Short-period Kepler exoplanet candidates: search for orbital period variations based on 17 quarter data

Zoltán Garai

Astronomical Institute of the Slovak Academy of Sciences

Abstract

A unique close-in Mercury-size Kepler exoplanet candidate KIC012557548b has been discovered recently by Rappaport et al. (2012). This object is a transiting disintegrating exoplanet with a comet-like tail. Close-in exoplanets, like KIC012557548b, are most prone to the planet-star interaction which may cause formation of the comet-like tail, or another form of circum-planetary material. Strong interaction with the host star, or presence of an additional planet, may also lead to variations in the orbital period of the planet. Our main aim was to search for long-term orbital period variations. We concentrated on a sample of 20 short-period exoplanet candidates with a period similar to KIC012557548b from the Kepler mission. We used the publicly available 17 quarter long cadence Kepler data.

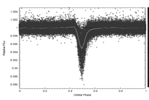
Short-period Kepler exoplanet candidates: search for orbital period variations based on 17 quarter data

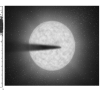
Zoltán Garai[1]
([1]Astronomical Institute of the Slovak Academy of Sciences, 059 60 Tatranská Lomnica, Slovakia)

Abstract

A unique close-in Mercury-size Kepler exoplanet candidate KIC012557548b has been discovered recently by Rappaport et al. (2012). This object is a transiting disintegrating exoplanet with a comet-like tail. Close-in exoplanets, like KIC012557548b, are most prone to the planet-star interaction which may cause formation of the comet-like tail, or another form of circum-planetary material. Strong interaction with the host star, or presence of an additional planet, may also lead to variations in the orbital period of the planet. Our main aim was to search for long-term orbital period variations. We concentrated on a sample of 20 short-period exoplanet candidates with a period similar to KIC012557548b from the Kepler mission. We used the publicly available 17 quarter long cadence Kepler data. We found 3 cases of exoplanet candidates which showed some change of the orbital period. In one case we observed an orbital period increasing, other exoplanet candidates showed an orbital period shortening. The preliminary orbital periods were improved. We did not confirm the preliminary orbital period in one case.

The light-curve of the exoplanet candidate KIC012557548b





KIC012557548b (NASA)

Recently, Rappaport et al. (2012) discovered the short-period Mercury-size Kepler exoplanet candidate KIC012557548b with an asymmetric transit. It shows a significant brightening just before the eclipse – a pre-transit brightening, a sharp ingress, followed by a short sharp egress and a long smooth egress, followed by a weak post-transit brightening. Moreover, it exhibits strong variability in the transit core on timescale of one day (Rappaport et al. 2012) and variability in the egress on the timescale of about 1.3 years (Budaj 2013). It is most probably due to a comet-like tail emerging from the exoplanet. Similar conclusion was obtained independently by Brogi et al. (2012) and Budaj (2013).

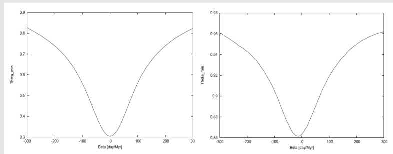
Figure above: The light-curve of the candidate KIC012557548b with the transit (Borucki et al. 2011; analyzed by Budaj 2013).

An overview of our sample

Serial Number	KIC Number	Orbital period (day)
1	3848972	0.3705290
2	8561063	0.4532875
3	6666233	0.5124040
4	6047498	0.5187486
5	9030447	0.5667281
6	6934291	0.5678562
7	4055304	0.5710391
8	10024051	0.5773752
9	8235924	0.5879933
10	11774303	0.6140747
11	10975146	0.6313298
12	10028535	0.6630983
13	10468885	0.6640818
14	11600889	0.6693163
15	8278371	0.6773911
16	5513012	0.6793614
17	10319385	0.6892040
18	9761199	0.6920069
19	9473078	0.6938521
20	5972334	0.7085982

Kepler mission exoplanet candidates are described in the catalog of Batalha et al. (2013). From this catalog we chose our sample. The sample consists from 20 exoplanet candidates with range of orbital periods from 0.370 to 0.708 days. Almost half of the objects have period over 0.6 day – from viewpoint of orbital periods we work with very similar candidates, as the candidate KIC012557548b. It has also extremely short orbital period of 0.65356(1) days.

