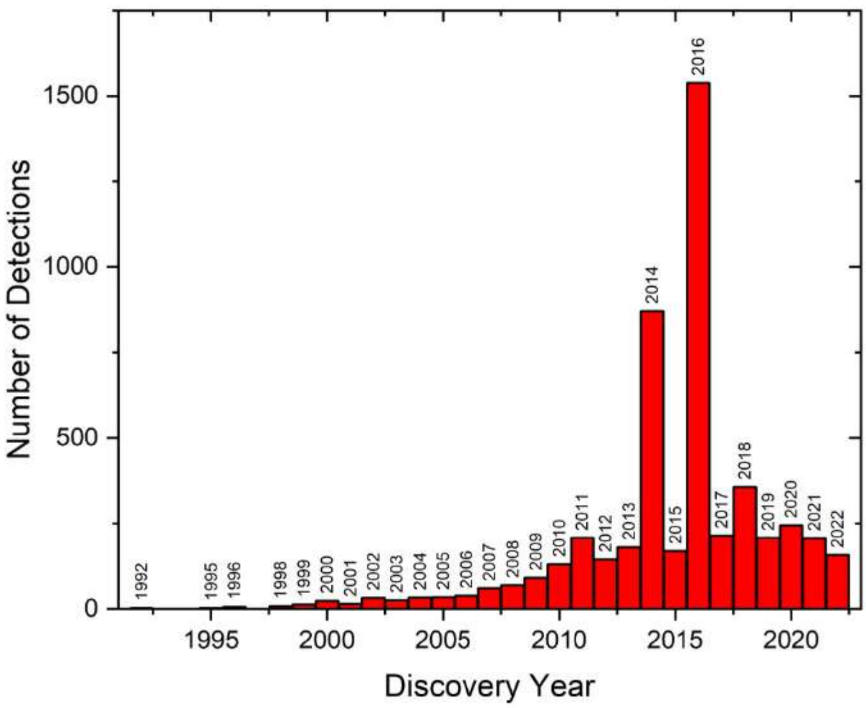

Figure 1. Detection Per Year.

James Webb Space Telescope was launched by NASA, ESA, and CSA in 2021 to study exoplanets and their atmospheres. In order to investigate these extrasolar bodies, Webb will use four instruments operating at infrared wavelengths. The observation of transiting planets with similar size and mass characteristics using highly sensitive spectroscopic methods. Using infrared wavelengths, Webb will measure absorption, reflection, and emission spectra of exoplanet atmospheres. Additionally, some exoplanets that orbit at larger distances from their parent star will be visible directly by it (Gardner et al., 2006, Kalirai, 2018). Detecting extrasolar planets is commonly done using Direct Imaging, Microlensing, Radial Velocity, and Transit techniques (Wright & Gaudi, 2012). Masses, radiuses, densities, and orbital parameters of exoplanets. As well as their orbits, a number of exoplanets were determined around single, double, and multiple systems. The physical properties of the outer planets can be calculated either by astronomical calculations or by imaging. According to astronomy calculations, for example, more than 50% of stars are binary stars (Al-Tawalbeh et al., 2021, Docobo et al., 2018, Hussein et al., 2022), which are observed and then their physical characteristics and orbital characteristics are determined, which allows us to determine when the planets are stable and their eligibility around these systems (Abushattal, 2017, Abushattal et al., 2019a, Docobo et al., 2018). The exoplanets are affected by physical processes, including mass loss and exchange, variability of components, relativistic processes, X-ray Binaries stability.(Abushattal et al., 2019b, Taani et al., 2019a,b, 2020). The Extrasolar Planets Encyclopaedia (Schneider, 2007), NASA Exoplanet Archive (Akeson et al., 2013), and The Open Exoplanet Catalogue (Rein, 2012) are helpful websites that provide a database of extrasolar planets of single stars.

