THE OCCURRENCE OF PLANETS IN THE ABIOGENESIS ZONE. M. Jusino[1,2] and A. Méndez[2], [1]Department of Physics, University of Puerto Rico at Mayaguez (marcos.jusino1@upr.edu), [2]Planetary Habitability Laboratory, University of Puerto Rico at Arecibo (abel.mendez@upr.edu).

Introduction: Precursor molecules to the building blocks of life such as ribonucleotides, amino acids and lipids could have been produced in an early, prebiotic Earth in which ultraviolet radiation induced the activation energy required to trigger photochemical reactions. Accordingly, to the Primordial Soup theory, these reactions are to occur in the presence of surface liquid water, to which the positioning of the planet inside the conservative Habitable Zone is vital (see Figure 1).

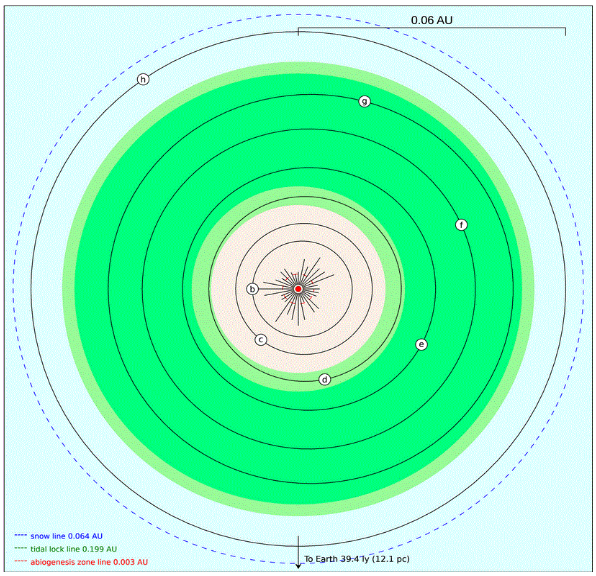

Figure 1. Plot of the orbits of the planets around TRAPPIST-1 and the habitable zone (green shades) (PHL, UPR Arecibo).

The Abiogenesis Zone, as defined by Rimmer *et al.* [1], is the zone in which a yield of 50% for the photochemical products is obtained, adopting the current UV activity as representative of the UV activity during the stellar lifetime and assuming a young Earth atmosphere. Rimmer *et al.* [1] portrayed this by modeling the UV detachment of electrons from anions in solution, such as H_2S and SO_2 in the presence of HCN to produce HS^- and SO_3^{-2} for the latter, in representation of past works involving reactions to form the pyrimidine nucleotide RNA precursors [2, 3].

Details for the Abiogenesis Zone. This zone approximately ranges in UV radiation from 200nm to 280nm, since this is the critical wavelength range for photochemical reactions as proved by Todd *et al.* [4]. A weakly reduced atmosphere with a plausible composition of N_2, O_2, H_2, and CO_2, as speculated to have had existed in prebiotic times between 3.8 and 3.5 Ga [5], is essential for the photochemical reactions to occur, since UV radiation at its critical wavelength range is weakened in present-day Earth's atmosphere.

Lingam and Loeb [6] proved that planets orbiting around stars type M-dwarfs cannot sustain Earth-like biospheres because they do not receive enough photons in the photosynthetically acting range of 400 to 750 nm, unless they are active enough for flares to compensate. However, since only a 20% of M-dwarfs are active [1], and flares give rise to other positive and negative effects [6], we do not consider them in our study.

Known Planets in the Abiogenesis Zone: When applying the Abiogenesis Zone to our catalog of Potentially Habitable Exoplanets we found seven candidates: Kepler-452 b ($R_E = 1.63$), Kepler-1638 b ($R_E = 1.87$), Kepler-1606 b ($R_E = 2.07$), Kepler-1090 b ($R_E = 2.25$), Kepler-22 b ($R_E = 2.38$), Kepler-1552 b ($R_E = 2.47$), and Kepler-1632 b ($R_E = 2.47$). Although all of these seven exoplanets are inside both the Habitability Zone and the Abiogenesis Zone, they are all warm superterrans (i.e. Super-Earths or Mini-Neptunes), and less likely to support life. A large planetary radius might suggest the presence of a thick gaseous atmosphere, deep oceans, or both. Thus, these planets are less likely to be of rocky composition.

Kasting [5] showed that the presence of the Carbon cycle in a planet is key to its habitability since it acts as a temperature regulatory system to preserve liquid water on its surface - specially the silicates weathering component. Vast amounts of water oceans in a planet create obstacles (ice VII) between the planetary surface and the water, and gaseous planets imply high temperatures and high pressures, significantly decreasing the chances of liquid water on its surface; both cases interrupt the Carbon cycle [7].

