The Viability of Life on Exoplanets

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The first confirmed exoplanet was discovered when astronomers Aleksander Wolszczan and Dale Frail discovered two planets, Poltergeist and Phobetor, which orbit the pulsar PSR B1257+12. Today, we know more than 6000 exoplanets and the number of known exoplanets grows constantly. Since we can now categorize exoplanets, the estimation of the viability of life on exoplanets has become viable, and that is what I'm going to do in my thesis.

First, we must consider the habitable zone (HZ). HZ is an area around the star, where potentially habitable planets can exist. There are three different limits for the outer edge of HZ. The first condensation limit is the distance from the star, where carbon dioxide clouds start to condense when the planet's surface temperature is 273K. The second limit is the maximum greenhouse limit, where a cloudless carbon dioxide atmosphere can keep the surface temperature at 273K. The third limit presumes that Mars was once able to keep large bodies of water on its surface. The inner edge of HZ is defined by the preservation of water. The surface temperature can't be higher than 647K, otherwise the water vapor starts to dominate the atmosphere, which will eventually lead to water braking to hydrogen and oxygen and hydrogen leaving the planet's atmosphere (Kasting et al. 1993)

The properties of the host star affect the size of the habitable zone. The properties of the host star that affect the size of the HZ are the luminosity of the star, the size, the effective temperature, and the spectrum. Bigger, hotter and more luminous stars have larger HZs, and the inner and outer edges of HZs are further away from the star. Smaller, colder, and less luminous stars have smaller HZs, and the inner and outer edges of HZs are closer to the star. And since stars' properties change during their main sequence, the habitable zone isn't a static area around a star. It constantly evolves alongside the star's properties. In my work, I am going to study planets that orbit M-, K-, G-, and F-type stars. This is because these types of stars have lifespans long enough to make the beginning of life on a planet's surface possible. These types of stars are also more abundant compared to other types of stars.

The activity of a host star is also an important factor, when the habitability of a planet is considered. Coronal Mass Ejections (CMEs) and flares eject high energy particles from the star towards the planet. Stars also emit ultraviolet radiation and x-ray radiation. All of this can cause erosion of the planet's atmosphere and in extreme scenarios the atmosphere can wear off completely. How much erosion all of this can cause depends on the strength of the planet's magnetic field (provided that a planet has one), the distance of a planet from its host star, the thickness of a planet's atmosphere, and of course how active the host star is (more active = more flares, CMEs and more intense radiation). UV radiation and X-ray radiation are also harmful to life itself, but a certain amount of UV radiation is also needed that certain compounds necessary for life can form.

Terrestrial planets are considered to be the best options for the birthplaces of life. For a planet to be able to support life, the planet must be able to sustain large bodies of liquid water on its surface. For this to be possible, the mass of a planet should be between 0.1 and 10 Earth masses, bulk density between 0.7 and 1.5 Earth densities and radius between 0.5 and 1.9 Earth radii. The atmosphere of a planet should be composed primarily of nitrogen. A planet's surface temperature should be around 273-323K (Schulze-Makuch et al. 2011). While not necessary, volcanic and tectonic activity would help keep a planet warm and silicate-carbon cycle would be easier to sustain. A molten core could enable the planet to have a magnetic field around it, and this would protect the planet from high energy particles and harmful radiation. An exoplanet can also be compared to Eart by using Earth Similarity Index (ESI). If a planet's ESI is zero, it has nothing in common with Earth. If a planet's ESI is one, the planet is identical to Earth.

In my thesis, I am going to study planets orbiting the stars Gliese 581 (GJ 581), Proxima Centauri, Kepler-442, and Keppler-22, and my aim is to determine whether or not these planets are viable for life. To achieve this, I am going to analyze stellar spectral energy distributions, and their evolution, do statistical analysis of exoplanet characteristics, and study how changes in stars' magnetic activity affect the viability of life on exoplanets.