Astrophysics theories can be tested quantitatively using statistical methodology, which has deep roots in probability theory. Statistics has become increasingly sophisticated and comprehensive in recent decades. After introducing mathematical statistics from a historical perspective, this review discusses hypothesis tests, point estimation, and elements of probability theory (Barlow, 1993, Feigelson & Babu, 2012).

Identifying new exoplanets around a wide variety of stars relies on modern astrostatistics to turn huge amounts of information into something useful for astronomers. The goal of this work is to collect data from different sources and analyze them statistically in order to provide a summary of the physical and orbital characteristics of exoplanets.

doi:https://doi.org/10.52526/25792776-22.69.2-235

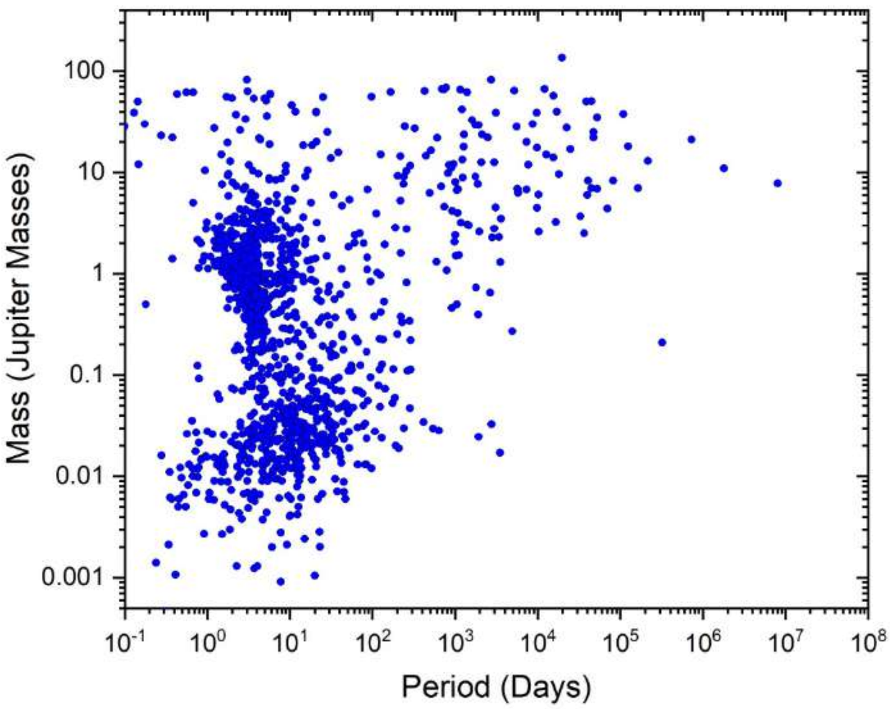

Figure 2. Mass - Period Distribution.

