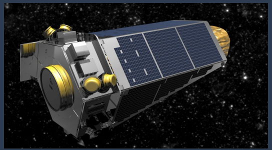

KEPLER 452b

REVIEW ON A PROMISING PLANETARY COMPANION OF KIC8311864

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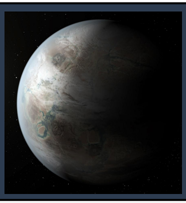
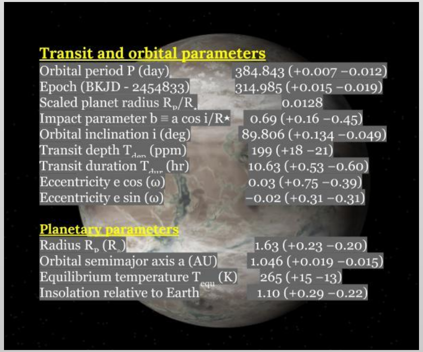


Introduction

Kepler 452b is possibly the first Earth-like planet to be found in a Sun-like star's habitable zone—the orbital region where an Earth-like planet could possess liquid water on its surface and thus possibly support life. Kepler-452b was discovered in 2015, from the transit data that the Kepler satellite had gathered, before the first phase of its mission ended in 2013. The star that Kepler-452b orbits, has the same spectral type (G2) as that of our Sun and is about 1,400 lightyears from Earth. The planet's radius is approximately 1.63 times that of Earth. If the planet has a rocky composition, its mass would be about 5 times that of Earth. However, it is equally likely that the planet's composition is like that of Neptune: a small rocky core surrounded by a thick mantle of ice and a gaseous envelope, and therefore its mass may be less. Kepler-452b's orbital period is 384.8 days, and it orbits at a distance of 156.5 million km.

Properties



Transit and orbital parameters	
Orbital period P (day)	384.843 (+0.007 −0.012)
Epoch (BKJD - 2454833)	314.985 (+0.015 −0.019)
Scaled planet radius $R_p/R_\star$	0.0128
Impact parameter $b \equiv a \cos i/R_\star$	0.69 (+0.16 −0.45)
Orbital inclination i (deg)	89.806 (+0.134 −0.049)
Transit depth T_{dep} (ppm)	199 (+18 −21)
Transit duration T_{dur} (hr)	10.63 (+0.53 −0.60)
Eccentricity e cos (ω)	0.03 (+0.75 −0.39)
Eccentricity e sin (ω)	−0.02 (+0.31 −0.31)
Planetary parameters	
Radius R_p ($R_\oplus$)	1.63 (+0.23 −0.20)
Orbital semimajor axis a (AU)	1.046 (+0.019 −0.015)
Equilibrium temperature T_{equ} (K)	265 (+15 −13)
Insolation relative to Earth	1.10 (+0.29 −0.22)

Detection Method

Kepler-452b was discovered in a test run of the NASA's Kepler Science Operations Center (SOC) 9.2 codebase in 2014 May, According to the Data Validation pipeline module, the transit signature of this object featured four 10:5hr, 199-ppm deep transits spaced 384.846 days apart, a radius of 1.1 $R_\oplus$. Due to the curiously small stellar radius of KIC 8311864 for the effective temperature available at the time of the 2014 May planet search, it was clear that reconnaissance spectroscopy was called for in order to obtain a reasonable interpretation of the nature of the source of the transit-like features in the Kepler Lightcurve. To improve the stellar parameters derived from spectroscopy, a spectrum was obtained from the Keck Observatory with the HIRES instrument in 2014 July. The HIRES data were analyzed with three independent analysis packages in order to better understand the effects of systematics in the software codes and to determine the most reasonable stellar parameters to use for interpreting the photometry in this system.

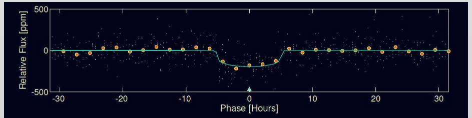
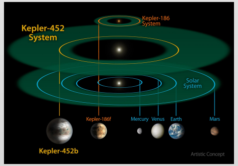


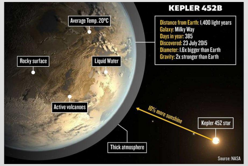
Figure 2. Phase-folded, detrended flux time series for Kepler-452 versus phase in hours. The flux time series plotted here is the same as that of Figure 1, except that it has been phase folded at the period of the planet, 384.84 days. The triangle symbol indicates the location of the four transits at zero phase. The full resolution data are represented by black dots. The cyan filled circles represent the results of binning the data in phase with a bin width of 1/5 of the DV-fitted duration of the transit, 10.5 hr.

