R2202069

2nd International Poster Competition 2022
competition2.univbd.com

A catalog of Earth's solar transit zone exoplanets and their habitability characterization using a novel surface gravity-mass pattern

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COMPETENCE BEYOND THE BOX

1. Abstract

Detecting exoplanets by observing the amount of starlight blocked during a transit event is known as the transit method. Some authors have asked the question from a different viewpoint: from which exoplanets the Earth can be seen as a solar transiting planet? In this work, I extend that question and seek the habitability of *Earth's Transit Zone (ETZ)* exoplanets. Using the *Gaia DR3* and *NASA Exoplanet Archive (NEA)* data, I prepared a catalogue of objects within *ETZ*. Then I filtered out exoplanets that can be most closely associated with terrestrial features. I found a novel pattern in the surface gravity-mass distribution of all the exoplanets discovered so far. By analyzing the pattern, I propose **WASP-47 e** as the most suitable exoplanet to host life that is also within the *ETZ* region. I argue that this planet deserves much more attention in the *Search for Extraterrestrial Intelligence (SETI)* project.

2. Introduction

Even though there are more than a dozen methods of detecting exoplanets, the transit method is so far the most successful one discovering about **75%** of the **5090** confirmed exoplanets. There are many other transiting exoplanets that have been discovered by other methods but later confirmed by transit method too. This abundance of transiting exoplanet naturally warrants a question. *Assuming there are intelligent extraterrestrials and they are looking for us, from which exoplanet they can detect Earth as a transiting exoplanet?* In this study, I offer an answer to this question. In the literature, ***Heller & Pudritz (2016)*** first proposed ETZ as a special celestial region with significance related to *SETI.* Later, ***Kaltenegger & Pepper (2020)*** identified 1004 nearby stars within ETZ. In this work, I focus on planets rather than stars. I studied all the exoplanets within ETZ. Since I routinely observe exoplanets in ~1000pc, I didn't limit ourselves only in nearby stellar systems (~100pc). Moreover, I take account not only the possibility of a full transit, but also of exoplanets that can see Earth as a grazing, or partial, transiting exoplanet. In the characterization part, I motivated from the pattern proposed by ***Ballesteros & Luque (2016)*** but I found a novel pattern absent in existing literature.

