6th Conference on Hot Subdwarf Stars and Related Objects
ASP Conference Series, Vol. 481
V. Van Grootel, E. M. Green, G. Fontaine, and S. Charpinet, eds.

Low-Resolution Radial-Velocity Monitoring of Pulsating sdBs in the *Kepler* Field

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Abstract.
We present preliminary results from an ongoing spectroscopic campaign to uncover the binary status of the 18 known pulsating subdwarf B stars and the one pulsating BHB star observed with the *Kepler* spacecraft. During the 2010–2012 observing seasons, we have used the KP4m Mayall, NOT, and WHT telescopes to obtain low-resolution (R∼2000–2500) Balmer-line spectroscopy of our sample stars. We applied a standard cross-correlation technique to derive radial velocities, and find clear evidence for binarity in several of the pulsators, some of which were not previously known to be binaries.

1. Introduction

During the *Kepler* survey phase as many as 15 pulsating subdwarf B (sdB) stars were discovered. More recently, three sdB stars in the old open cluster NGC 6791 and a single Blue-Horizontal-Branch star were found to be pulsating in their *Kepler* light curves. All these pulsating sdB stars are being or were monitored by *Kepler* to yield light curves with unprecedented duration, duty cycle and accuracy. Pulsation frequencies, atmospheric parameters, and the first seismic studies of these stars were described in a series of papers: Østensen et al. (2010a,b, 2011); Kawaler et al. (2010a,b); Reed

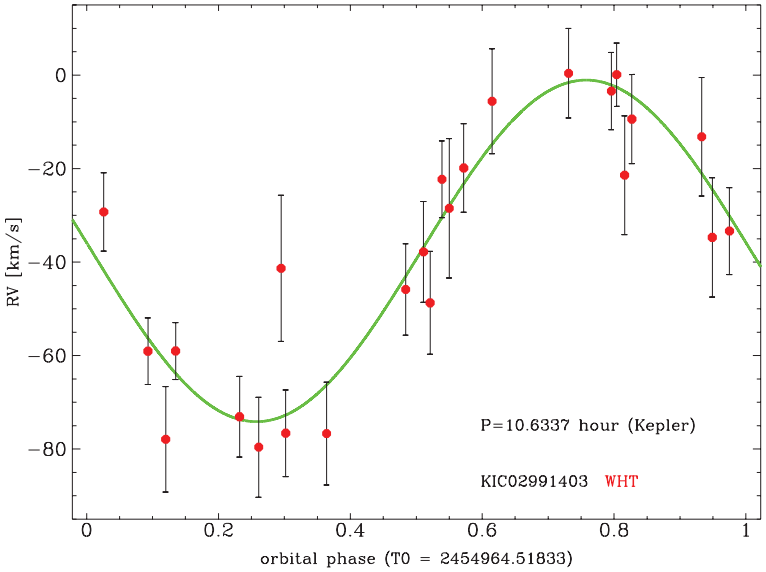

Figure 1.: Radial-velocity curve based on WHT spectra of the sdB + dM binary KIC02991403. The binary nature of this pulsating sdB star was discovered in the *Kepler* light curves.

et al. (2010, 2012); Van Grootel et al. (2010); Baran et al. (2011); Charpinet et al. (2011a,b), Pablo et al. (2011); Telting et al. (2012).

Most, if not all, of these pulsating sdBs were found to show g-mode pulsations, albeit with relatively low amplitudes. As g-modes probe deeply into the interiors of the stars, seismology of these objects has the potential to enhance our understanding of the cores of sdB stars.

Models that aim to explain the existence of sdB stars allow for a few evolutionary channels in which sdB stars may form (see Heber 2009 for an excellent review on hot subdwarf stars). There are binary-interaction channels that predict that a considerable fraction of sdB stars should be in close binaries (periods less than 10 days), while other channels produce single sdB stars for instance through mergers.

As the prior evolution of an observed sdB star may have influence on the internal structure of that star, it is valuable to know for the established sample of pulsating sdB stars in the *Kepler* field what the current binary status is. Thus, the main goal for this study is to establish for each individual star in our sample the most likely evolutionary path that has led to the loss of its envelope. Secondly, as the detailed study of sdB stars in binaries may lead to accurate determination of the dynamic mass of such stars, we aim to derive masses or constraints on masses for all the binaries in our sample. Reversely, seismic constraints on the mass of an individual sdB star will put constraints on the mass of the binary companion through determination of the mass function. These aims can be achieved from accurate determinations of the orbital radial-velocity curves of these stars.

In this paper we present a new progress report showing preliminary results for some of the brightest stars in our sample. From our spectroscopy obtained in 2010 – 2012 we can confirm the binary nature for two of the three brightest sdB + dM objects that show binary signatures in the *Kepler* light curves. Secondly, we present the dis-

covery of new binaries in the sample, where the binarity was not suspected from the *Kepler* light curves, but is clearly detected in our radial-velocity data. A first progress report was already presented at the sdOB5 conference; whereas that report included also non-pulsating *Kepler* sdB stars, we focus on the pulsating sample in this paper.

