Determining the Habitability of Exoplanets

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Abstract

Given the many possible variables in the detection of life and the habitability of planets, there must be a method implemented to efficiently process the data collected from the Kepler telescope and other imaging systems. The general process of identifying a habitable exoplanet first includes collecting spectroscopy data, among other information regarding a particular exoplanet. Finally, these planets are determined to be habitable in accordance with the analysis, which should produce information such as the location of an exoplanet with respect to its star’s habitable zone, and the planet’s possible composition. This research has made use of the NASA Exoplanet Archive, which is operated by the California Institute of Technology, under contract with the National Aeronautics and Space Administration under the Exoplanet Exploration Program.

Approximating Habitable Zones

In general, the habitable zone (HZ) refers to the area around a particular star where liquid water could exist on the surface of a planet in orbit, given the parameters of the host star and the planet being observed. An approximation of the inner and outer boundaries of the HZ is given by the equations \( r_i = \frac{a}{(1-e^2) + e \cos \theta} \) and \( r_o = \frac{a}{1+e} \), where \( a \), \( e \), and \( \theta \) are the values of the inner and outer radius, \( L \) is the absolute luminosity of the host star, and the values 1.1 and 0.53 are constants describing stellar flux at the inner and outer radius respectively. This estimate is based on the concentration and form of \( CO_2 \) in the atmosphere of a planet which relates to a stable atmosphere and the presence of liquid water on the surface.

Fig. 1 depicts the relationship between star luminosity and the position of the HZ (increasing distance at a square root rate), while Fig. 2 displays the position of each viable planet in their respective zones (e.g., + lower zone + (1) / zone width). Most are clustered around the inner limit of the HZ. Overall, in the dataset, 39 planets are located in a favorable HZ.

Planetary Composition

Planetary composition is an exoplanet characteristic depending on various factors – the gases and elements during solar system formation, distance from the sun, and even proximity to other massive / dense planets (Seager 2007). Because of these determinants, some of which may be known but have an unknown combined result, it is difficult to categorize a given planet as being likely to have a large ocean or being composed of mostly metallic compounds (Seager 2007). For this dataset, in order to improve prediction accuracy of the makeup of such planet, three models were used: computing to a Harvard dataset mapping theoretical mass and radii to distinctions between 100% iron, 45% water planets, etc. (Einstein-Sassinov et al. 2015). This research has made use of the NASA Exoplanet Archive, which is operated by the California Institute of Technology, under contract with the National Aeronautics and Space Administration under the Exoplanet Exploration Program.

Equilibrium Temperature

According to a study done by Kaltenegger and Sasselov, for planets similar to Earth in size, the limits of the habitability zone can be defined by a planet’s equilibrium temperature falling between 175K and 270K. This range considers the temperature needed for liquid water to exist on the surface, given atmospheric conditions, such as the greenhouse effect, that would exist on a theoretically habitable exoplanet. Of these planets with a listed equilibrium temperature, 7 fall within the range, as shown in Fig. 3. Only 3 planets satisfy the Goldilocks Zone restrictions and are in the viable temperature range – Kepler 186f, Kepler 1653b, and TRAPPIST 1f.

Eccentricity

The eccentricity of a planet’s orbit can be crucial for determining habitability. If a planet’s orbit is too eccentric it can lead to planets that cannot maintain liquid water year round as they move further and closer to their host star. Lissmann et al. (2015) studied the influence of both obliquity and eccentricity for ocean covered planets orbiting a Sun-like star on a 375 day orbit and a 24 hour day, like Earth. They found that planets with eccentricities higher than 0.2 can only sustain surface liquid water for a part of the year.

Of the planets on NASA’s exoplanet archive, only 80 have eccentricities of Less than 0.2. That is 21.5% of the planets that could potentially sustain liquid surface water year round.

Surface Gravitational Acceleration

Gravity is an essential aspect on all planets in terms of habitability. Gravity influences the retention of atmospheric components and elements as well as the ability to survive on the planet’s surface.

In a research paper at the University of California Berkeley, it was found that there is a correlation between the gravitational acceleration and the mass of the planet. Surprisingly, these categorized as Super-earths had a similar gravitational acceleration of the earth.

References

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