HyperScience International Journal

Original Research Papers
Open Access Journals
ISSN: 2821-3300

HIJ, Vol 1, No 1, pp 8-12, July 2021
https://doi.org/10.55672/hij2021pp8-12

B.Nikouravan

The Prediction of Three Undetected Planets in Kepler-186: Reinvestigated 2021

Bijan Nikouravan [1, 2] *

[1] *The Indian Planetary Society (IPS), B-201, Vishnu Apartment, Lokmanya Tilak Road, Borivali (West), Mumbai – 400092 (India),*
ips.science@gmail.com
[2] *Department of Physics, Islamic Azad University (IAU)-Varamin-Pishva Branch, Iran*
nikouravan@gmail.com

ABSTRACT
In 2015, after the discovery of Kepler-186f, the fifth exoplanet in orbit of its star, Kepler-186, we investigated for three new undetected planets in the Kepler-186 system [1]. Of the planets which are owned by the Kepler-186, the first Earth-like planet and far from its star is Kepler-186f. Considering the order of these five discovered planets, there is a strong possibility for the existence of three new and undetected planets. Theoretically, we have recognized these three new planets locating before and after Kepler-186f. The first two new planets, orbit in the gap between Kepler-186e and Kepler-186f, and are called Kepler-186e(X1) and Kepler-186e(X2) respectively. The third planet also orbits in the exterior region of Kepler-186f is called Kepler-186f(X1). Now, after 6 years, we have reinvestigated these findings using the new information and data available.

Keyword: New Exoplanet; Kepler-186 system; three new planets.

INTRODUCTION

Exoplanet or extrasolar planet is a planet that orbits a star other than the Sun, a stellar remnant, or a brown dwarf. An exoplanet is a planet located outside the Solar System. The first verified recognition of exoplanets was announced in 1992, with two planets found orbiting a pulsar and also the first confirmation of an exoplanet orbiting a main sequence star was made in 1995, when a giant planet was found in a four-day orbit around the nearby star 51 Pegasi.

Some of these exoplanets detected directly by telescopes, but the most of exoplanets have been discovered through indirect methods such as the transit method and the radial-velocity method. As yet (May, 2021), astronomers have recognized about 4521 such planets, in 1212 planetary systems and 482 multiple planetary systems [1].
Recently new results were presented to discovery of the first planet at a conference on 19 March 2021, and it is called Kepler-186f [1-3]. Accordingly, Kepler-186f, as the first Earth-size planet, located in the liveable zone

of its star which is known as Kepler-186[4, 5]. Kepler-186 is a main-sequence red dwarf star, M1-type class and located by 151±18 parsecs (492±59 light years) away in the constellation of Cygnus (Fig 1).

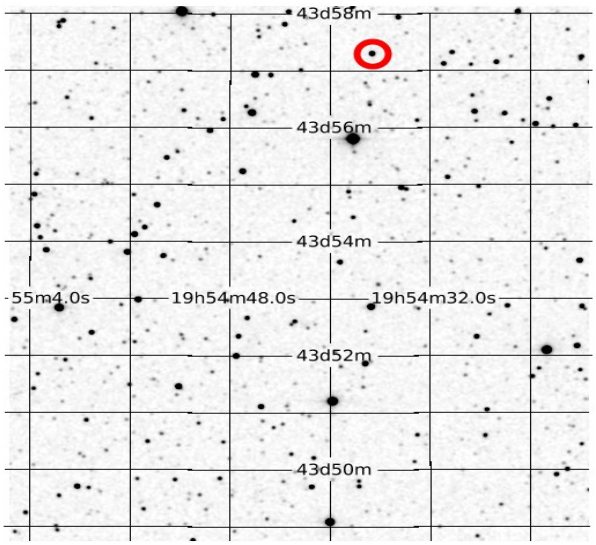

Fig 1. A 2MASS J band image, the star 2MASS J19543665+4357180 (Kepler-186) is highlighted [6].

It is a little cooler than the sun, with roughly half its the metallicity about Fe/H-0.28±0.10. Stars with a higher metallicity than the Sun are more likely to have planets, especially giant planets, than stars with lower metallicity [7]. In astronomy, the metallicity or Z of a star, is an approximate estimation of their chemical abundances that change over time by the mechanisms of stellar evolution [8] or other kinds of astronomical objects, excluding their hydrogen (X) and helium (Y). Kepler-186 planetary system is included by five planets with physical radii of $1.0 - 1.5 R_{\oplus}$ and orbital periods of 4-130 days [9]. The Kepler-186 planetary system hosts have known planets including Kepler-186f, an Earth-sized planet in the HZ [10, 11].

