What Gatherable Data on Exoplanets Tells Us About Its Chances at Habitability

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There are thousands of confirmed exoplanets outside of our own solar systems. Scientists and researchers have been actively investigating these exoplanets and their host stars. These exoplanets have a chance at being habitable, which means that they can be capable of suiting life like the earth. Although trying to live there is unreasonable due to how far they are, the hope that life could be sustained there provides a good opportunity to prepare for bad scenarios in the future. This paper on its own focuses on how an algorithm that I created can help identify if exoplanets can be habitable. It takes in an exoplanet's habitable zone, the elements it contains, and also the possibility for liquid water, then ultimately determining whether or not a planet was habitable, and ranking it on a scale of 1-4. I had mainly tested for the habitable zone and proceeded with the other information from there, as in essentially 100% of the cases, if an exoplanet is not within the habitable zone, it's not habitable. What this paper attempts to do by the end is to explain how a planet is habitable and how that can be applied to prioritization for space exploration. In terms of bad scenarios, research on planets outside of Earth can help us realize what we can do to fix things such as climate change and pollution.

Introduction

History of Subject

The search for habitable planets is mainly done by using satellites to track the brightness of a star. The satellites determine where the planets are in relation to the star by tracking when the light of the star dimmed, or when the planet passed in front of the star[1–3]. Scientists then use an AI recognition model to determine whether or not the celestial body is truly an exoplanet instead of an asteroid or moon[3,4]. After determining whether or not there is a planet in the star system, scientists then determine whether or not the planet itself is habitable.

There are a multitude of different criteria that need to be looked at when it comes to judging a planet's habitability, but the most important is the habitable zone[5,6]. The habitable zone of a planet is the range in which planets can be in to have a chance at habitability. The habitable zone relies primarily on the size and luminosity of the star. Depending on those factors, the habitable zone can be calculated. A planet only has the possibility of having liquid water if it is within the habitable zone of its host star, which is why the habitable zone is important[7].

Other than the habitable zone, there are other things that affect a planet's habitability. As mentioned before, liquid water, carbon, hydrogen, oxygen, phosphorus, sulfur, and nitrogen are all required for a planet to be considered for habitable[6]. The weather on a planet also has a massive influence on a planet's habitability, as it can change the landscape and conditions on specific planets[8].

Exoplanet research these days is primarily focusing on things such as how to identify exoplanets, detection of specific molecules and elements within a planet's atmosphere, and technological advancements to telescopes and satellites in order to find life[9]. In the past few years, the most important things to happen to exoplanet research have been the official classification of over 5000 exoplanets, as well as the launching of the James Webb Space Telescope that was meant to further research on the exoplanets[10]. Over time, since the time that exoplanets were discovered until now, exoplanet research has changed from just trying to find exoplanets and researching their conditions, towards actually trying to learn more about the exoplanets and seeing whether or not it is capable of hosting life and seeing what information it could give us[9].

My paper is building off of past knowledge, specifically by reconfirming habitability status, as well as providing a somewhat easier method of classification. I am primarily using old knowledge that is being studied or has been studied in order to build my algorithm. I primarily looked at some qualifications that were set up in the past to make the habitability decision process much quicker. The one problem that this would entail is complexity, as the algorithm that I use throughout the paper isn't able to account for outliers.

Although trying to go and live in potentially habitable exoplanets would be nearly impossible, the potential knowledge that could be gathered from rovers or drones could be incredibly beneficial in understanding more about habitability. This could even help in finding ways to improve our status of living here on

Earth through analysis of success on the exoplanets and seeing how we can apply extra conditions on Earth to increase our planet's "health".

What this paper aims to do, is to come up with a simple algorithm in basic java that takes in known information to determine whether or not a planet could be habitable. Although the algorithm in this paper doesn't make finding exoplanets easier it could make deciding whether or not to research said exoplanets easier.