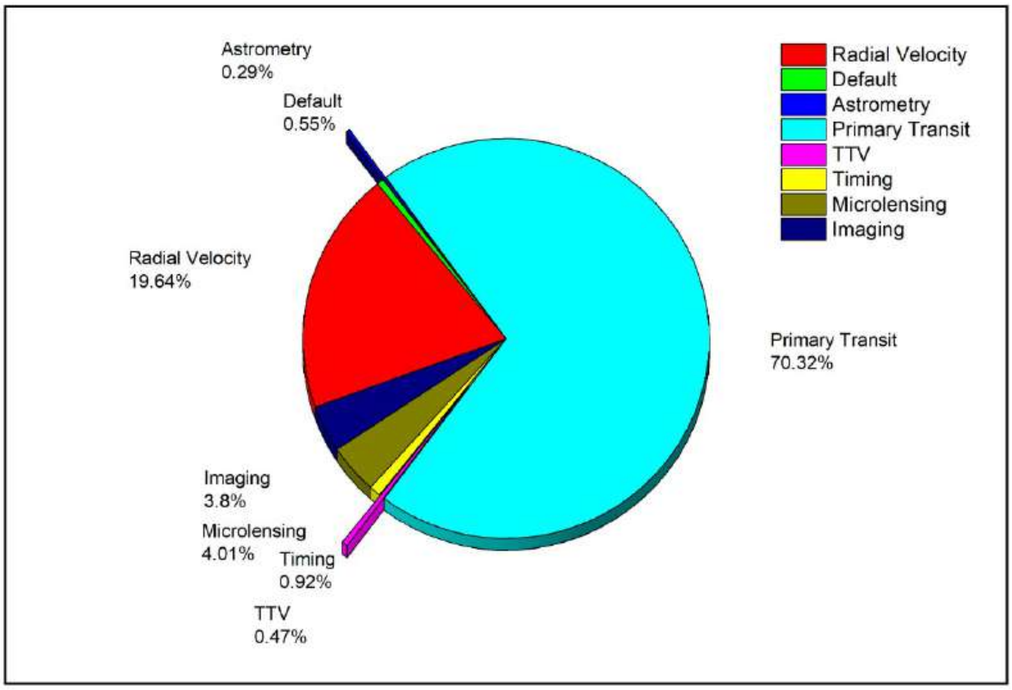

Figure 3. Detection Methods Distribution.

2. Methodology

Exoplanets took us years to discover because we spent so much time studying how our solar system formed before we learned about them. Observing exoplanets, even in our own solar system, can provide information

doi:https://doi.org/10.52526/25792776-22.69.2-235

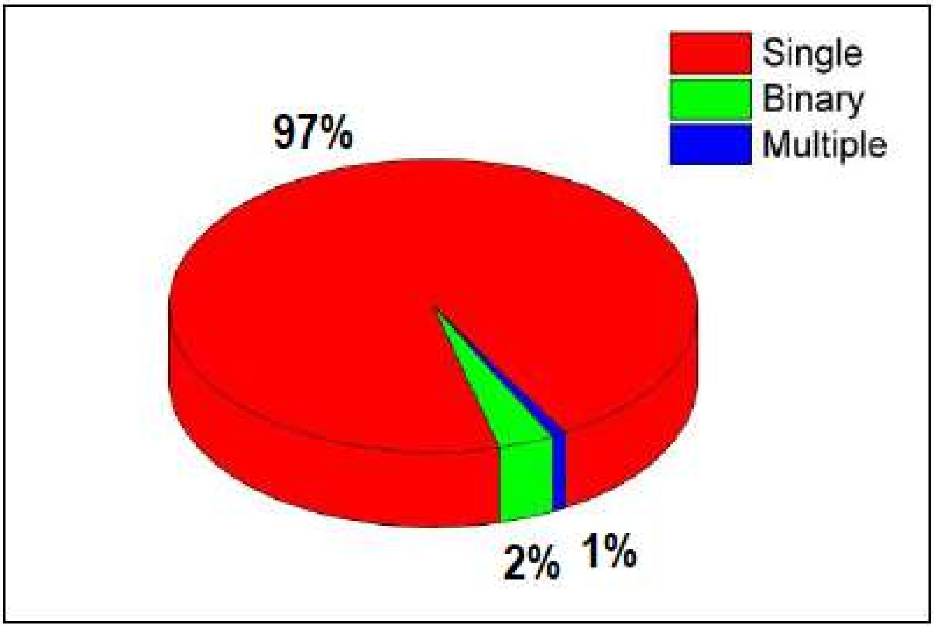

Figure 4. Exoplanets distribution.

about their processes. Discovering exoplanets allows us to imagine life elsewhere more realistically, because we are able to find earth-like planets that might have life. Statistical methods can be used to test astrophysics theories quantitatively. Astronomers need to transform this massive amount of data about exoplanets into something that can help them identify, detect, and discover new candidates. Data for this study are gathered from three main sources:

