Calculating the Hill Sphere of Known Exoplanets: Which Exoplanets Could Host Moon Systems?

Introduction

As to date, there are still no confirmed exomoons orbiting the exoplanets in the outer space. The difficulty comes down to the detection methods and techniques used to identify them. Currently, there are 4514 confirmed exoplanets according to NASA Exoplanet Archive; out of those, only 588 had the suitable properties for their Hill Sphere to be calculated. Moreover, to determine habitability to host an Earth-mass moon in such harsh conditions.

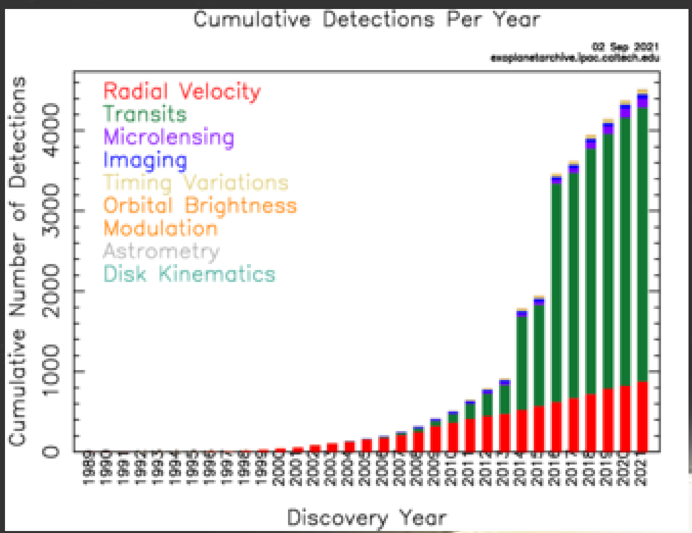


Figure 1. *A plot representing confirmed exoplanets and the methods used to detect them as of the 2nd September 2021; retrieved from the NASA Exoplanet Archive.* [1]

Aims

The project aimed to investigate possible candidates that could host an exomoon based on their calculated Hill Sphere. In addition, consideration of the exoplanet's characteristics needed to be studied to determine whether a stable orbit could be present to accommodate an exomoon.

References

[1] "Confirmed Planets." *NASA Exoplanet Archive*, [Online] Sep. 02, 2021. Available: https://exoplanetarchive.ipac.caltech.edu/exoplanetplots/

[2] "Habitable exomoon." *NASA Exoplanet Exploration*, [Online] Apr. 06, 2016. Available: https://exoplanets.nasa.gov/resources/118/habitable-exomoon/?category=looking-for-life

Methodology

Retrieving the data from the NASA Exoplanet Archive was an essential starting point in calculating the Hill Sphere of the known to date exoplanets. The archive provides in-depth information about the exoplanets and their properties needed to compute the calculations. To ensure needed information was collected, filtering columns was necessary. The data was then exported into an Excel file, where further adjustments were made.

The Hill Sphere of the exoplanets is approximated using the following equation:

$$r_H \approx a(1-e)\sqrt[3]{\frac{m}{3M}}$$

where:

- r_H - Hill Sphere
- a – Semi-major axis (Average distance from the star)
- e – Eccentricity
- m – Mass of the smaller body (The planet)
- M – Mass of the larger body (The star)