Methods

Java Algorithm

I had used information that I had gotten online in order to develop an algorithm more properly suited to determine a planet's chance at habitability. The algorithm would take values that I would find online, run through multiple equations in order to determine the habitable zone, and then let me know whether or not this planet was in the habitable zone. The first thing I did was find the habitable zone for a planet. When doing this, I had used a source that had relied on past research to formulate a simple set of equations. Unfortunately, the equation didn't have a margin of error that I could refer to. I first got the absolute magnitude of star by using the equation: $M_v = m_v$ - 5log(d/10) whereas Mv is the absolute magnitude of a star, mv is the apparent magnitude of a star on the visual spectrum, and d is the distance from the Earth to the star in parsecs[5]. Next, I calculated for the bolometric magnitude of a star by first finding the bolometric correction constant. To get this, I figured out what my star's spectral class was after searching it up online[11]. Depending on the spectral class of my star, I was able to get the bolometric correction constant. I then used it in the equation: Mbol = Mv + BC whereas Mbol is the bolometric magnitude of the star, Mv remains as the absolute magnitude of the star, and BC is the bolometric correction constant. I then calculated the star's luminosity using the equation L_{star}/L_{sun} = 10(Mbol star - Mbol sun)/-2.5) whereas Lstar/Lsun is the absolute luminosity of the star in terms of the absolute luminosity of the sun, Mbol star is the bolometric magnitude of the star, and Mbol sun is the bolometric magnitude of our sun, which is 4.72. Lastly, in order to find out the radii for the habitable zones, I used the equation $ri = \sqrt{\frac{Lstar}{1.1}}$ to get the inner radius of the habitable zone, and to get the outer radius, i used $ro = \sqrt{\frac{Lstar}{0.53}}$[5]. After it determined that, it was able to test the likelihood of water and the 6 elements needed for life, mainly relying on the habitable zone data as the primary factor for both, before ultimately deciding if the planet was habitable or inhabitable on a scale out of 4. Something that I had found in my research was that if a planet was not within the habitable zone of its host star, then the other two criteria (elements and liquid water) would not be able to form on the planet, leaving it entirely inhabitable. On the other hand, just because a planet was within the habitable zone, didn't mean that it guaranteed to have the other criteria.

Results

Planet's Chances of Habitability

For all the data inputted regarding the algorithm in this section, all of the orbital radii and spectral classes came from the NASA Exoplanet Database[11], and the apparent magnitude came from the CalTech Exoplanet Archives[12].

Kepler-22 b - After inputting all the star's magnitudes that I could receive from online sources and databases that aligned with the algorithm[11,12], the algorithm was able to properly determine that Kepler-22b was within the habitable range of its star Kepler-22. It also determined that the planet had a high chance of habitability, aligning with currently known knowledge[11].

GJ 411 b - After inputting the information I had from online databases, such as NASA's official exoplanet database and CalTech's Exoplanet Archive[11,12]. I was able to get the magnitudes and the spectral class, allowing me to find the exoplanet's habitable zone, as well as a good prediction over the other two criteria. After the algorithm finished working, it determined that GJ 411 b is entirely inhabitable, lining up with current databases[11,12].

K2-38 b - After inputting the information I had from the previous online databases[11,12]. I was able to get the necessary information for my algorithm, allowing me to find the exoplanet's habitable zone, and predict the other two criteria after a quick search online. The algorithm determined that K2-38 b was also entirely inhabitable, lining up with current databases[11,12].

Kepler-1797 b - The algorithm predicted that Kepler-1797 b was not within the habitable zone of its host star: Kepler-1797. The algorithm also determined that it had not fulfilled any other criteria to have it considered habitable. This aligns with the general consensus[11,12].

Kepler-1540 b - The algorithm was able to determine that Kepler-1540 b was in the habitable zone of its host star, after I input the information. Using the fact that the planet was not in the habitable zone, the algorithm had concluded that it wouldn't have the elements or water either. The information the algorithm gave me led me to conclude that Kepler-1540 b had a chance to be habitable, which matched the online databases[11,12].

Analysis

In the end, my algorithm had a 100% success rate with current knowledge. Although this sounds amazing at first, my code was quite simple and could have definitely used more complexity. More complexity would make sure that my results are 100% accurate, accounting for outliers for exoplanets.