- **The Extrasolar Planets Encyclopaedia** : A database of all known extrasolar planets and candidate extrasolar planets, as well as an interactive catalog spreadsheet, was founded by Jean Schneider in February 1995 at the Meudon Observatory in Paris, France. Among the main catalogue's features is a database of all confirmed and unconfirmed extrasolar planet detection. All error ranges and the year of discovery of the planet are included, as well as the mass, orbital period, radius, transit time, semi-major axis, eccentricity, inclination, periastron time, maximum variation in time, and longitude of periastron. In addition to providing information about the planet, the planet data pages also provide information about its parent star, including its name, distance in parsecs, apparent magnitude, spectral type, effective temperature, radius, mass, and age. The interactive spreadsheet catalogue does not list all of these figures, and many are blank when Kepler's third law of motion would suffice (Schneider, 2007, Schneider et al., 2011).

- **NASA Exoplanet Archive**

  Exoplanet Archive is an online database that tracks and catalogs extra-solar planets (exoplanets) and their hosts, supporting the search for and characterization of exoplanets. Infrared Processing and Analysis Center at California Institute of Technology owns and operates this facility. The Exoplanet Exploration Program of NASA's Exoplanet Science Institute launched the archive in 2011. A total of 4,000 exoplanets have been confirmed as of June 2019. A total of 5,246 exoplanets have been confirmed in 3,875 planetary systems, with 842 systems having more than one exoplanet. Time-series data from surveys searching for transiting exoplanets are included in the archive along with light curves, spectra, images, and parameters. The archive also develops Web-based tools and services to analyze the data, including displaying and analyzing transit data sets from Kepler and CoRoT missions, whose U.S. data portal is Exoplanet Archive. A number of surveys and telescopes have contributed data to the archive, including SuperWASP, Trans-Atlantic Exoplanet Survey, HATNet Project, and KELT. In the Exoplanet Archive, objects with planetary parameters (transits, radial velocity, microlensing, eclipse timing variations, imaging, transit timing variations, and astrometry) equal to or less than 30 Jupiter masses (or minimum mass) are represented (Akeson et al., 2013, 2017, Christiansen, 2022).

