

Searching for planets around sdB stars

Andrzej S. Baran¹, Szymon Bachulski¹ and Małgorzata Curyło²

¹Uniwersytet Pedagogiczny w Krakowie,
ul. Podchorążych 2, 30-084 Krakow, Poland

²Jagielonian University
ul. Orla 171, 30-244 Krakow, Poland

Abstract. We present the results of our search for planets around subdwarf B stars. We look for wobbles of the sdB stars seen as sinusoidal variations of the pulsation periods. For a p-mode dominated pulsating sdB star we did not find any signatures of a companion and we marked KIC 10139564 to be a single star. In the case of the g-mode dominated objects the method turned out to be inefficient not leading to any conclusion on the planet existence.

Keywords. subdwarfs, pulsating stars, exoplanets

1. Introduction

One of the evolutionary channels leading to the subdwarf B (sdB) stars require a companion which helps to strip of the hydrogen envelope from the sdB star. The companion may be another star or a planet. Surveys taken thus far revealed that about 50% sdB stars reside in binaries. There are also several objects harboring planets (Table 1). In this work we undertook an effort to look for other sdB stars with planets. We selected a number of pulsating sdB stars (sdBV) observed by the Kepler spacecraft. We analyzed stability of the periods of the pulsation modes which may bear a signature of the Rømer effect. This effect may uncover a presence of a companion. One star in our sample KIC 10139564 is p-mode dominated while the other stars, KIC 2438324, KIC 2991403, KIC 7668647, KIC 3527751, KIC 10670103 pulsate mostly in g-modes.

2. Methodology

Pulsation modes can be used to look for companions to the host stars. If a star is orbiting a companion the periods of the pulsation modes are modulated due to the Rømer delay. To measure such modulation we sliced the data into 300-day bins with two adjacent bins overlapping by 20%. This bin size was chosen to minimize uncertainties of the sinusoidal fit which was performed to derive the phase of a sinusoid and resolve close frequencies which could cause beating. The period of the pulsation mode was kept fixed in each fit and adopted from the solution obtained from the analysis of all data. Finally, we calculated the Observed minus Calculated (O-C) diagram from the times of flux maxima to verify stability of the pulsation periods.

3. Data

We used short cadence data collected with the Kepler spacecraft. These stars were continuously monitored for over 12 quarters (three years of data). This limits our ability to detect companions in orbits shorter than the data coverage. We downloaded PDC fluxes from the Mikulski Archive for Space Telescope database, 4σ clipped and stitched

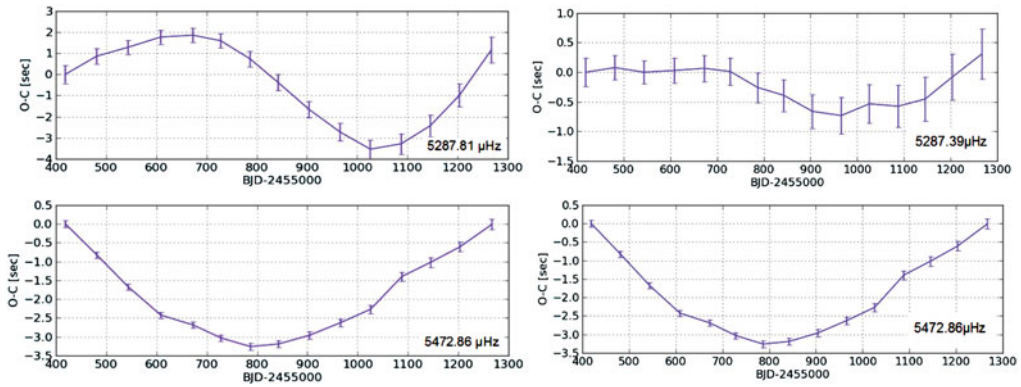


Figure 1. The O-C diagrams of four selected modes in KIC 10139564.

Table 1. The list of sdB stars with planets. See text for details.

name	# of planets	tool used	paper
V391 Peg	1	O-C, pulsations	Silvotti <i>et al.</i> 2007
HW Vir	2	O-C, eclipses	Lee <i>et al.</i> 2009
NY Vir	1+1?	O-C, eclipses	Lee <i>et al.</i> 2014
NSVS 14256825	2	O-C, eclipses	Almeida <i>et al.</i> 2013
2M 1938+4603	1	O-C, eclipses	Baran <i>et al.</i> 2015
KIC 5807616	2	reflection effect	Charpinet <i>et al.</i> 2011
KIC 10001893	3	reflection effect	Silvotti <i>et al.</i> 2014