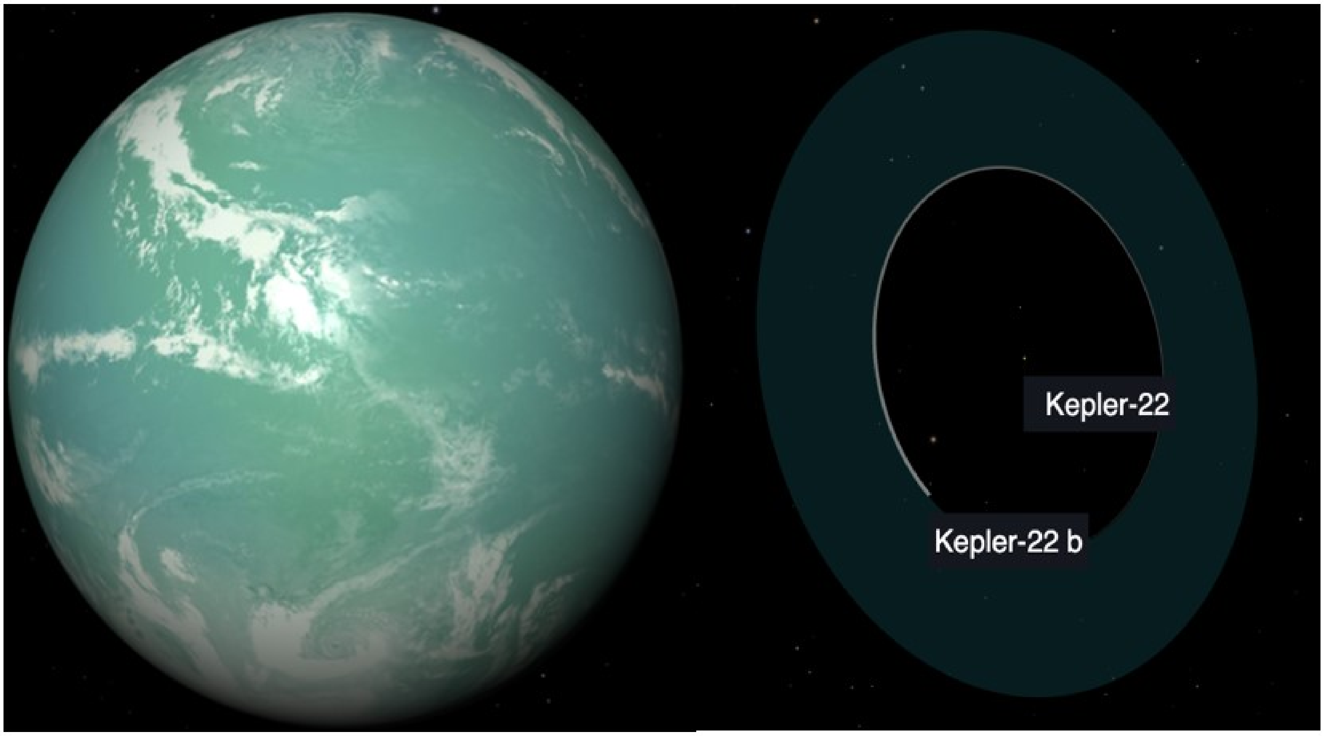

Fig. 1 Hypothetical picturing of Kepler-22 b and its star system[11]