- **The Open Exoplanet Catalogue**

doi:https://doi.org/10.52526/25792776-22.69.2-235

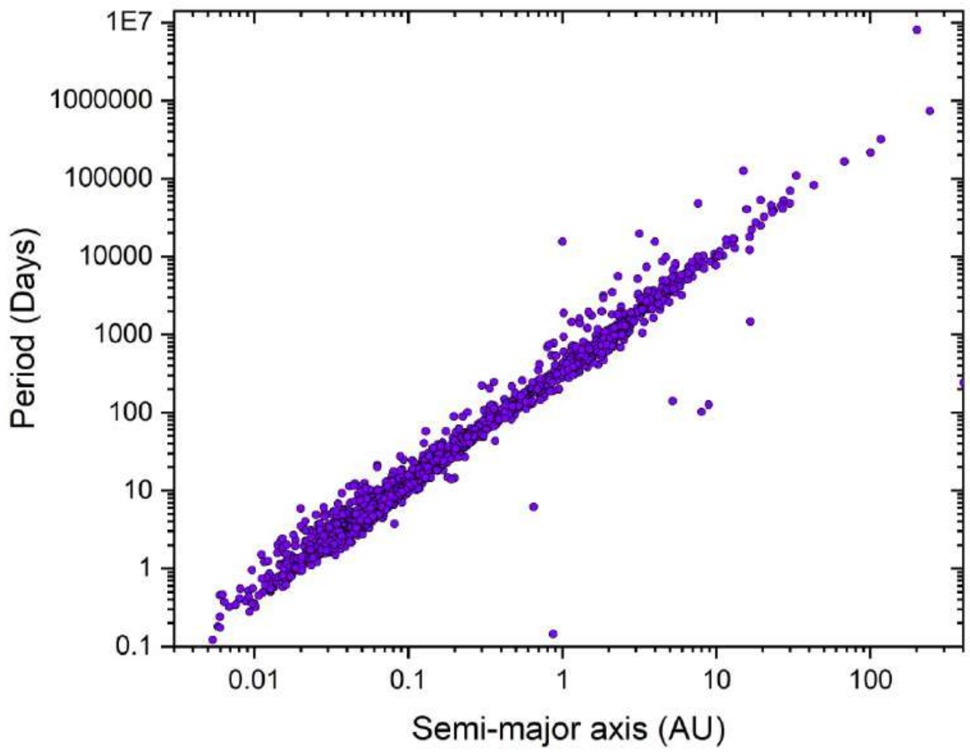

Figure 5. Period with Semi-major axis Distribution .

A catalogue of all extra-solar planets discovered is the Open Exoplanet catalogue. This is a completely decentralized and open astronomical database. With the Extrasolar Planets Encyclopedia, NASA Exoplanet Archive, and Exoplanet Data Explorer, it is considered one of the most widely used exoplanet catalogues. According to Hanno Rein, a distributed version control system and small text files are the basis of a new kind of astronomical database presented in 2012. Varley introduced ExoData in 2016, which provides an exploratory analysis tool and Python interface for the Open Exoplanet Catalogue. An example of a database is the Open Exoplanet catalogue, which is a daily updated list of all discovered extrasolar planets. Furthermore, it is the only catalogue capable of accurately storing and representing planets in any star system (s- or p-type binaries, triples, quads, etc) (Rein, 2012, Varley, 2015).

Data mining, astrophysics, and statistical analysis are all included in the scope of astrostatistics. Astrophysical data can be analyzed using it, complex datasets can be characterized, and astronomical data can be linked with astrophysical theory. In the same way as Astroinformatics, this field studies the stars. The data from all previous catalogues is processed and collected by computer programs in this project. Once the data has been sorted and identified, arrange it so that it is easier to analyze. These sources will be useful to astrophysics researchers and specialists studying exoplanets.

3. Results

A distribution of exoplanet-containing stars over the last decade was determined, as well as the number of exoplanets in single stars, binary systems, and multiple systems. We conclude with a description of the diversity of exoplanets. Here we summaries the statistical analysis of Detection Per the year of the discovery, the Mass - Period Distribution of all 5000 discovered exoplanets, the Mass - Period Distribution, the Period with Semi-major axis Distribution, finally the Exoplanets distribution.

doi:https://doi.org/10.52526/25792776-22.69.2-235

Conclusions and Future Work

New technologies enable more accurate characterization of previously detected extrasolar planets, leading to the detection of smaller and more distant planets. Recent years have seen the discovery of many extrasolar planetary systems, but they are very difficult to detect with current technology because they are similar to those in our solar system. Therefore, most of the surveyed stars have no detectable planets, making it impossible to determine if this is a typical or unusual solar system. In the 1990s, extrasolar planets were discovered, resulting in an explosion in exoplanet searches. Our study presents a statistical analysis of the 5000 exoplanets discovered to date. Several sources were used to compile this information, including the NASA Exoplanet Archive, the Open Exoplanet Catalogue, and the Exoplanet.eu database.

Acknowledgements

Thanks to Gor Mikayelyan, the Scientific and Local Organizing Committee of the International Conference "Space Sciences and Technologies" at Byurakan Astrophysical Observatory (BAO), Armenia.

References

Abushattal A. A., 2017, PhD thesis, Universidade de Santiago de Compostela

Abushattal A. A., Docobo J. A., Campo P. P., 2019a, The Astronomical Journal, 159, 28

Abushattal A., Al-Wardat M., Taani A., Khassawneh A., Al-Naimiy H., 2019b, in Journal of Physics: Conference Series. p. 012018

Akeson R., et al., 2013, Publications of the Astronomical Society of the Pacific, 125, 989

Akeson R., Christiansen J., Ciardi D. R., Ramirez S., Schlieder J., Van Eyken J. C., et al., 2017, in American Astronomical Society Meeting Abstracts.