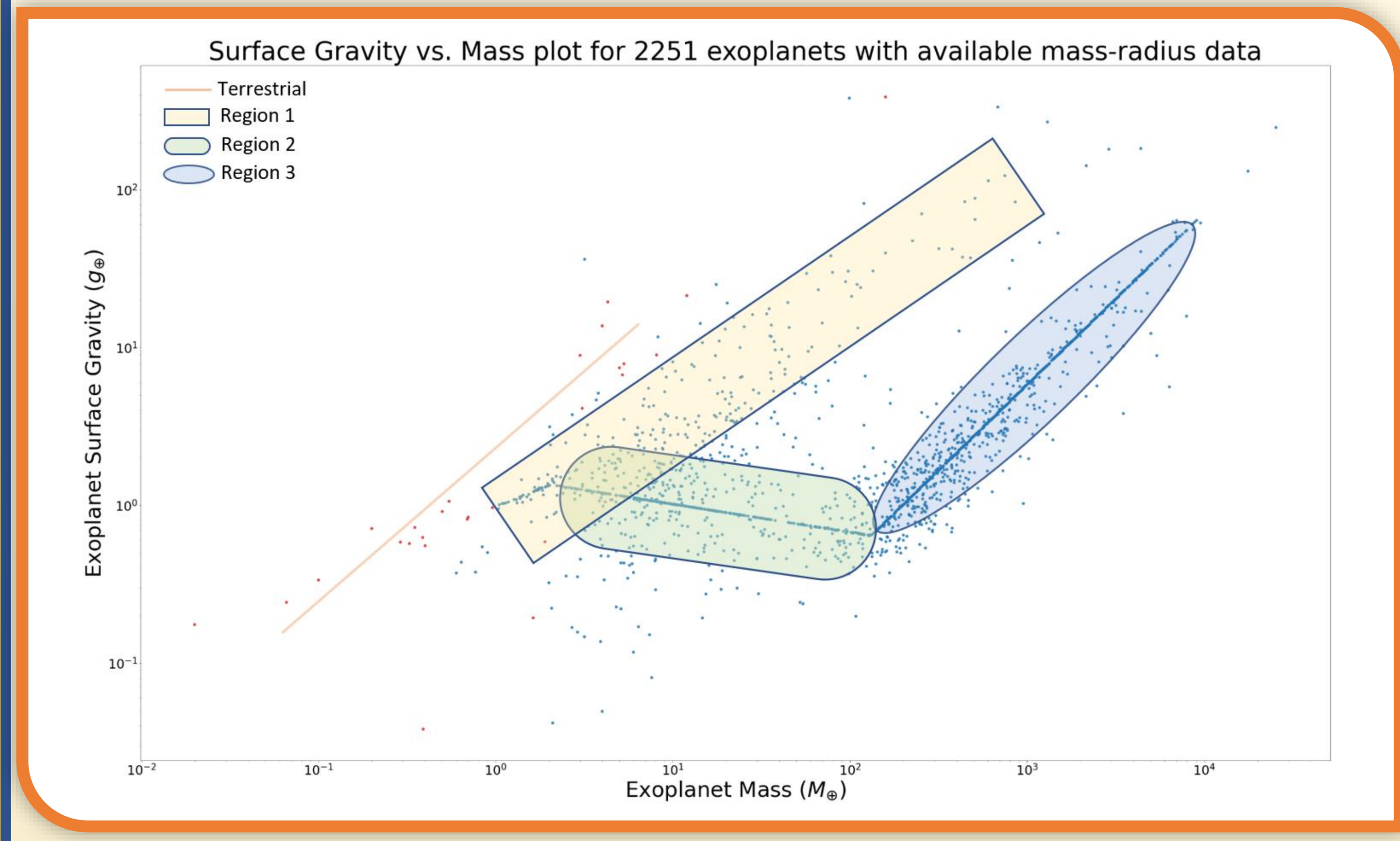
3. Methodology

This study has two independent parts: data analysis and characterization of the best-fit exoplanet(s). The flow chart is given below:

Data collection by web scraping and querying from catalogs (NEA and Gaia DR3) → Data cleaning and separation of the variables of interest → Pattern extrapolation using data visualization techniques → Characterization of the best exoplanet(s) according to the developed pattern

Possible source of bias: all the data has been queried from the *Planetary System Composite Data* of *NEA* that uses a mass-radius relationship to estimate the mass of exoplanet. I discarded all these entry and included only the entries with known mass-radius value. Moreover, I didn't take the uncertainties of the data into account since for such qualitative study, small uncertainty is negligible. Lastly, I discarded 18 data points because of their extreme values which is almost obviously due to measurement error.

4. Results



Motivated by *Ballesteros & Luque (2016),* I plotted the surface gravity-mass distribution but instead of 3, I identified 4 different regions in the plot. This extra region is coming mostly due to the advancement in the data collection after they published their result. In the table below I summarize the findings. Here G is the surface gravity, M is the mass, M_e is the Earth-mass and tilde(~) denotes order-of-magnitude relation.

Loci	G~M relation	comment
Region 1	G~M, M > M_e	Super-Earths (possibly rocky)
Region 2	G~1, M > M_e	Ice giants, Neptunes and mini-Neptunes
Region 3	G~M, M >> M_e	Gas giants and hot Jupiters
Terrestrial	G~√M, M ≈ M_e	Rocky planets

From the literature, I found the ETZ region as **0.538°** wide, i.e., the region of the ecliptic latitude between **-0.269°** to **+0.269°.** I found **33** exoplanets in NEA in this region, 2 of which are discarded due to their controversial flag. 2 more are discarded due to having a distance of more than 500pc and essentially no parameter measurement. Then I calculated the surface gravity of each exoplanet and devised a metric to determine how much terrestrial an exoplanet is as follows: **%terrestrial** $= \left(1 - \frac{|\sqrt{M} - G|}{M}\right) \times 100\%$. After discarding all exoplanets in **Region 3** (since only **Region 1** and **Region 2** have overlapping region with respect to the **Terrestrial region**), I found **WASP-47 e** to be the best candidate of terrestrial planets in our list with a %terrestrial score of **92.6%**.

Moreover, from the literature listed in NEA and *Gaia DR3,* I found that the host star **WASP-47** is a G-type star just like our Sun. Several archive described this planet as super-Earth which usually refers to the potentially terrestrial worlds. This study suggests that **WASP-47 e** is in fact a terrestrial world and also this is within 200pc, so relatively near to us. The density of the planet is also very similar to Earth.

5. Discussions and Conclusions

The search for extraterrestrial intelligence is a one way process of finding life on other planets. Here I considered if some such intelligence looks for us, which of them could find us (exoplanets within ETZ region) and which of these planets are possibly rocky. Our approach yields **WASP-47 e** as the best candidate. However, this planet is very close to its host star and water may not exist there. So, any possible life form is probably an alternative life form. Moreover, since the stars are in motion within the galaxy, ETZ stars are not permanent. Many stars will enter and exit ETZ in the upcoming years depending on their proper motion. This study doesn't take that effect into account. Nevertheless, **WASP-47 e** is still of great importance since instead of a random all-sky-search, this is the best candidate planet to look for the remains of deliberate message from possible extraterrestrial intelligence. Lastly, there is no spectroscopy data available for this planet which can be collected using *James Webb Space Telescope* and this study recommends investigating this planet further.

6. Future Work

The remarkable feature that I get in the surface gravity vs mass plot warrants further explanation about the origin of such feature. Additionally, while I conducted this study for planets within ETZ only, this study can be extended to a more general region. ETZ is the preferred celestial region only because of its significance to the SETI searches. However, an analytical model based on the pattern this study provides, if possible to derive, can offer valuable insight about the surface of any exoplanets, not just of those in ETZ.

7. References

Ballesteros F. J., Luque B., 2016, Astrobiology, 16, 325
Heller R., Pudritz R. E., 2016, Astrobiology, 16, 259
Kaltenegger L., Pepper J., 2020, MNRAS, 499, L111

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