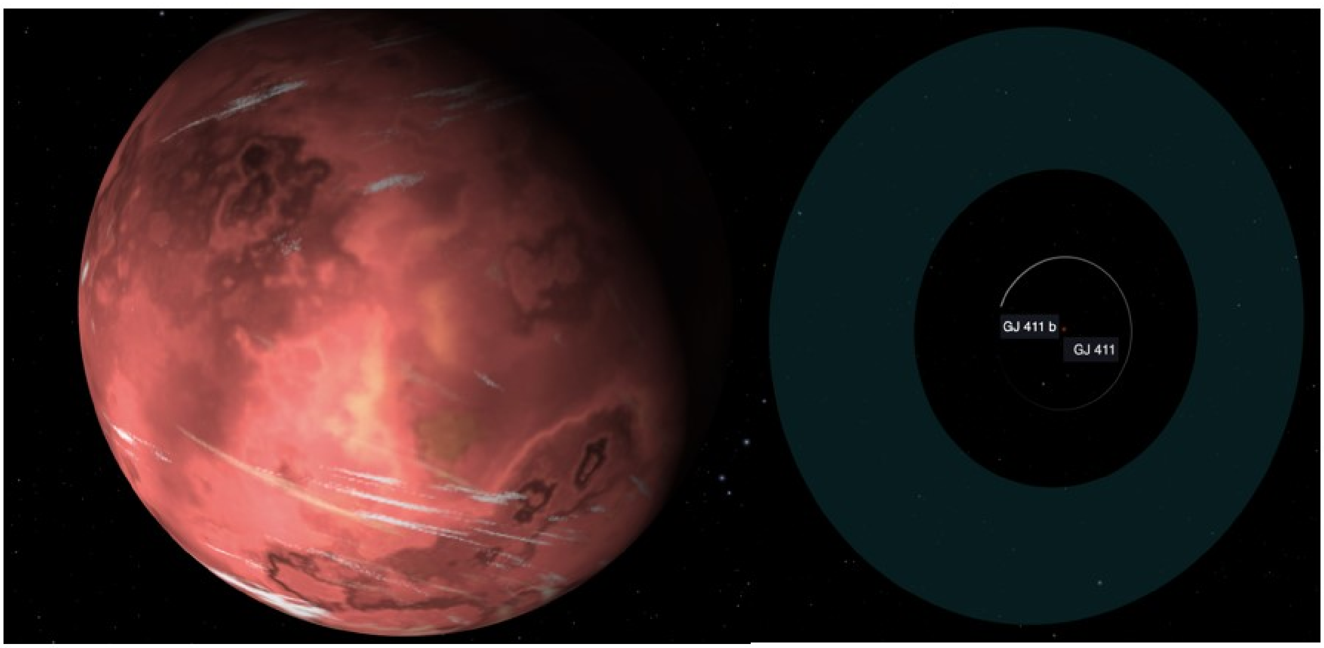

Fig. 2 Hypothetical picturing of GJ 411 b and its star system[11]

The algorithm used three factors. The first thing the algorithm did was calculate the host star's habitable zone[5]. This required the apparent magnitude of the star itself—the magnitude of a celestial object compared with Earth—as well as the bolometric

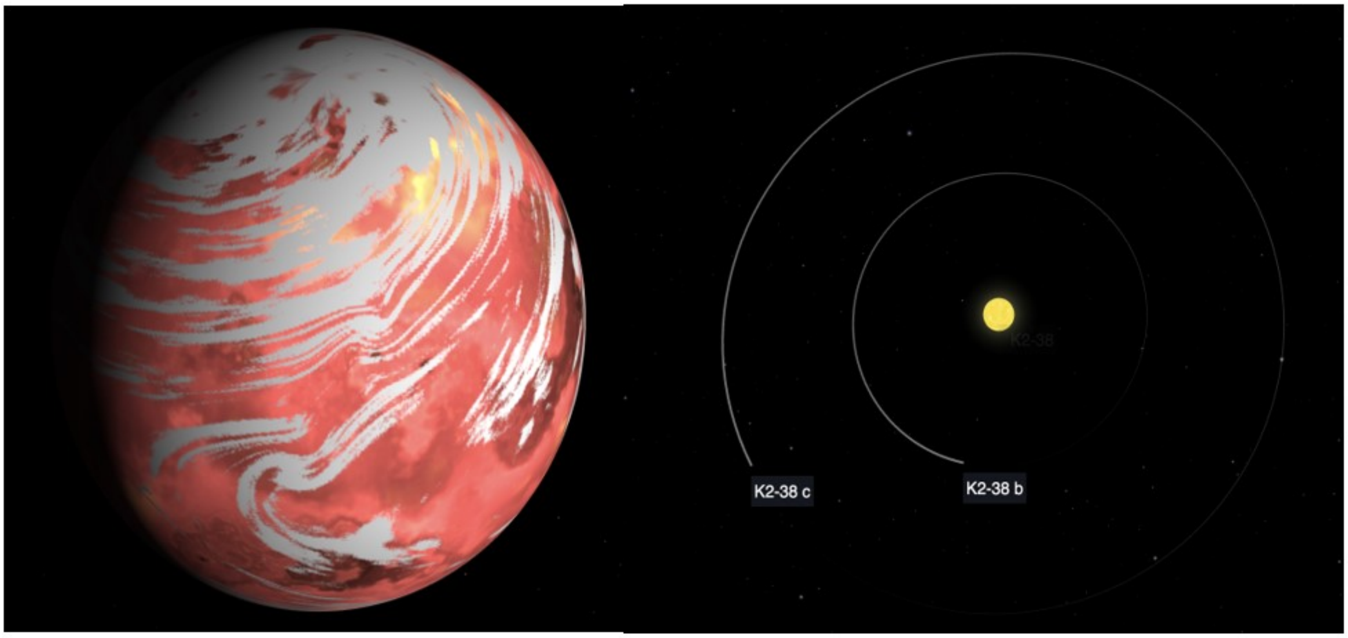

Fig. 3 Hypothetical picturing of K2-38 b and its star system, second picture different as habitable zone is farther away [11]