Markov chains were used to derive model dependent measurements of the transit depth, T_{dep}, and transit duration, T_{dur}. The transit model parameters were convolved with the stellar parameters to compute the planetary radius, $R_p = 1.6\ R_\oplus$, and the flux received by the planet relative to the Earth (S = 1.1 S). A fit was performed forcing the orbit to be circular in the transit model and thereby an estimate for the density of the star of ρ(star) = 1.1 ± 0.3 g cm^{-3} was obtained and this value is perfectly consistent with the spectroscopic work.

Habitability

A conservative estimate for the width of the HZ from the "one-dimensional (1D), cloud-free, climate model" in our solar system is 0.95-1.67 AU. According to Jenkins et. al., optimistic habitable zone lies within the range from~20% to~180% of the radiation experienced by earth today [Jenkins, 2015]. This combined with the rough estimates of what we know about the exoplanet puts Kepler 452b in the optimistic habitable zone.For the high CO_2 abundance case, the surface pressure should be ≲ 1 – 2 bar to allow ≳ 20% habitability, and ≲ 0.5 bar for≳ 50% habitability. For lower CO_2 content, most solutions have currently ≳ 50% habitable surface.Atmospheric biosignatures may conceivably be produced in detectable amounts only in presence of a widespread and long term surface biological activity.





According to ESTM model [Silva, et.al.], for all models(except the low CO_2 and low pressure case), the total *life- time* (ie. life time weighted by habitability index h_o) is ≥ 2 Gyr., all of which are currently on the verge of exiting their habitable phase. The exoplanet would have had enough time to potentially produce atmospheric biosignatures which makes Kepler 452b a good candidate in the search for biomarkers.

Since the planet receives 10% more sunlight from its parent star than Earth it's a bit warmer, also the parent star of Kepler 452b is 1.4 billion years older than Earth. There is a chance that it might have lost its atmosphere due to increased energy output coming from its parent star, since the planet is much more massive than Earth, the planet's gravity might hold the atmosphere for a much longer time as compared to the Earth.

Future Prospects

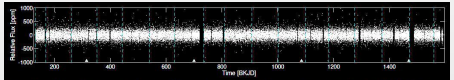


Figure 1. Detrended flux time series for Kepler-452 versus barycentric-corrected *Kepler* Julian day (BKJD - 2,454,833.0). The triangle symbols indicate the locations of each of the four transits which occur in quarters 3, 7, 11 and 15. All 4 years of *Kepler* data are plotted here with vertical dashed red lines indicating the boundaries between consecutive quarters. The detrending was accomplished by subtracting the result of passing the systematic error-corrected light curve through a moving median filter with a window width of five times the ~10.5hr pulse duration. The light curve residuals are remarkably uniform across all 17 quarterly data segments, showing no evidence of electronic image artifacts which are responsible for a large number of long period false positive transit-like features in the *Kepler* light curves.

Kepler 452b is a huge prospect in terms of our quest to find an earth-like planet outside the solar system. Serious study is being dedicated towards understanding the planet characteristics. Where a lot has been understood about the planet, some studies have also cast serious doubts on its existence and tremendous promises as a habitable zone exoplanet. Recent study (Mullally et al. 2018 May, ApJ) indicates that Kepler has inability to confirm individual planet candidates by statistical techniques but it should not be considered a failure of the Kepler mission. We need to make some independent detection to get more assurance about the parameters we know. In the next few years , we can have a better understanding of the habitability parameters using the newly launched or future missions like JWST. Scientists with the SETI (Search for Extraterrestrial Intelligence Institute) have already begun targeting Kepler-452b, the first near-Earth-size world found in the habitable zone of a Sun-like star. SETI Institute researchers are using the Allen Telescope Array, a collection of 6-meter (20 feet) telescopes in the Cascade Mountains of California, to scan for radio transmissions from Kepler-452b.

References

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