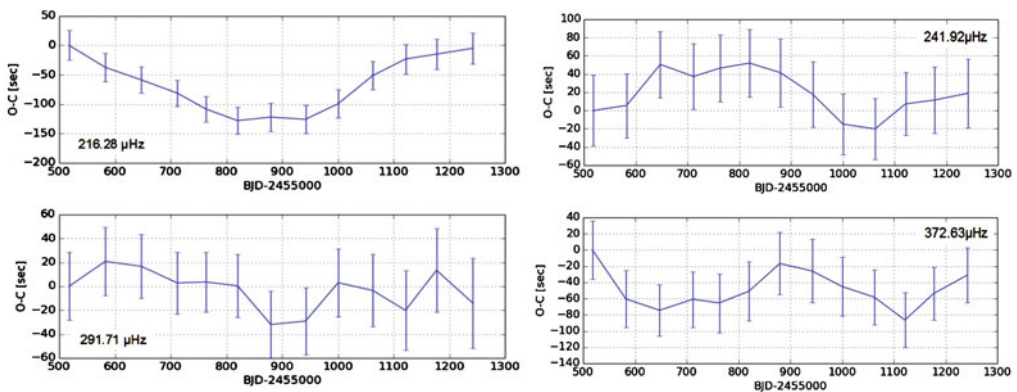


Figure 2. The O-C diagrams of four selected modes in KIC 2438324.

individual months. Next, we calculated the amplitude spectra and selected a few modes with relatively high and stable amplitudes.

4. Results

Short-period modes (p-modes in sdBV stars) are excellent tools for probing the O-C diagrams since they allow us to chunk data into narrow bins still covering many pulsation cycles. In addition, the amplitudes of p-modes are usually high enough to obtain precision

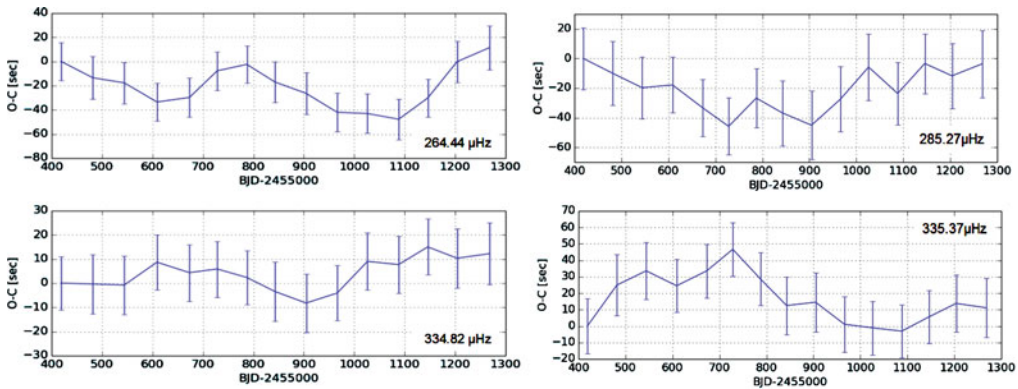


Figure 3. The O-C diagrams of four selected modes in KIC 2991403.

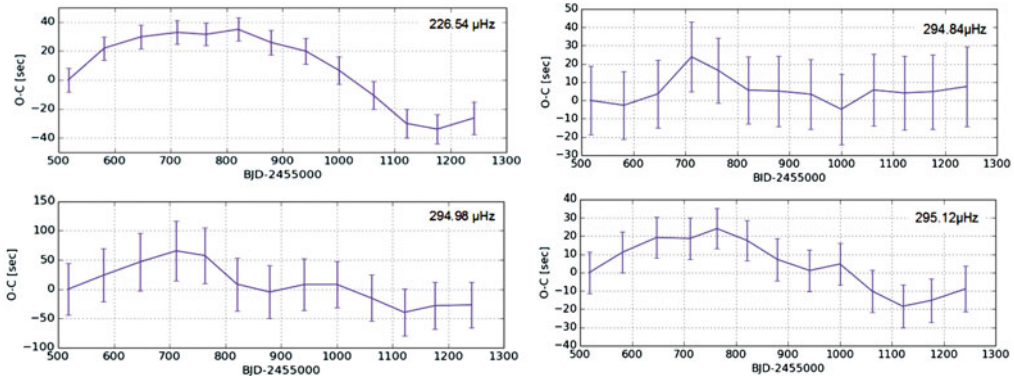


Figure 4. The O-C diagrams of four selected modes in KIC 7668647.

