Exploring the Habitable Zone for Kepler planetary candidates

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OVERVIEW

Applied simple approach to evaluate habitability of terrestrial planets by assuming different types of planetary atmospheres for current Kepler planetary candidates (also applies to other transit mission and other searches).

Depends to a first approximation on 4 main parameters: 1) incident stellar flux which depends on stellar luminosity, spectral energy distribution and eccentricity of the system, 2) planetary albedo, 3) greenhouse gas concentration, and 4) energy distribution in the planetary atmosphere.

MAIN POINTS

Simply estimate if a planet is pot. habitable: 185K < T_{eq} < 270K

$$T_{eq}=T_{star}((1-A)r_{star}^2/4\beta D^2(1-e^2)^{1/2})^{1/4}$$

A=Bond albedo, β=reradiation parameter, e=eccentricity, D=orbital distance, T_{eq}=planet equilibrium T

Spectroscopy needed to CHARACTERIZE planets

Atmospheric gases (biomarkers) in emission/reflection and transmission for Earths and super-Earths

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THE HABITABLE ZONE

We focus on the circumstellar HZ, that was defined by Kasting et al. (1993) as an annulus around a star where a planet with an atmosphere and a sufficiently large water content like Earth can host liquid water permanently on a solid surface. This definition of the HZ implies surface habitability because it is defined to allow remote detectability of life as we know it.

Table 1 shows the characteristics of the potentially rocky habitable Kepler planetary candidates (KOI, star:T_{eff}, R_{star}, planet: R_{pl}, Period, T_{eq}, orbital distance a) and the water loss limit of the HZ for 0, 50% and 100% clouds.

KOI	T_{eff} (K)	R_{star} R_{Sun}	R_{pl} R_{Earth}	a AU	T_{equ} clouds:50%	HZ_{in} (AU) Water loss 0%	50%	100%	HZ_{out} (AU) 0%	50%	100%
1026.01	3802	0.68	1.8	0.325	230	0.29	0.24	0.16	0.57	0.65	0.79
854.01	3743	0.49	1.9	0.217	235	0.20	0.17	0.11	0.40	0.46	0.55
701.03	4869	0.68	1.7	0.454	247	0.47	0.38	0.26	0.87	1.00	1.22
268.01	4808	0.79	1.8	0.406	278	0.53	0.43	0.29	0.99	1.14	1.39
326.01	3240	0.27	0.9	0.05	316	0.08	0.07	0.05	0.17	0.19	0.23
70.03	5342	0.7	2	0.35	310	0.58	0.46	0.31	1.04	1.21	1.48

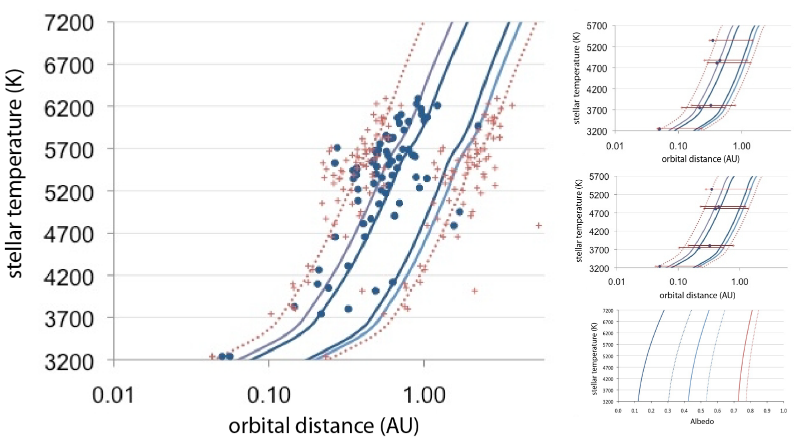

Fig. 1 Extent of the Habitable Zone (water loss limit) for 0% and 50% (inner limits) and 100% cloud coverage (outer limit dashed line), individual HZ limits are indicated with crosses. (right) Detail for the 6 potentially rocky planets and limits for the HZ for water loss (upper) Greenhouse onset (middle) and maximum albedo at the inner edge of the HZ (lower panel).

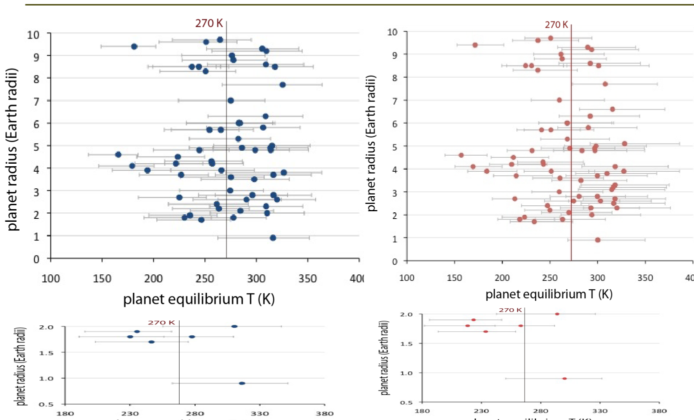

Fig. 2 Minimum equilibrium Temperature of the Kepler planets candidates (left) water loss limit and onset greenhouse (right) for 50% cloud coverage. Error bars indicate 0% and 100% cloud cover, the line indicates 270K. Detail for the 6 pot. rocky planets (lower panel)

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HABITABLE KEPLER PLANET CANDIDATES

Applying our analysis to the whole Kepler planetary sample of 1235 transiting planetary candidates, assuming the maximum Earth-like Bond albedo for rocky planet atmospheres (see Fig.1) circular orbits and 50% cloud coverage in accordance to the "Venus water loss limit" leads

-27 Kepler planetary candidates: 185K < T_{eq} < 270K.

-3 radii smaller than 2 Earth radii (Table 1).

The biggest change in T_{eq} change of planet albedo depending on cloud coverage (see Fig.1, Fig.2)

-12 (2 pot. rocky) planets for a clear atmospheres

-67 (4 pot. rocky) planets for 100% cloud coverage

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