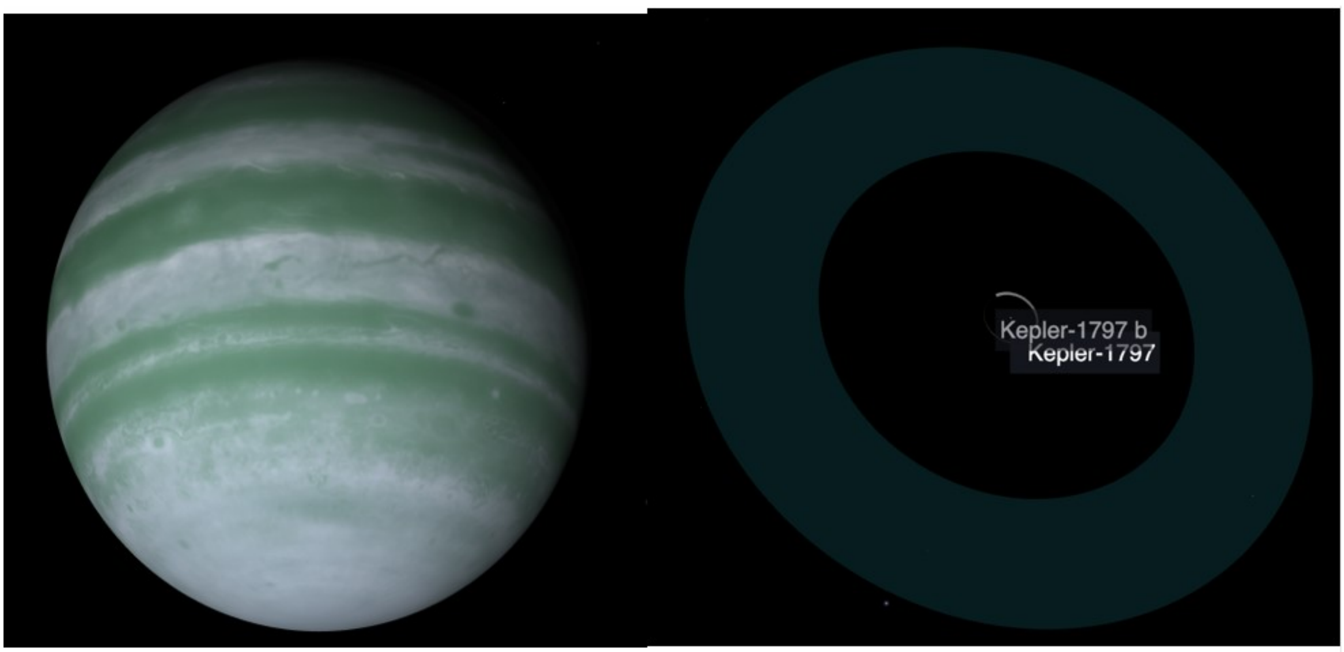

Fig. 4 Hypothetical picturing of Kepler-1797 b and its star system [11]

correction constant, a specific constant that changes depending on the type of star. This allows the code to calculate the bolometric magnitude, the measure of the total radiation a star gives off. The algorithm then calculates the host star's habitable zone (the area around a star that has the possibility for liquid water to form on a planet). Finally, it finds the planet's distance from the host star to see if it lies in the habitable region. After determining whether or not a planet is within the habitable region I had gone through sources online and inferred from the habitable zone data to see whether it had the six elements necessary for life (carbon,