The application PDM2 4.13



Close-in exoplanets, like KIC012557548b, are most prone to the planet-star interaction which may cause formation of the comet-like tail, or another form of circum-planetary material. Strong interaction with the host star, or presence of an additional planet, may also lead to variations in the orbital period of the planet. Our main aim was to search for long-term orbital period variations. First we improved the preliminary orbital period of the exoplanet (Batalha et al. 2013) using the method of phase dispersion minimization (Stellingwerf 1978); application PDM2 4.13 (Stellingwerf 2004). According to the improved orbital period we defined the frequency range for our search of a temporal change of the period. The frequency in this case means the reciprocal value of the orbital period. We assumed that the period changes linearly:

$$P = P_0 + \beta t$$

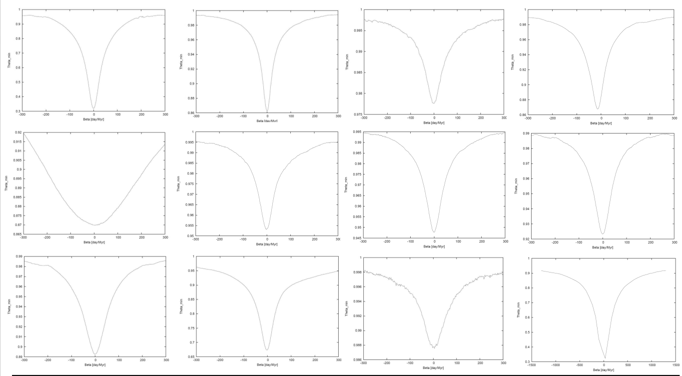
where Beta is a dimensionless value, but is often expressed in days/million years (d/Myr). The output from the analysis PDM2 4.13 in this case is a curve (see Figure above: left – there is no significant evidence for long-term period change, right – there is possible evidence for long-term period change, Beta = -11.4 d/Myr), which shows the dependence of Theta_min on Beta. Theta_min is a dimensionless statistical parameter (Stellingwerf 1978). The minimum value of Theta_min indicates the value of the period change – Beta.

The period improving

No.	Period by *Batalha et al. (2013)* (day)	Period by PDM (day)	Period by FA (day)
1*	0.3705290	0.37052870	0.37052750
2	0.4532875	0.45328705	0.45328830
3	0.5124040	0.51240883	0.51240860
4*	0.5187486	0.51872845	0.51872930
5	0.5667281	0.56670873	0.56680630
6	0.5678562	0.56785838	0.56785920
7	0.5710391	0.57103788	0.57104400
8	0.5773752	0.57737694	0.57736750
9	0.5879933	0.58800171	0.58800290
10	0.6140747	0.61408403	0.61409220
11	0.6313298	0.63133287	0.63133840
12	0.6630983	0.66308772	0.66307940
13	0.6640818	0.66407462	0.66406930
14	0.6693163	0.66931924	0.66930920
15	0.6773911	0.67737580	0.67737370
16	0.6793614	0.67933835	0.67933710
17	0.6892040	0.68920953	0.68920870
18*	0.6920069	0.69201741	0.69204530
19	0.6938521	0.69384010	0.69383390
20	0.7085982	15.35747382	15.36051120

First we improved the preliminary orbital period of the exoplanet (Batalha et al. 2013) using the method of phase dispersion minimization (PDM – Stellingwerf 1978; application PDM2 4.13 – Stellingwerf 2004) and then using the Fourier analysis (FA) with Deeming's routine (Deeming 1975). Improved orbital periods are summarized in the Table above. Exoplanet candidates signed at their No. with * may have twice as long orbital period. We did not confirm the preliminary orbital period in case of candidate No. 20. We obtained the period of 15.35747382 days using the PDM and 15.36051120 days using the FA method which is in agreement with the period P = 15.359 days found by Steffen et al. (2010). We did not confirm the second transiting object with P over 2.420 days in this system suggested by the same authors. The results from the Fourier analysis are in good agreement with the results from PDM analysis.

