

Comparative Habitability of Transiting Exoplanets in Terms of the Eccentricity-Albedo Degeneracy

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The first exoplanet biosignature observation could be made by transit transmission spectroscopy with NASA's *JWST* [1,2,3]. Given the deluge of small, transiting exoplanets expected from the *TESS* satellite (launch date: Aug 2017), a prioritization scheme for identifying the best targets for spectroscopic follow-up by *JWST* and other resources is critical. Here we propose a simple and fast method for ranking potentially habitable planets that leverages the available astronomical information from transit discovery data and makes as few assumptions as possible regarding the physical and orbital properties of the planet.

Planetary habitability is a strong function of the orbit-averaged emitted energy flux F from the planet. The maximum flux F_{max} and minimum flux F_{min} can be estimated from previous results [4,5,6], and are a function of the stellar luminosity L , semi-major axis a , eccentricity e , bond albedo A , and, in some cases, tidal heating T :

$$F = \frac{L(1-A)}{16\pi a^2 \sqrt{1-e^2}} (1+T). \quad (1)$$

Kepler's Laws can provide an accurate value for a based on the orbital period if the stellar mass is well-known. Tidal heating can be estimated for planets of low-mass stars [7,8], many of which will be examined by *TESS*. Ignoring T for now, the flux is then a function of the unknown values of e and A . Note in Eq. (1) that as e increases, F increases, but as A increases, F decreases, a feature we dub the "Eccentricity-Albedo Degeneracy." In some cases e can be constrained, but A cannot. Thus, to determine the likelihood for a planet to be habitable, *i.e.* $F_{min} < F < F_{max}$, we must consider a range of values for both parameters.

To demonstrate our method, we considered the *Kepler* Objects of Interest (KOIs) as of 1 Dec 2014. We conservatively narrowed our search to those planets with planetary radii less than $2.5 R_{Earth}$ and equilibrium temperatures between 150 and 400 K, producing an initial list of 269 KOIs. None of these exoplanets can be characterized by *JWST*, but they are likely representative of the sample of closer targets, which are accessible. For each planet, we calculated F over a plausible range of e and A . We then calculate each planet's ratio of potentially habitable parameter space to the total in a variable we call h . Higher values of h represent planets that are more likely to be habitable.

However, more phenomena must be incorporated before we should perform "Comparative Habitability." Tidal heating is negligible for KOIs, but could be im-

portant for *TESS* targets and can be incorporated into our method. But we do need to assign a probability for the planet to be rocky, p_{rocky} , which is difficult to estimate currently. Based on limited information [*e.g.* 9,10,11], we set it to 1 for planetary radii below $1.5 R_{Earth}$ and decrease it linearly to 0 at $2.5 R_{Earth}$. Finally we define the "Habitability Factor" as $H = h \cdot p_{rocky}$, whose values range from 0 to 1, and prioritizes exoplanets for astrobiological potential.

Fig. 1 shows our results for the *Kepler* sample and assuming flux limits for Earth-like exoplanets [4,6]. No KOI has $H > 0.9$. The highest priority objects have incident stellar fluxes S_{eff} (assuming circular orbits) in the range 0.6–0.8 times the solar constant, assuming $e = 0$. We conclude that small transiting planets discovered in the solar neighborhood within this range are the highest priority in the search for life beyond the Solar System for at least the next 10 years.

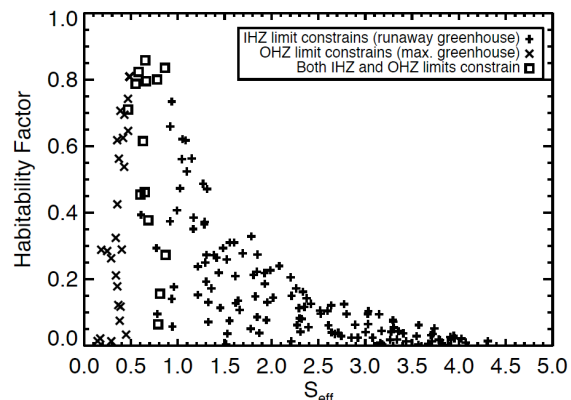


Fig. 1 – Habitability Factor for KOIs in terms of incident stellar radiation, relative to the solar constant, for a circular orbit. Higher values indicate a larger probability of being rocky and possessing a habitable atmosphere based on all available planetary system data. Symbols denote which flux limit(s) reduce the planet's Habitability Factor.

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