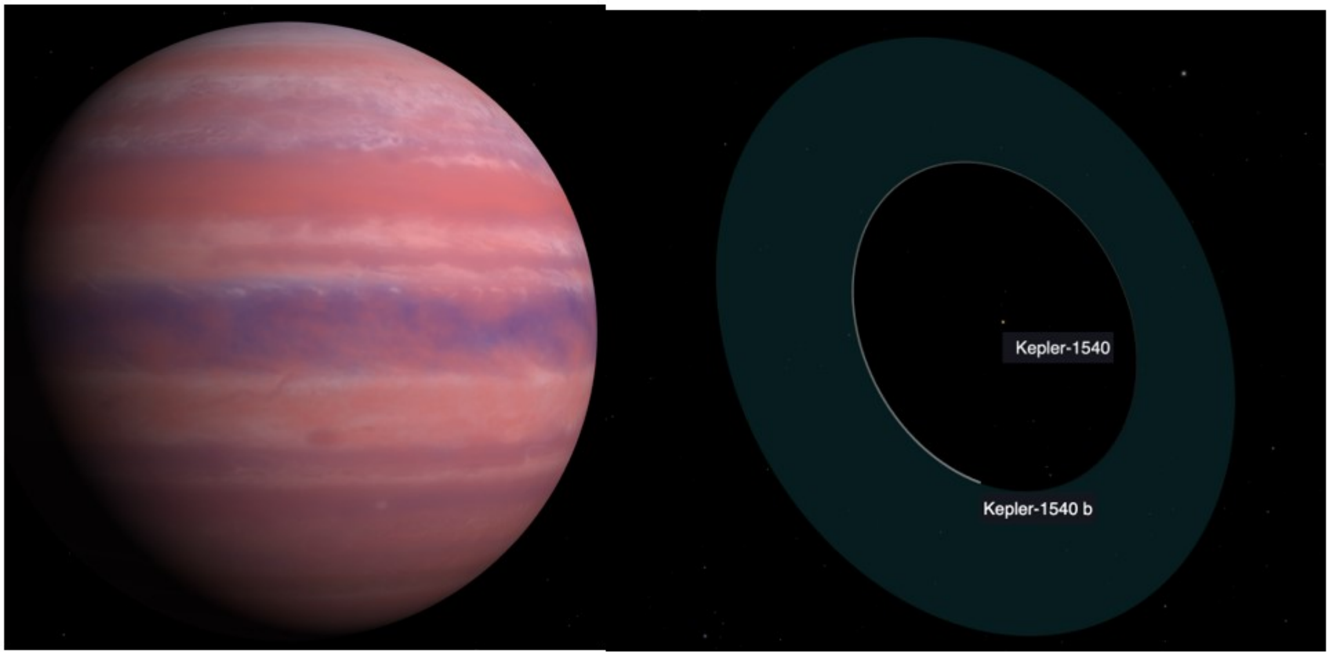

Fig. 5 Hypothetical picturing of Kepler1540 b and its star system[11]

hydrogen, oxygen, sulfur, phosphorus, and nitrogen), as well as if the planet had confirmed liquid water[6,13]. These 3 criteria are all very important to determining habitability. Although the habitable zone was the ultimate factor, the other two were also important in determining probability of habitability. As soon as all the information was processed through the algorithm, it would return results regarding whether the planet whose data I had entered had a high, Medium, low, or no chance of being habitable. This 4 point scale was primarily based on the habitable zone. If the exoplanet wasn't within the host star's habitable zone, then the planet was automatically non-habitable; if the exoplanet was within the habitable zone and the data was unsure, then the planet would have a low chance of habitability; if any one of the two other factors (the elements and water) were confirmed, the planet would have a medium chance at habitability; and if the exoplanet was within the habitable zone and both other criteria were confirmed, then there would be a high chance at habitability.

In comparison to other works designed to look for and classify habitable planets, I would say that my work isn't seriously elevating research to a new level, but I would hope that it can give researchers an easier time in the future when they look into the topic, specifically with trying to quickly identify which planets are worth researching.

Potential Issues

While the algorithm had seemed to be working fine throughout my usage of it in trying to figure out planet habitability, the code could've been better. Although code being too simple doesn't sound like a huge problem at first, it actually leads to much more issues. The radius of the habitable zone is measured in astronomical units, which is approximately 150 million kilometers. Because of this, a small miscalculation or rounding error could lead to the radius being millions of kilometers off. Because my code is too simple, miscalculations and rounding errors are bound to be much more frequent. Two specific things make me believe this. My first thought as to how to improve the algorithm is to be able to perfectly determine a star's habitable zone. While the algorithm seems to be getting the job done fine, the calculations could be off, as when information isn't available, it could be purely based on luck with the conclusions on my habitable zone. While I don't currently know what I could do to improve the algorithm, I would imagine that a more effective/detailed equation could allow me to get more accurate results at the cost of more information inputted. The second thing that could be improved on is code complexity. As of now, I feel that the code I am making is far too simple, mainly due to the fact that I don't have as much information or knowledge in order to implement more features and criteria that could help me more accurately determine whether or not a planet is habitable. I only mainly used a simple input and output method, however, if I had more practice and knowledge, I would've attempted to