The aim of this paper is to investigate for possibility of some new exoplanets between Kepler-186e and Kepler-186f and after Kepler-186f in Kepler-186 planetary system theoretically.

Using Kepler's third law and with help of a simple mathematics, we try to realize some properties of these achievable new planets such as semi-major axis, orbital period and location of these planets and compare with solar system.

KEPLER-186f

Many planets orbiting other stars, have been found by researchers and astronomers from last decade [1, 2]. But up to now they did not find any habitable planet similar to Earth. In 2014, the first Earth-size planet, discovered in the habitable zone of its red M-dwarf star (Kepler-186) and it is called Kepler-186f [4, 5]. Except Kepler-186f, this system is consist of four extra planets so that these planets are probably rocky or at least solid [9, 12].

The smallest one, Kepler-186b, is only 8% larger than Earth, while the largest one, Kepler-186d, is almost 40% larger.

Kepler-186f is situated with 490 light years from Sun (151 pc from the Earth), ~10 % larger than Earth and rocky in nature[13]. This new planet have been detected with NASA's Kepler spacecraft exploration, using the transit method, along with four additional planets (all modestly larger than Earth) orbiting much closer to the star [4]. Kepler-186f orbits its M-dwarf star with about 4% of the Sun's luminosity with an orbital period of 129.9 days and an orbital radius of 0.36 [4] or 0.4 [9] times that of Earth's (compared to 0.39 AU for Mercury).

The discovery of Kepler-186f confirms that Earth-size planets exist in the habitable zones of other stars and signals a significant step toward finding a world similar to Earth [14]. All exoplanets which have previously been found in the habitable zone, they are all at least 40% larger in size than Earth, and understanding their form is challenging. Kepler-186f is more significant of Earth, but there is other possibility to find out three more new and undetected planets between Kepler-186e and Kepler-186f and also further distance of Kepler-186f in Kepler-186 planetary system.

THREE NEW THEORETICALLY CALCULATED EXOPLANETS

According to our investigation and research work presented in this paper, It is found that, three new and undetected planets is possible in Kepler-186 planetary system. The first two new planets, orbit in the gap between Kepler-186e and Kepler-186f and here called Kepler-186e(X1) and Kepler-186e(X2) respectively, and the third planet also orbits in the exterior region of Kepler-186f which is called Kepler-186f(X1).

With regarding to our precise mathematical (not mentioned in this paper) and calculations it is show that

these planets are following by Kepler's third law accuracy so that these new exoplanets, orbiting with Semi-major axis of 0.1816(AU), 0.2685(AU) and 0.5871(AU) respectively. Moreover, the orbital period of Kepler-186e(X1), Kepler-186e(X2) and Kepler-186f(X1) also calculated with 0.1104, 0.1985 and 0.6401 in Earth year unit, respectively. For non-crossing orbits, the eccentricities of Kepler-186c, Kepler-186d, Kepler-186e and Kepler-186f, have to be lower than 0.3, 0.13, 0.2 and 0.6 respectively[15], but the radius and ellipticity of these new planets have not calculated yet in our calculation (Table 1).

Table 1. Kepler-186 system

Exoplanet	**Radius** $R_{\oplus}$	**Semi-major axis** **AU**	**Orbital period** **(Earth year)**	**e**
Kepler-186b	1.08	0.0380	3.887	< 0.24
Kepler-186c	1.25	0.0562	7.267	< 0.3
Kepler-186d	1.39	0.0831	13.343	< 0.13
Kepler-186e	1.33	0.1228	22.408	< 0.2
Kepler-186e(*X*1)	-	0.1816	40.288	-
Kepler-186e(*X*2)	-	0.2686	72.436	-
Kepler-186f	1.11	0.3971	129.946	< 0.6
Kepler-186f(X1)	-	0.5871	233.636	-

The situation of all planets included in Kepler-186 system and solar system, shown in the following Fig 2 as below.