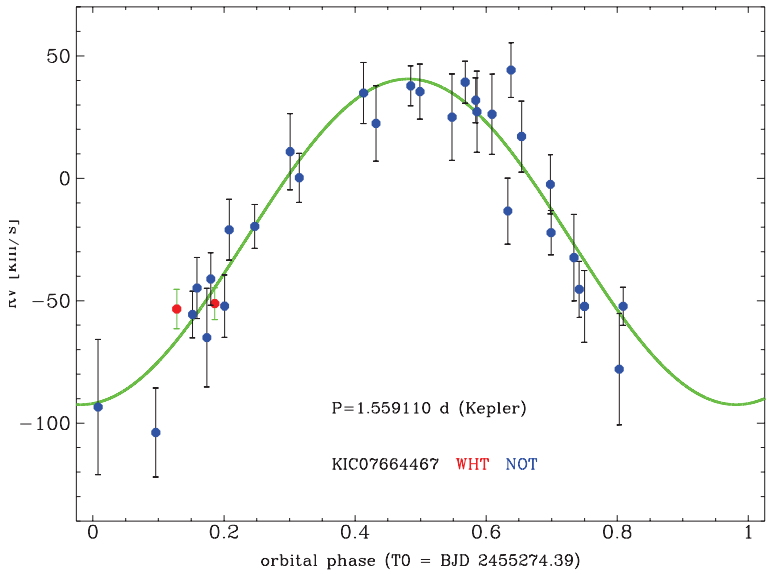

Figure 2.: Radial-velocity curve based on NOT and WHT spectra of KIC07664467. Binarity of this star was discovered from this radial-velocity curve.

2. The Sample

Our sample consists of all 19 sdB stars that show pulsations in the *Kepler* light curves, including the one pulsating BHB star. For the eclipsing sdB + dM binary 2M1938+4603 (KIC09472174) the radial-velocity curve was already presented by Østensen et al. (2010a).

The *Kepler* light curves of two stars in our sample were screened for light reflection off possible close-in planets: for KIC05807616 (Charpinet et al. 2011a) and KIC10001893 (Silvotti et al. 2014, these proceedings) evidence for such planets was found, while no significant radial-velocity variations were measured with low-resolution spectroscopy, showing no evidence for stellar-mass companions.

The three pulsating sdB stars B3, B4, B5 in the open cluster NGC 6791 are rather faint, and may be targeted in forthcoming observation runs. Therefore we so far focussed our observations on the remaining pulsating sdB stars in the *Kepler* field.

3. Observations

Low-resolution spectra (R~2000-2500) have been collected using the Kitt Peak 4m Mayall telescope (RC-Spec/F3KB with kpc-22b grating and 1.5–2.0 arcsec slit), Nordic Optical Telescope (ALFOSC with grism #16 and 0.5 arcsec slit), and William Herschel Telescope (ISIS with R600B grating and 0.8–1.0 arcsec slit), in the observing seasons

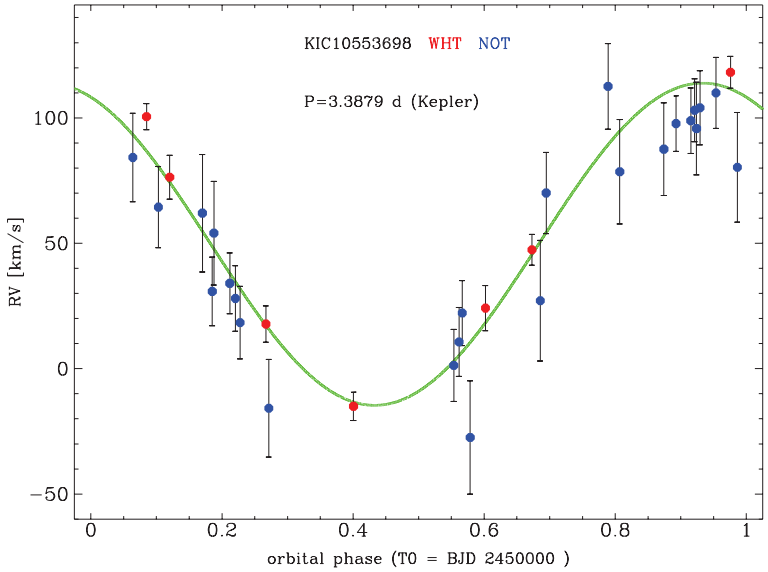

Figure 3.: Radial-velocity curve based on NOT and WHT spectra of KIC10553698. The binary nature was discovered in this radial-velocity study.

of 2010 – 2012. With exposure times below or equal to 1200 s, the spectra typically have S/N ratios of 25–60. See Table 1 for an observing log.

Spectra comprising the Hβ line together with the higher Balmer series were used for radial-velocity determinations using a standard cross-correlation technique (task FXCOR in IRAF). Even though for some stars there are clear helium lines visible in the spectra, the cross-correlation results are dominated by the Balmer lines. Since for some of our spectra the Hβ line was compromised by observational effects, our radial-velocity values were consistently derived using only the H9, H8, Hδ, and Hγ lines. Note that we did not use the Hϵ line as it is blended with the (interstellar) CaII H line.