Al-Tawalbeh Y. M., et al., 2021, Astrophysical Bulletin, 76, 71

Al-Wardat M., Docobo J., Abushattal A., Campo P., 2017, Astrophysical Bulletin, 72, 24

Baglin A., Auvergne M., Barge P., Michel E., Catala C., Deleuil M., Weiss W., 2007, in AIP Conference Proceedings. pp 201–209

Barlow R. J., 1993, Statistics: a guide to the use of statistical methods in the physical sciences. Vol. 29, John Wiley & Sons

Borucki W. J., et al., 2010, Science, 327, 977

Brescia M., Djorgovski S. G., Feigelson E. D., Longo G., Cavuoti S., 2017, Astroinformatics

Broeg C., et al., 2013, in EPJ Web of Conferences. p. 03005

Catala C., 2009, Experimental Astronomy, 23, 329

Christiansen J. L., 2022, Nature Astronomy, 6, 516

Docobo J. A., Griffin R. F., Campo P. P., Abushattal A. A., 2017, Monthly Notices of the Royal Astronomical Society, 469, 1096

Docobo J., Balega Y., Campo P., Abushattal A., 2018, Double Stars Information Circular, 196, 1

Duquennoy A., Mayor M., 1991, Astronomy and Astrophysics, 248, 485

Feigelson E. D., Babu G. J., 2012, Modern statistical methods for astronomy: with R applications. Cambridge University Press

Gardner J. P., et al., 2006, Space Science Reviews, 123, 485

Hartkopf W. I., Mcalister H. A., Mason B. D., 2004

Hatzes A. P., 2016, Space Science Reviews, 205, 267

Howell S. B., et al., 2014, Publications of the Astronomical Society of the Pacific, 126, 398

Hussein A. M., Al-Wardat M. A., Abushattal A., Widyan H. S., Abu-Alrob E. M., Malkov O., Barstow M. A., et al., 2022, The Astronomical Journal, 163, 182

Jack D., Hernández Huerta M. A., Schröder K.-P., 2020, Astronomische Nachrichten, 341, 616

Kalirai J., 2018, Contemporary Physics, 59, 251

Matson R., Williams S., Hartkopf W., Mason B., 2020, United States Naval Observatory, Washington, DC

Muller R., Cersosimo J., Rosado-de Jesus I., Cotto D., Miranda V., Martinez C., Centeno D., 2006, Journal of Double Star Observations, 2, 138

Pourbaix D., et al., 2004, Astronomy & Astrophysics, 424, 727

doi:https://doi.org/10.52526/25792776-22.69.2-235

Raghavan D., et al., 2010, The Astrophysical Journal Supplement Series, 190, 1

Rein H., 2012, arXiv preprint arXiv:1211.7121

Ricker G. R., et al., 2014, Journal of Astronomical Telescopes, Instruments, and Systems, 1, 014003

Schneider J., 2007, http://exoplanet. eu

Schneider J., Dedieu C., Le Sidaner P., Savalle R., Zolotukhin I., 2011, Astronomy & Astrophysics, 532, A79

Taani A., Abushattal A., Mardini M. K., 2019a, Astronomische Nachrichten, 340, 847

Taani A., Karino S., Song L., Mardini M., Al-Wardat M., Abushattal A., Khasawneh A., Al-Naimiy H., 2019b, in Journal of Physics: Conference Series. p. 012029

Taani A., Khasawneh A., Mardini M., Abushattal A., Al-Wardat M., 2020, arXiv preprint arXiv:2002.03011

Varley R., 2015, Astrophysics Source Code Library, pp ascl–1512

Vavilova I., 2016, Odessa astronomical publications, pp 109–115

Wolszczan A., Frail D. A., 1992, Nature, 355, 145

Wright J. T., Gaudi B. S., 2012, arXiv preprint arXiv:1210.2471

doi:https://doi.org/10.52526/25792776-22.69.2-235