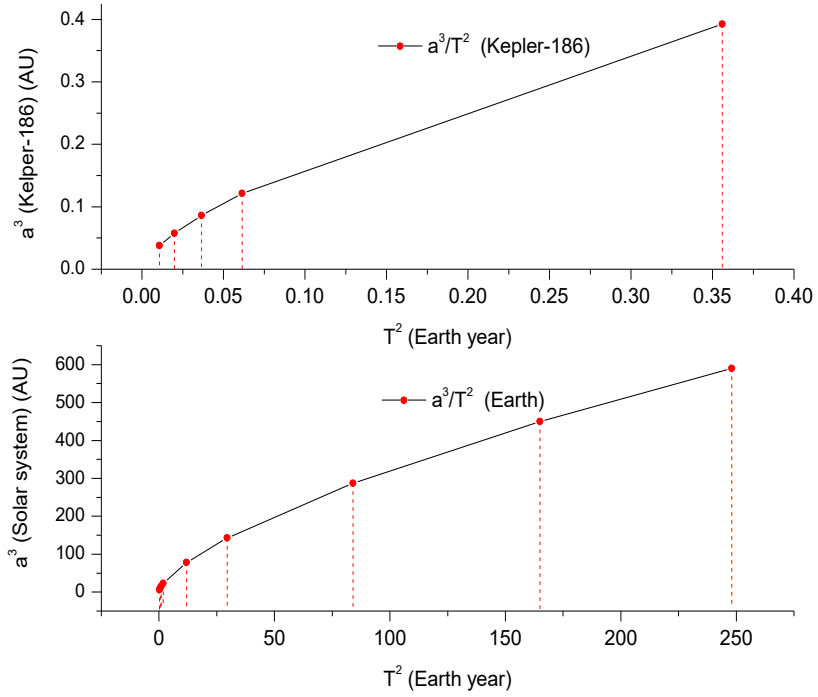

Fig 2

CONCLUSION

In this paper, we have concentrated our investigation on newly found planets in Kepler-186 system. According to five exoplanets discovered in orbit of Kepler-186, three more and newly planets found before and after Kepler-186f. Using Kepler's third law with a simple mathematics (not mentioned here) physical properties such as semi-major axis (AU), and orbital period (Earth year) of these three new planets, calculated.

Result of our calculation indicated a well significant with all other planets in Kepler-186 system. The radius and ellipticity of these new planets not intended yet. Figure 3, show a comparison Semi-major axis of planets in solar system and Kepler-186 system.

A well relationship between Semi-major axis of Planets including three new planets in Kepler-186 System shown in Figure 4.

