EPSC Abstracts
Vol. 12, EPSC2018-244, 2018
European Planetary Science Congress 2018

Possible discovery of two Mini-Neptune type planets around a dim K-star

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Abstract

We report the detection of two planets around EPIC 212737443, a magnitude 14.4 star using photometric data from the Kepler-K2 mission. By using multi-band photometric measurements to get a Spectral Energy Distribution (SED), the star was determined to have temperature of 4500±50 K, an effective surface gravity of logg = 4.5±0.25, a metallicity of [Fe/H] = 0, which is evidence that this is a K-type star. The planets have orbital periods of 13.60 and 65.60 days with transit depths of approximately 1000 ppm each. The radii of the two planets (2.18±0.04 R_{earth} and 2.42±0.04 R_{earth}) and their estimated masses imply that they are Mini-Neptune type worlds, though further measurements are required to constrain their masses. An RV follow-up study of these planets would be crucial for determining the exact density and mass of these planets as they lie in the transition region between Super-Earth's and Mini-Neptunes. The outer planet may reside in the habitable zone of the host star and both planets are possible candidates for follow-up studies with the JWST for atmospheric studies.

1. Introduction

EPIC 212737443 was observed during Campaign 6 of the K2 mission between July 13, 2015 and September 30, 2015. The light curve was obtained from the K2 archives hosted by the Mikulski Archive for Space Telescopes (MAST). We measured the mid-transit time for each individual transit event using the Kwee-Woerden technique. A total of six transits for the inner and two transits for the outer planet were identified and a linear ephemeris was determined (Table 1).

1.1 K2 photometry and transit vetting

Due to a malfunction in the reaction wheels of the Kepler spacecraft, the light curve contained position dependent and time dependent (mostly due to stellar variability) systematic trends. We used the *K2SC* correction algorithm (Aigrain et al 2016) which uses a Gaussian Process regression model to separate and remove the trends. Then a Box Least Square (BLS) algorithm was used to find transit signals followed by the fitting of Mandel & Agol (2002) transit models to determine if there are differences in the odd-even transits, and if there are any secondary eclipses. After finding transits with periods of 13.60 and 65.60 days, it was determined that the transits do not have odd-even depth variations or secondary eclipses. This mostly rules out the possibility that the transits are binary stellar companions. For the inner planet no significant transit-timing variations beyond the ephemeris uncertainty were found during the time period of the data.

2. Stellar characterization and additional observations

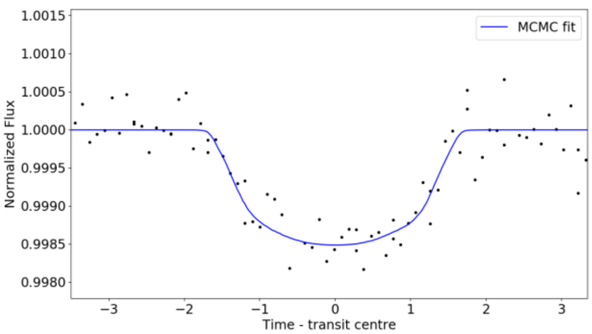
We also attempted to infer atmospheric properties of the host star via spectral energy distribution fitting. The VOSA/SED tool was utilized. For this we acquired intermediate- and broad-band photometric data from various sky-survey archive databases including WISE and 2MASS data. We probed several atmospheric models. The BT-SETTL CIFIST model provided an optimum description of the data revealing an effective temperature of 4500±50 K, logg = 4.5±0.25 and [Fe/H] = 0 for a solar abundance in metallicity. The stellar radius of 0.57 R_{sun} was taken from Huber et al (2016) which did a spectroscopic survey of K2 targets. Additionally we have acquired Lucky Imaging data using the two-instrument EMCCD cameras at the Danish 1.54m telescope (ESO/La Silla). A preliminary but close to certain investigation of the photometry revealed that no nearby companions are present.

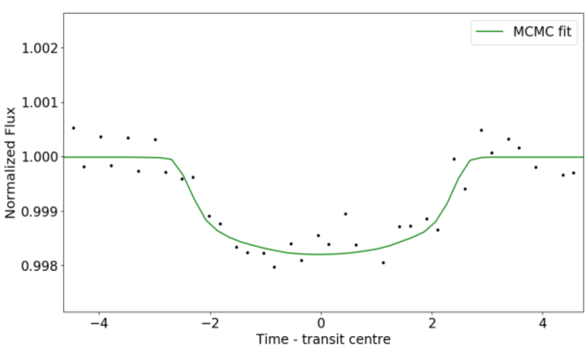
3. MCMC fitting, orbital stability and a preliminary mass

We re-extracted the transits for each planet candidate and fit them with a Monte Carlo Markov Chain (MCMC). We used the *emcee* package (Foreman-Mackay et al. 2013) to fit the model light curves produced by the *PyTransit* package (Parviainen et al 2015), which uses the Mandel & Agol algorithm. We supersampled the data by a factor of 10 and adjusted for the K2 long cadence time of 29.5 minutes. The MCMC was implemented with 10 variables including the limb darkening parameters for which we used the triangular sampling as suggested by Kipping (2013). We ran 60,000 chains with 150 walkers and a burn-in of 200 chains. The final parameters and their errors can be seen in Table 1. We estimated the mass of each planet using the mass-radius relationship proposed by Weiss & Marcy (2014), which is given here as Equation 1. The masses were found to be 5.54 M_{Earth} and 6.11 M_{Earth} respectively. As a final investigation we numerically integrated the orbits of the two-planet system over 10^7 years using a symplectic algorithm within the MERCURY (Chambers 1999) orbit integration package. Initial circular orbits were assumed. We find an overall orbital stability with small perturbations in the orbital elements. The system is found not to be locked within a specific mean-motion resonance.

4. Figures

Figures 1&2: The best fit curves with the observed data for each planet in EPIC 212737443. Planet a (blue) with 13.60 days and Planet b (Green) with 65.60 days.





5. Equations

$$\frac{M_E}{M_s} = 2.69 \left(\frac{R_E}{R_s}\right)^{0.93} \qquad (1)$$

6. Tables

Table 1: Parameters measured through MCMC fitting for the planets in EPIC 212737443

	Planet a	Planet b
Epoch (BJD)	2457221.35	2457227.80
Period (days)	13.602±0.0004	65.601±0.0002
R_p/R_{star}	0.035±0.0005	0.039±0.0005
Impact param.	0.42±0.05	0.44±0.06
a/R_{star} (scaled)	32.4±0.30	90±0.60
eccentricity	0.002±0.0006	0.004±0.0003
Radius (R_{Earth})	2.18±0.04	2.42±0.04

7. Summary and Conclusions

We have provided observational evidence for the possible detection of a transiting two-planet system EPIC 212737443. The transit signals seem to be in accordance with other planetary systems detected from the K2 mission. We have attempted to characterize the host star via SED modelling determining it to be a K-type star. The planetary architecture points towards a non-resonant and stable configuration. This is partially supported by non-significant timing variations of the inner planet. The masses measured by using the Weiss & Marcy relation show that the two planets are within the mass range of Super-Earth's but the radii imply they are not quite dense enough. This puts them firmly in the boundary between Super-Earth's and Mini-Neptunes. Future photometric and spectroscopic follow-up observations will provide a more detailed characterization of the two planets. Studying this system would be particularly important in order to study the transition region between Super-Earth's and Mini-Neptunes and to better constrain our understanding of planet formation.

References

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