Habitability of Various Classes of Exoplanets

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Introduction

The search for life on other planets has captivated our imaginations for centuries. Starting with William Whewell in 1853 and continuing to the work of Kopparapu in 2013, the concept of the habitable zone (HZ) has evolved significantly over more than 170 years. Beyond the HZ, many additional metrics have been developed to evaluate the habitability of exoplanets, including the ESI, PHI, BCI, and SEPHI, among others. In this study, we will focus on the Habitable Zone Distance and the Earth Similarity Index. We aim to share the findings from our recently published research, which assesses habitability across five classes of exoplanets: rocky (0.5-1 $R_\oplus$), super-Earths (1-1.75 $R_\oplus$), sub-Neptunes (1.75-3.5 $R_\oplus$), sub-Jovians (3.5-6 $R_\oplus$), and Jovians (6-14.3 $R_\oplus$). Our analysis is based on 4542 exoplanets data sourced from the University of Puerto Rico's PHL-EC database.

Habitability Metrics

The habitable zone distance (HZD) metric indicates how far an exoplanet is from the centre of the HZ. This metric can be calculated using the following equation:

$$\frac{(2r - r_o - r_i)}{(r_o - r_i)} \tag{1}$$

where r is the planet's distance from its star, r_o is HZ's outer boundary and r_i is the HZ's inner boundary. Exoplanets with values between -1 and +1 are considered to be within the HZ and can further be classified as either conservative or optimistic estimates. On the other hand, the Earth similarity index (ESI) measures how similar an exoplanet is to Earth based on factors such as radius, temperature, density, and escape velocity. The ESI values are already provided in the catalog, and we will use these for our plots.

Radius vs. Optimistic Habitable Zone Distance

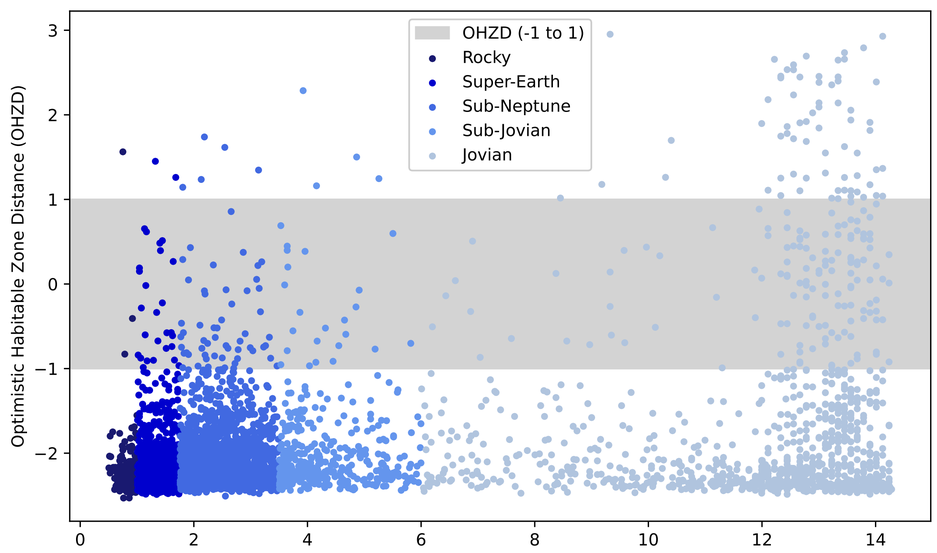

Figure 1. The Radius vs. OHZ scatter plot indicates that all classes of exoplanets have few members within the OHZ. Among these, Jovians (134) have the greatest number of planets in the OHZ, while rocky planets (2) have the least.