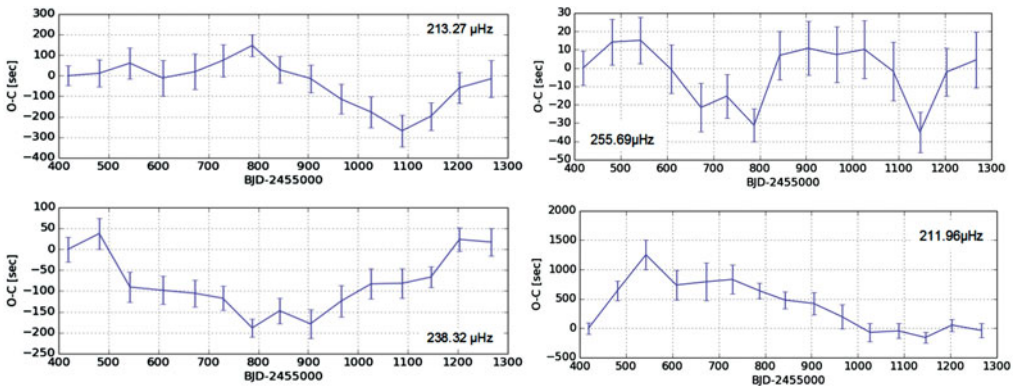


Figure 5. The O-C diagrams of four selected modes in KIC 3527751.

in the O-C diagrams below 1sec. KIC 10139564 is the only p-mode dominated *sdB* star among all KIC stars. Figure 1 shows the O-C diagrams of the four selected modes down to a second precision. The periods vary significantly but they do not show consistency between modes which is expected if the pulsation periods are influenced by a companion. Therefore, we conclude that the amplitudes vary intrinsically and we can exclude small mass bodies down to the Jovian mass in orbits shorter than three years.

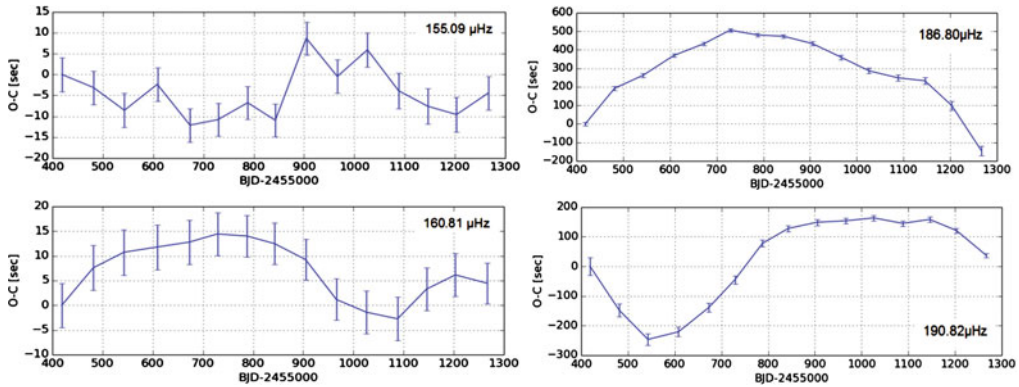


Figure 6. The O-C diagrams of four selected modes in KIC 10670103.

The other five stars presented are g-mode dominated pulsators. The periods of g-modes are hours long and we have fewer cycles in individual bins. In addition, they are of low amplitudes causing derivation of pulsation phases to be less accurate. The O-C diagrams of these stars show a few tens of seconds precision, therefore we are unable to find low-mass bodies. Figures 2-6 present the O-C diagrams for the four most suitable modes for each object.

5. Conclusions

Our work shows that even the Kepler spacecraft has limitation and cannot overcome precision issues in the O-C diagrams for g-mode dominated sdBV stars. Only p-modes are short enough to achieve seconds precisions in the O-C diagrams. We excluded a possibility that KIC 10139564 harbors a planet while we placed no constraints for the g-mode dominated sdB stars. Therefore, we did not increase the number of sdB stars with planets and we show the current list of them in Table 1. We included only planets around KIC stars (regardless of the detection method) or those confirmed from the O-C analysis using either pulsations or eclipses.

References

- Almeida, L. A., Jablonski, F., & Rodrigues, C. V. 2013, *ApJ*, 766, 11
 Baran, A. S., Zola, S., Blokesz, A., Østensen, R. H., & Silvotti, R. 2015, *A&A*, 577, 146
 Charpinet, S. *et al.* 2011, *Nature*, 480, 496
 Lee, J. W. *et al.* 2009, *AJ*, 137, 3181
 Lee, J. W., Hinse, T. C., Youn, J.-H., & Han, W. 2014, *MNRAS*, 445, 2331
 Silvotti, R. *et al.* 2007, *Nature*, 449, 189
 Silvotti, R. *et al.* 2014, *A&A*, 570, 130