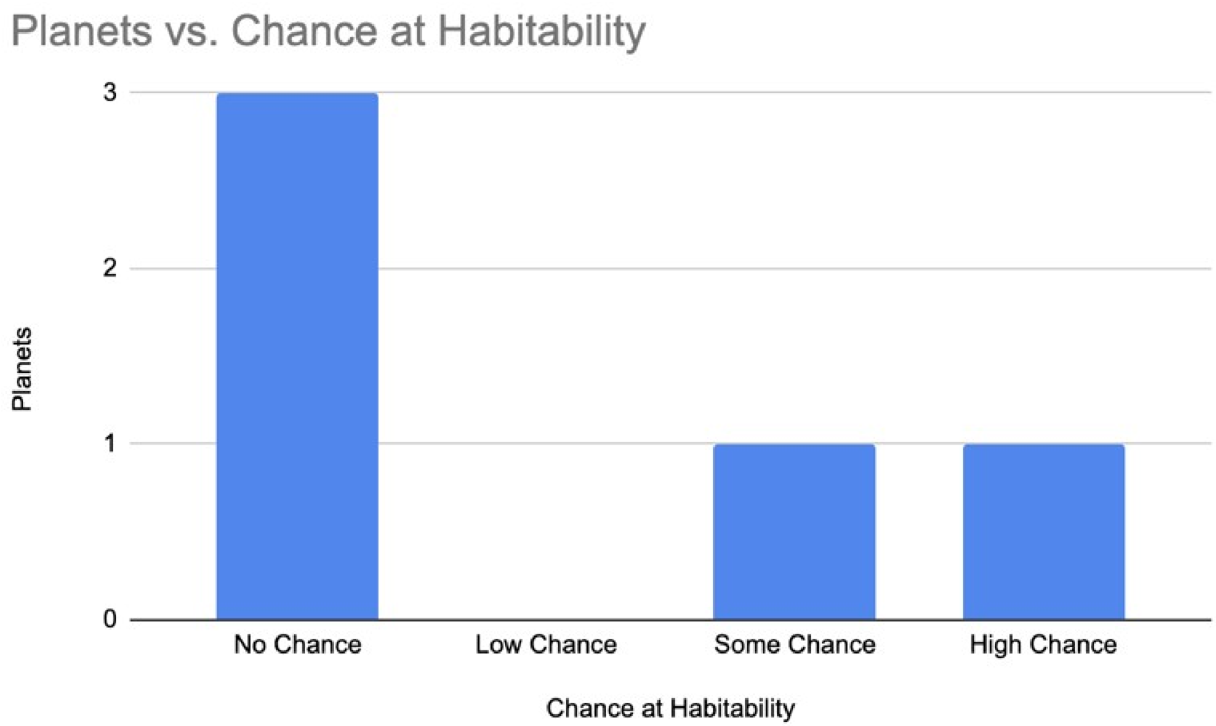

Fig. 6 Chart to show the different levels of habitability and how many exoplanets fall within each category.

make a more AI algorithm that could scour the internet for the numbers that I needed. A better code using AI to search rather than me would likely turn out better results as the AI would be much more efficient, as well as being able to gather more accurate data. There are many issues that arise, even with adding in all of my concerns. As of now, the code doesn't take into account unusual phenomena, including earthquakes, messed up magnetic fields, punctured atmospheres, etc. Luckily, the code only takes in one data set at a time, so it is practically impossible for it to overload.

Another issue that might have occurred while I worked on this paper is the sources. Although a vast majority of them are incredibly recent and provide good data for the planets. Despite these sources being from credible databases such as ones from CalTech and NASA, the one issue is not within the sources but within the technology. Because these planets are all lightyears away from Earth, whatever we see here happened however many years ago this information was gathered, with the distance in lightyears being equal to time dilation in years. This is a problem because a lot can change for a planet in just a few years, and with planets a couple hundred lightyears away, by the time these planets are studied, things could be drastically different, and my code doesn't have the capabilities to automatically detect change. I hope that if I were to improve on this code, I can account for missing information and the constant adaptability to new information, which is why I wanted to implement an AI to search for the data instead. Other than that, I felt that the criteria I set as a base was sufficient.

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