Radius vs. Conservative Habitable Zone Distance

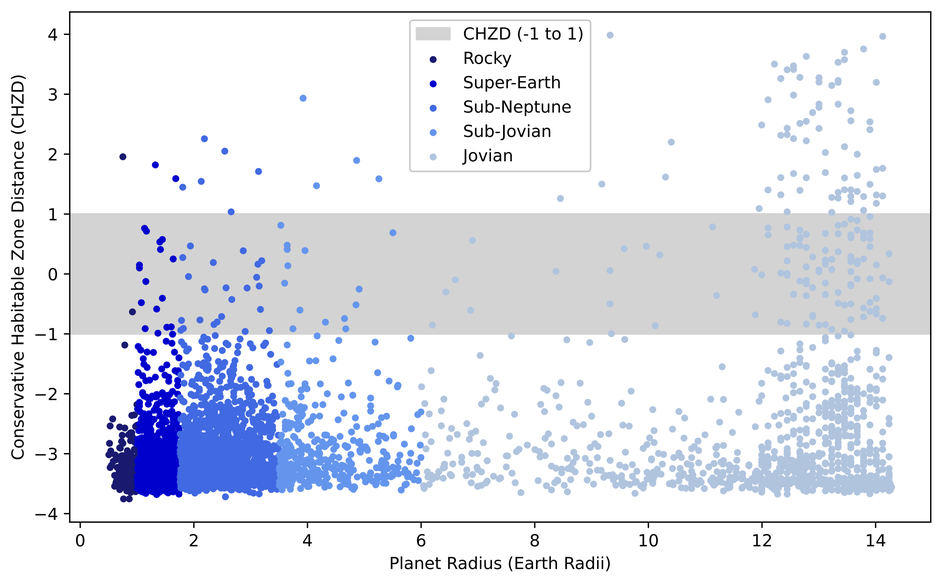

Figure 2. The Radius vs. CHZ scatter plot indicates that all classes of exoplanets have few members within the CHZ. Among these, Jovians (104) have the greatest number of planets in the CHZ, while rocky planets (1) have the least.

Radius vs. Earth Similarity Index

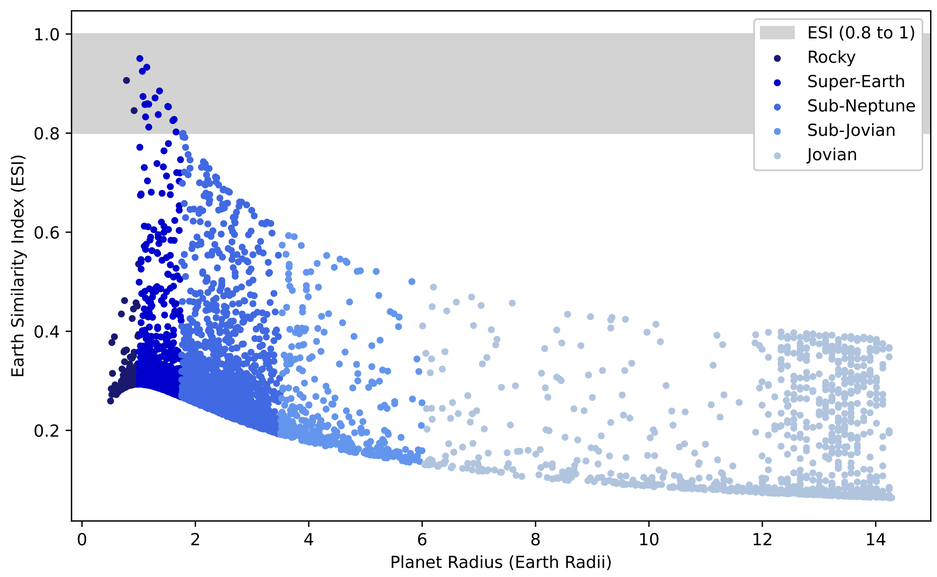

Figure 3. The Radius vs. ESI scatter plot indicates that only rocky (2) and super-Earth (18) classes have exoplanets with ESI > 0.8.