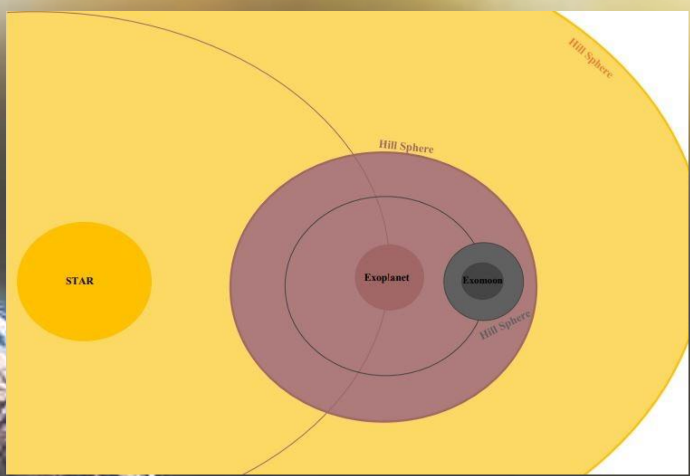
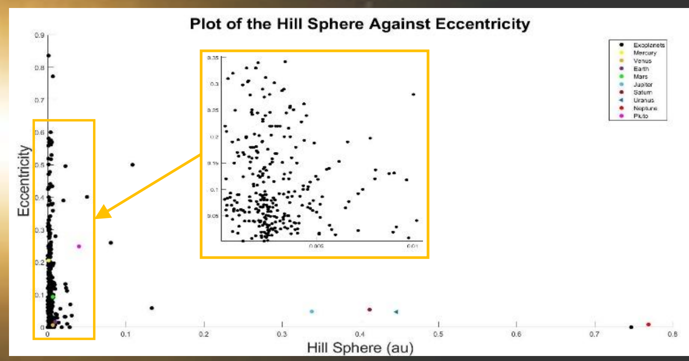
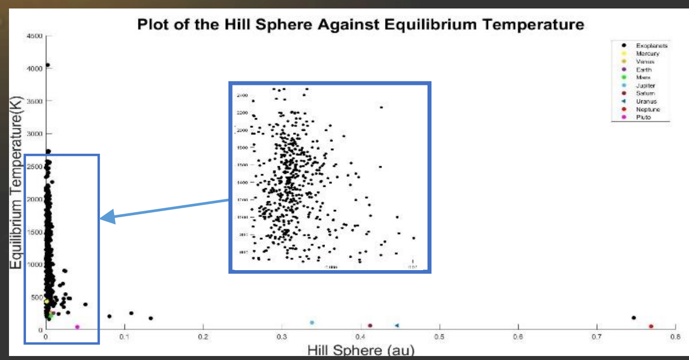


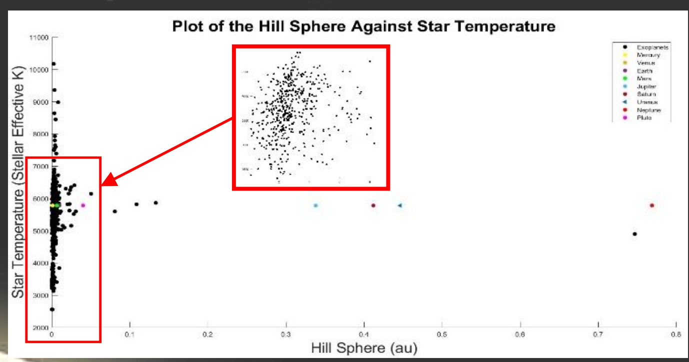
Figure 2. *A visual demonstration showing where the Hill Sphere dominates the attraction. The shaded areas show the regions of stability for each body.*

As seen from **Figure 2,** an exomoon would need an orbit that lies inside the planet's Hill Sphere. To assess the possible candidates, plots were created on MATLAB so a visual observation could be made. For comparison, planets from our Solar System were added to the plot. Interest was placed on the exoplanets with the largest Hill Spheres.

Results







The plots have shown some interesting results and a consistent pattern of the outliers. The outliers are precisely what had been looked out for when making the calculations as they are the ideal candidates with the largest Hill Spheres. This suggests that the exoplanets are at a distance where a possibility of an exomoon being captured could be considered. The exoplanets with the largest Hill radii are EPIC248847494b (0.7469 au), HD86226b (0.1333 au), Kepler-539c (0.1086 au) and Kepler-1654b (0.08083 au).

Conclusion

This project used a different approach to define what exoplanets could be suitable candidates to accommodate an exomoon. The data showed some promising results based on their calculated Hill Sphere. Further research should focus on modelling these exoplanets and their capture process of Earth-mass moons using numerical simulations.

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