Search for orbital period variations



Search for orbital period variations in cases Nos. 1 – 8 and Nos. 17 – 20. From top left to bottom right we can see the distribution of values Theta_min around the vertical axis Beta = 0. We found 3 cases of exoplanet candidates (Nos. 4, 18 and 20) which showed some change of the orbital period. In one case we observed an orbital period increasing (exoplanet candidate No. 20, Beta = 33.3316 +/- 11.9749 d/Myr), other exoplanet candidates showed an orbital period shortening (exoplanet candidate No. 4, Beta = -15.05017 +/- 1.94760 d/Myr; exoplanet candidate No. 18, Beta = -3.01003 +/- 0.43245 d/Myr). In one case (No. 13) we found an orbital period increasing (Beta = 3.0 d/Myr), however, based on the Monte Carlo test, we could not consider this result as significant enough (std = +/- 8.7 d/Myr). Other exoplanet candidates did not show long-term orbital period variations.

Since KIC012557548b is close-in exoplanet candidate, that is apparently being disintegrated and loosing material, one might expect all kinds of interaction that could lead to the long term period evolution. That is why Budaj (2013) also searched for possible long-term changes of the orbital period with the PDM method (Stellingwerf 1978; application PDM2 4.13 – Stellingwerf 2004). He obtained Beta = 0.3 +/- 0.5 d/Myr which means that there is no significant evidence for the long-term orbital period change.

Conclusions

- Our main aim was to search for long-term orbital period variations. We chose 20 short period exoplanet candidates, observed by the Kepler mission, with the shortest orbital periods, ranging from 0.370 up to 0.708 days which is similar to KIC012557548b.
- We found 3 cases of exoplanet candidates which showed some change of the orbital period. In one case we observed an orbital period increasing (candidate No. 20, Beta = 33.3316 +/- 11.9749 d/Myr), other exoplanet candidates showed an orbital period shortening (candidate No. 4, Beta = -15.05017 +/- 1.94760 d/Myr; candidate No. 18, Beta = -3.01003 +/- 0.43245 d/Myr).
- The preliminary orbital periods were improved. 3 exoplanet candidates may have twice as long orbital period.
- We did not confirm the preliminary orbital period in case of candidate No. 20.

Acknowledgements

This work was supported by the VEGA grants of the Slovak Academy of Sciences Nos. 2/0094/11, 2/0143/14 by the Slovak Research and Development Agency under the contract No. APVV-0158-11, and by the realization of the Project ITMS No. 26220120029, based on the Supporting Operational Research and Development Program financed from the European Regional Development Fund.

References

Batalha, N.M., Rowe, J.F., Bryson, S.T., et al.: 2013, ApJS 204, 24
Borucki, W.J., Koch, D.G., Basri, G., et al.: 2011, ApJ 736, 19
Brogi, M., Keller, C.U., de Juan Ovelar, M., et al.: 2012, A&A 545, 5
Budaj, J.: 2013, A&A 557, 72
Deeming, T.J.: Ap&SS 36, 137
Rappaport, S., Levine, A., Chiang, E., et al.: 2012, ApJ 752, 1
Steffen, J.H., Batalha, N.M., Borucki, W.J., et al.: 2010, ApJ 725, 1226
Stellingwerf, R.F.: 1978, ApJ 224, 953
Stellingwerf, R.F.: 2004, PDM2, Stellingwerf Consulting, Huntsville 2004