Optimistic Habitable Zone Distance vs. Earth Similarity Index

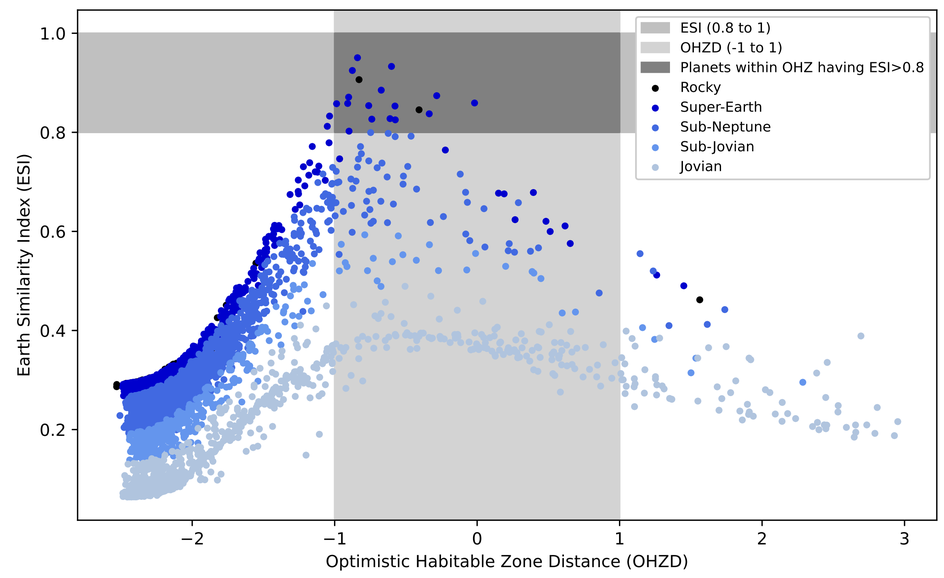

Figure 4. The OHZD vs. ESI scatter plot indicates that only rocky (2) and super-Earth (16) classes have exoplanets lying within OHZ and having ESI > 0.8.

Conservative Habitable Zone Distance vs. Earth Similarity Index

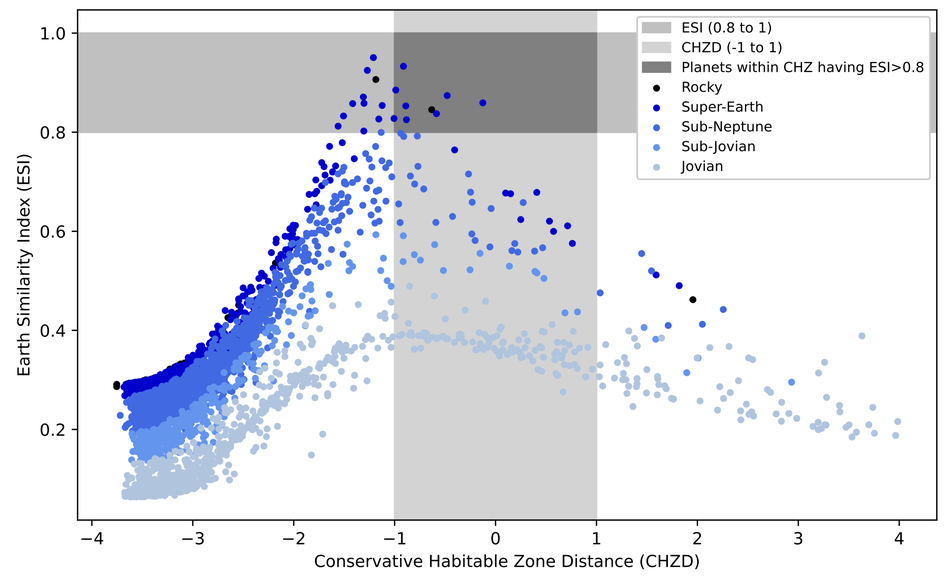

Figure 5. The CHZD vs. ESI scatter plot indicates that only rocky (1) and super-Earth (7) classes have exoplanets lying within CHZ and having ESI > 0.8.

Conclusion and Future Work

In this study, we combine the Habitable Zone Distance (HZD) and the Earth Similarity Index (ESI) to determine which class of exoplanets has the highest number of stars located within the habitable zone, while also having an ESI greater than 0.8. The table below presents the top five exoplanets from our findings, along with their respective Optimistic Habitable Zone Distance, Conservative Habitable Zone Distance, and Earth Similarity Index values.

Name	Class	ESI	OHZD	CHZD
TRAPPIST-1 e	Rocky	0.85	-0.41	-0.63
TOI-700 d	super-Earth	0.93	-0.60	-0.91
LP 890-9 c	super-Earth	0.89	-0.67	-0.99
Proxima Cen b	super-Earth	0.87	-0.28	-0.48
GJ 1061 d	super-Earth	0.86	-0.02	-0.13

Table 1. Top 5 exoplanets which are present within the HZ and have ESI > 0.8.

From the study, we conclude that while all classes of exoplanets have some planets within the Habitable Zone (HZ), only rocky and super-Earth classes have planets not only lying in HZ but also having an Earth Similarity Index (ESI) value greater than 0.8. Similarly, we can integrate these metrics with other advanced measures, such as the Planetary Habitability Index (PHI), Biological Complexity Index (BCI), etc., to achieve a better assessment of the habitability of various classes of exoplanets.

References

[1] Samridhi Dwivedi and Suresh Chandra.
Quantitative study of habitability of various classes of exoplanets.
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