Alibert [7] calculated the maximum planetary radius that would make a planet inhabitable. For planets in the Super-Earth mass range (1 to 12 Earth masses), the maximum radius that a planet, with a composition similar to that of Earth, can have varies between 1.7 to 2.2 Earth radii. Our best choice for a candidate would theoretically be Kepler-452 b ($R_E = 1.63$) because it is the planet with the lowest radius from our sample (see Figure 2).

Conclusion: The Abiogenesis Zone is the zone in which a yield of 50% for the photochemical products is obtained, adopting the current UV activity as representative of the UV activity during the stellar lifetime and assuming a young Earth atmosphere [1]. Although there are seven small exoplanets in this zone, none of them are very good candidates due to their size, except for maybe Kepler-452 b. So far, not a single Earth-sized planet has been discovered to be in both the Habitable Zone and the Abiogenesis Zone.

References: [1] Rimmer P. B. *et al.* (2018) *Sci. Adv.*, **4**. [2] Patel B. H. *et al.* (2015) *Nat. Chem.*, **7**, 301-307. [3] Xu J. *et al.* (2018) *Chem. Commun.*, **54**, 5566-5569. [4] Todd Z. R. *et al.* (2018) *Chem. Commun.*, **54**, 1121-1124. [5] Kasting J. F. (1993) *Science*, **259**, 920-926. [6] Lingam M. and Loeb A. (2019) *MNRAS*, **000**, 1-4. [7] Alibert Y. (2013) *Astronomy & Astrophysics*, **561**.

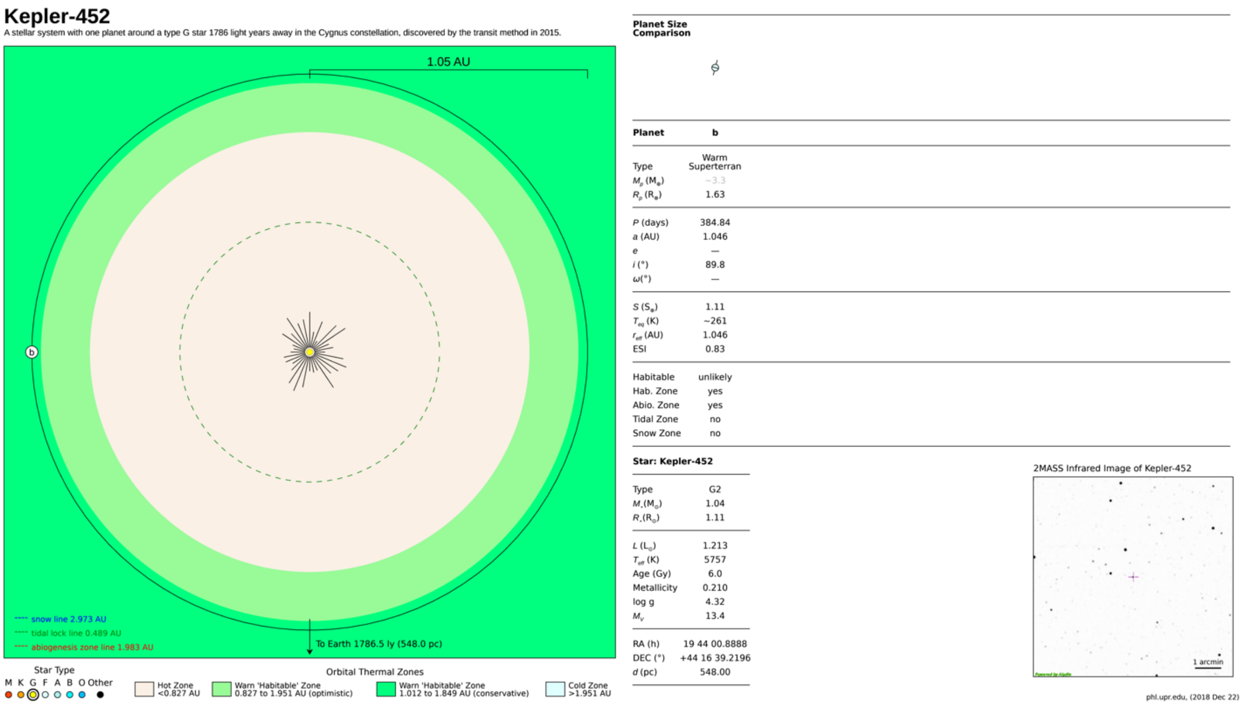

Figure 2. Plot of the orbits of the planets around Kepler-452. It is a stellar system with one planet around a G type star 1786 light years away in the Cygnus constellation, discovered by the transit method in 2015. This is the known smallest planet both inside the habitable and abiogenesis zone (PHL, UPR Arecibo).