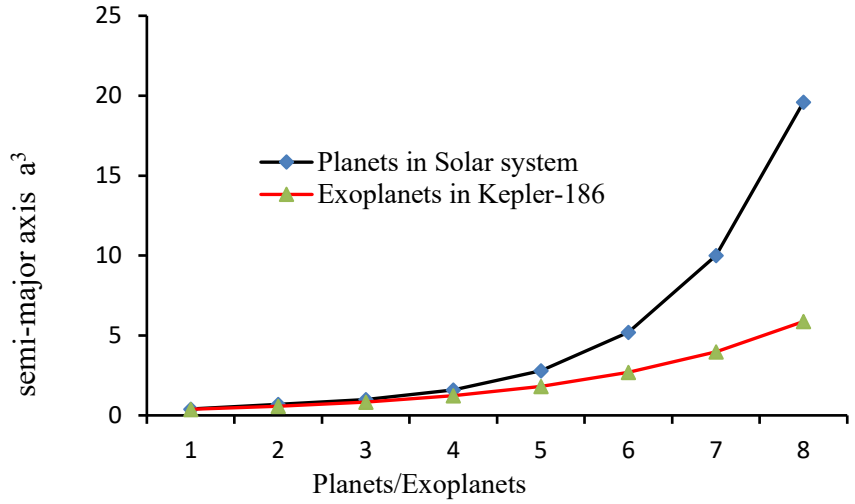

Fig 3. Semi-major axis of planets in solar system and Kepler-186 system

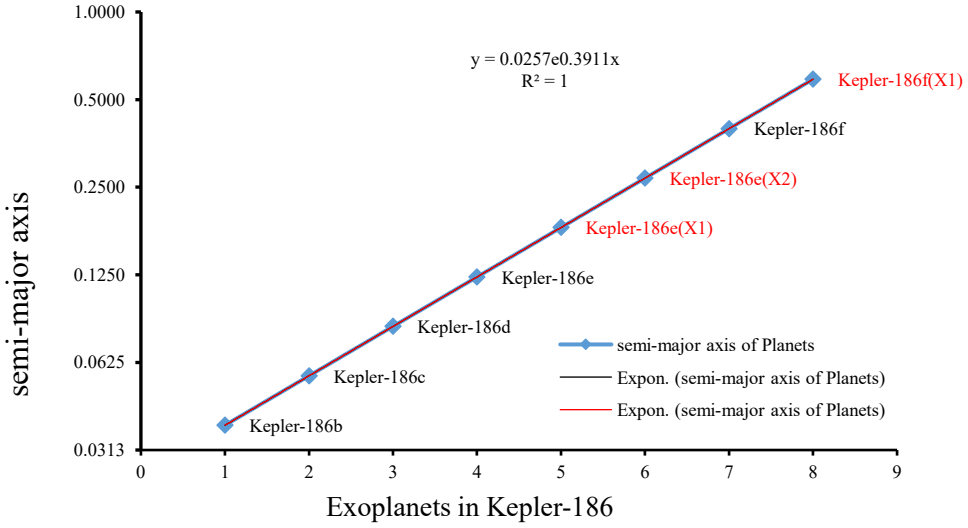

Fig 4. Semi-major axis of Planets (including three new planets) in Kepler-186 System.

REFERENCES

[1] J. Schneider, "Interactive extra-solar planets catalog," *The Extrasolar Planets Encyclopaedia,* 2010.

[2] J. Schneider, "The extrasolar planets encyclopedia," SCAN-97011121996.

[3] T. Barclay and E. Quintana, "The first Earth-sized habitable zone exoplanets," in *Search for Life Beyond the Solar System. Exoplanets, Biosignatures & Instruments*, 2014, vol. 1.

[4] E. V. Quintana *et al.*, "An Earth-sized planet in the habitable zone of a cool star," *Science,* vol. 344, no. 6181, pp. 277-280, 2014.

[5] A. Gould, T. Komatsu, E. DeVore, P. Harman, and D. Koch, "Kepler's Third Law and NASA's Kepler Mission," *The Physics Teacher,* vol. 53, no. 4, pp. 201-204, 2015.

[6] 2MASS J band image. (2014). *2MASS J19543665+4357180.* Available: http://irsa.ipac.caltech.edu/applications/2MASS/IM/interactive.html

[7] J. Wang and D. A. Fischer, "Revealing a Universal Planet–Metallicity Correlation for Planets of Different Solar-Type Stars," *The Astronomical Journal,* vol. 149, no. 1, p. 14, 2015.

[8] A. McWilliam, "Abundance ratios and galactic chemical evolution," *Annual Review of Astronomy and Astrophysics,* vol. 35, no. 1, pp. 503-556, 1997.

[9] E. Bolmont *et al.*, "Formation, Tidal Evolution, and Habitability of the Kepler-186 System," *The Astrophysical Journal,* vol. 793, no. 1, p. 3, 2014.

[10] F. Selsis, J. Kasting, B. Levrard, J. Paillet, I. Ribas, and X. Delfosse, "Habitable planets around the star Gliese 581?," *Astronomy & Astrophysics,* vol. 476, no. 3, pp. 1373-1387, 2007.

[11] R. K. Kopparapu *et al.*, "Habitable zones around main-sequence stars: new estimates," *The Astrophysical Journal,* vol. 765, no. 2, p. 131, 2013.

[12] E. R. Newton, D. Charbonneau, J. Irwin, and A. W. Mann, "An empirical calibration to estimate cool dwarf fundamental parameters from H-band spectra," *arXiv preprint arXiv:1412.2758,* 2014.

[13] P. Chaturvedi and A. K. Singal, "Worlds beyond our own," *arXiv preprint arXiv:1410.7695,* 2014.

[14] M. Johnson. (2014). *Kepler-186 and the Solar System*. Available: https://www.nasa.gov/ames/kepler/kepler-186-and-the-solar-system/#

[15] E. Bolmont, S. N. Raymond, J. Leconte, A. Correia, and E. Quintana, "Tidal evolution in multiple planet systems: application to Kepler-62 and Kepler-186," *Proceedings of the International Astronomical Union,* vol. 9, no. S310, pp. 58-61, 2014.