NEW PLANETARY LIMITS FOR EARTH-LIKE PLANETS BASED ON BIOPHYSICAL CONSTRAINS.

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Introduction: One of the main goals of exoplanet science is the detection and characterization of Earth-like planets. A planet is considered potentially habitable if it has the theoretical right size and orbit to support surface liquid water, i.e. an Earth-size planet in the habitable zone (HZ) (Fig. 1). So far, there are about 30 exoplanets considered potentially habitable [1] out of the nearly two thousands already confirmed. This is an optimistic number including some still unconfirmed planets. Some of these planets might not be able to support surface liquid water and therefore may not be habitable depending on their bulk composition and atmospheric properties. However, even if some have surface liquid water they might be quite different both chemically and physically from the necessary conditions to support all the diversity of life as we know it, especially complex life such as plants and animals.

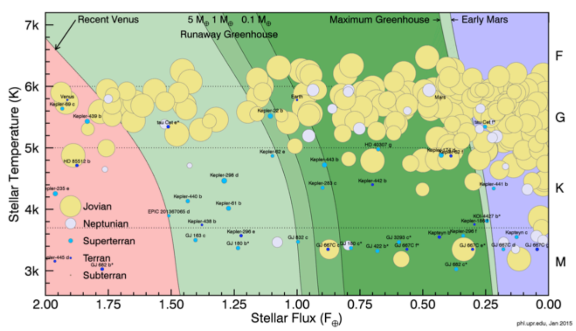

Fig. 1. All planets near the HZ (green shades). Those less than 10 Earth masses or 2.5 Earth radii are labeled. Size of the circles corresponds to the radius of the planets (estimated from a mass-radius relationship when not available). Unconfirmed planets are indicated with an asterisk in their name.

In this study we show that Earth-like planets, those with the right surface conditions to support both simple and complex life, are more restricted in size and orbit than previously thought. This suggests that many potentially habitable worlds are only habitable in any case to extremophiles or exotic life forms, but not Earth-like life. It is important to make this habitability distinction to correctly interpret the source of biosignatures detected by future space or ground-based telescopes, such as the JWST [2]. For instance, the potential biosignatures of a habitable but non Earth-like world might suggest an abiotic origin, extremophiles, or exotic life not as we know it.

Methods: We constructed a biophysical model of life based on its thermal and partial pressure requirements of water, oxygen and carbon dioxide. Although microbial life can survive in more diverse conditions all complex life depends on oxygen due to energy considerations [3]. We used this model to explore what planetary conditions allow for surface complex life, similar to the present Earth. Therefore, our model goes beyond the simpler habitability criteria of surface liquid water to more biological considerations.

We used our biophysical model and the current definition of the HZ [4] to define planetary size and orbit limits (i.e. currently observable quantities) for complex life on planets around main sequence stars. The current HZ can be subdivided into a optimistic and conservative HZ but we found that potential Earth-like planets are only possible within a zone much smaller than the conservative HZ. Additionally, we considered the effect of elliptical orbits on the size of the HZ. For simplicity, we also used an Earth Similarity Index (ESI) [5] based on stellar flux and planet size to approximately define the corresponding index values of Earth-like planets on this scale. In general, potentially habitable planets using optimistic definitions of size and HZ have ESI values over 0.5 but Earth-like worlds are much closer to one (Earth = 1.0 in the ESI scale).

Results: Our study shows that it is possible to further constrain the size of the HZ for potential Earth-like planets. Most potentially habitable worlds are not suitable for complex life as we know it but are still of interest in the search of biosignatures of simple life. Earth-like planets, as defined by this study, might show a stronger atmospheric biological signal and should become a high priority in the search of biosignatures. This presentation will discuss our new planetary limits for Earth-like planets, current Earth-like candidates, and strategies and potential errors associated with their detection and characterization.

References: [1] Habitable Exoplanets Catalog (phl.upr.edu/hec). [2] Seager, S. (2014), Search for Life Beyond the Solar System. Exoplanets, Biosignatures & Instruments (www.ebi2014.org) [3] Catling, D. C., Glein, C. R., Zahnle, K. J., & McKay, C. P. (2005), *Astrobiology*, 5, 415. [4] Kopparapu, R. K., Ramírez, R. M., SchottelKotte, J., *et al.* (2014), *ApJ*, 787, LL29. [5] Schulze-Makuch, D., Méndez, A., Fairén, A. G., *et al.* (2011), *Astrobiology*, 11, 1041.

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