Table 1.: Observing log for the 2010 – 2012 observing seasons.

Telescope	Instrument	Number of spectra
KP4m	RC-Spec/F3KB	~ 50
NOT	ALFOSC	~190
WHT	ISIS	~ 90

4. Results

The analysis of the data we acquired for this project is still ongoing, in particular the 2012 data from the different observatories still have to be merged. Nevertheless, while analysing the data some obvious orbital radial-velocity variability was found for 5 pulsating *Kepler* sdB stars. For KIC02991403 and KIC11179657, sdB + dM binarity had already been concluded from the *Kepler* light curves, and we find RV variabil-

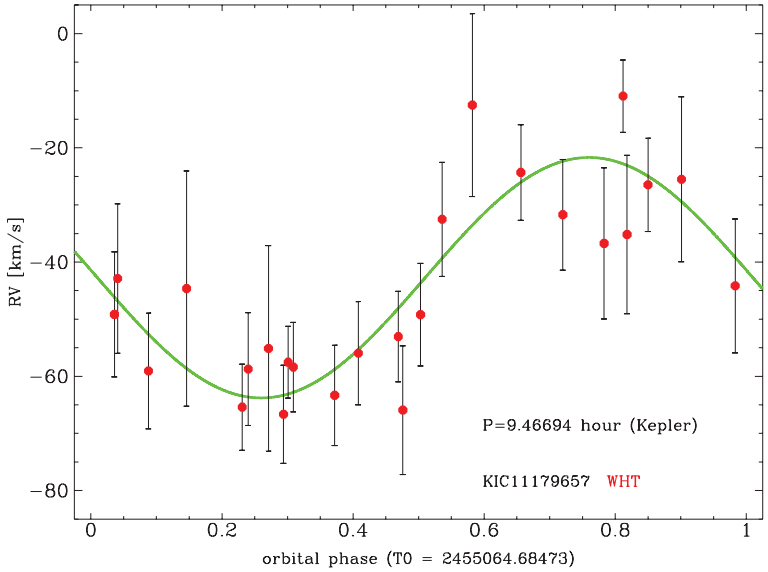

Figure 4.: Radial-velocity curve based on WHT spectra of the sdB + dM KIC11179657. Binarity of this star was discovered in the *Kepler* light curves.

ity with consistent periods. For three more stars, KIC07664467, KIC10553698 and KIC11558725, the binarity was found in this radial-velocity study. In Figs. 1–4 we present the preliminary orbital radial-velocity curves for four of these stars. A detailed orbit solution for KIC11558725 was presented by Telting et al. (2012) who concluded that the *Kepler* light curve of KIC11558725 is consistent with Doppler beaming (also called boosting) due to the orbital radial-velocity variations in this sdB + WD binary with P_{orb}=10.05 d and white-dwarf mass $M > 0.63\,M_{\odot}$.

Taking the above results together with those for the sdB + dM binaries 2M1938+4603 (KIC09472174; Østensen et al. 2010a) and B4 in NGC 6791 (KIC02438324; Pablo et al. 2011), it is now clear that at least 7 of the 19 pulsating sdB stars in the *Kepler* field are in binaries with periods between 3 hours and several days. The faintest of these 19 stars have not been surveyed for RV variations yet.

For one more star, KIC07668647, we suspect that the observed radial-velocity variations are due to binarity, but more data is needed to confirm this. Results for stars in our sample for which we did not detect significant orbital radial-velocity variations were discussed briefly by Baran et al. (2012; KIC10139564), Østensen et al. (2012; KIC01718290), and Reed et al. (in preparation; KIC10670103).

Acknowledgments. Based on observations made with the Nordic Optical Telescope, operated on the island of La Palma jointly by Denmark, Finland, Iceland, Norway, and Sweden, in the Spanish Observatorio del Roque de los Muchachos of the Instituto de Astrofísica de Canarias.

Based on observations made with the William Herschel Telescope operated on the island of La Palma by the Isaac Newton Group in the Spanish Observatorio del Roque de los Muchachos of the Instituto de Astrofísica de Canarias.

AB, MR and LF were Visiting Astronomers at Kitt Peak National Observatory, National Optical Astronomy Observatory, which is operated by the Association of Uni-

versities for Research in Astronomy (AURA) under cooperative agreement with the National Science Foundation.

MR and LF were supported by the Missouri Space Grant Consortium, funded by NASA.

RØ acknowledges funding from the European Research Council under the European Community's Seventh Framework Programme (FP7/2007–2013)/ERC grant agreement Nº 227224 (PROSPERITY), as well as from the Research Council of KU Leuven grant GOA/2008/04.

AB was supported by the Polish National Science Centre under project No. UMO-2011/03/D/ST9/01914.

RO acknowledges financial support from the Spanish MINECO by grant AYA 2011-30228-C03-01.

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