

Long-term EXOTIME photometry and follow-up spectroscopy of the sdB pulsator HS 0702+6043

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Abstract

Pulsating subdwarf B (sdB) stars oscillate in short-period p modes or long-period g modes. HS 0702+6043 (DW Lyn) is one of a few objects to show characteristics of both types and is hence classified as a hybrid pulsator. It is one of our targets in the EXOTIME program to search for planetary companions around extreme horizontal branch objects. In addition to the standard exercise in asteroseismology to probe the instantaneous inner structure of a star, measured changes in the pulsation frequencies as derived from an O–C diagram can be compared to theoretical evolutionary time scales. Based on the photometric data available so far, we are able to derive a high-resolution frequency spectrum and to report our efforts to construct a multi-season O–C diagram. Additionally, we have gathered time-resolved spectroscopic data in order to constrain stellar parameters and to derive mode parameters as well as radial and rotational velocities.

Individual Objects: HS 0702+6043, HS 2201+2610, HW Vir

Timing method and the EXOTIME program

The O–C (Observed minus Calculated) analysis is a tool to measure the phase variations of a periodic function. The observed times of the pulsation maxima of single runs are compared to the calculated mean ephemeris of the whole data set. Since a low-mass companion, due to its gravitational influence, would cause cyclically advanced and delayed timings of an oscillating sdB's pulsation maxima (due to motion around the common barycentre), this method can be used to search for exoplanets. A sinusoidal component in an O–C diagram is therefore a signature of a companion. In addition, this method can be used to derive evolutionary time scales by measuring linear changes in the pulsation periods. The signature would in this case be a parabolic shape in the O–C diagram. Using this timing method, Silvotti et al. (2007) detected a giant planet companion to the pulsating subdwarf B star HS 2201+2610 (V391 Peg) and recently Lee et al. (2008) reported two planets around the eclipsing sdB+M binary system HW Vir, also revealed by an O–C diagram analysis by measuring the timings of the eclipse minima.

The EXOplanet search with the Timing MEthod (EXOTIME) program is an internationally coordinated effort to examine pulsating sdB stars in terms of planetary companions and evolutionary aspects. Closely related to the puzzling evolution of sdB stars is the late-stage or post-RG evolution of planetary systems and the question if planets could be responsible for the extreme mass loss of the sdB progenitors (e.g. Soker 1998). EXOTIME performs ground based time series photometry from various sites with telescopes in the 0.5 m to 3.6 m range.

Table 1: Our current photometric data archive for HS 0702+6043. Sites: Calar Alto 2.2 m/1.2 m (CA2/1), NOT 2.56 m (N), Göttingen 0.5 m (G), Tübingen 0.8 m (T), Steward Bok 2.2 m (SB), Loiano 1.5 m (L), Mt. Bigelow 1.55 m (MB), Konkoly 1 m (K).

Date	Site	Length [h]	Date	Site	Length [h]
December 1999	CA1	8.4	Nov'07-Mar 2008	MB	424.0
October 2000	N	0.7	March 2008	G	0.6
February 2004	T	7.3	March 2008	L	8.0
February 2004	SB	12.0	March 2008	K	11.5
January 2005	CA2	56.0	May 2008	G	4.1
December 2007	T	31.8	September 2008	G	3.3
December 2007	G	12.0	October 2008	K	2.6
February 2008	T	20.1	October 2008	CA2	4.2
February 2008	G	32.2	November 2008	CA2	8.7

Long-term photometry

HS 0702+6043 was first identified as a variable by Dreizler et al. (2002). It is placed at the common boundary of the p - and g -mode instability regions in a $\log g$ - T_{eff} diagram. The two strongest p -mode pulsations at 363.11 s and 383.73 s (amplitudes of 30 and 6 mmag, respectively) will be used to construct multi-seasonal O–C diagrams, for which a time-base of several years is needed. For deriving a single O–C point, at least three to four consecutive nights of observations are needed to provide a sufficient frequency resolution. We aim for a minimum of six O–C points per year. Our data archive for HS 0702+6043 dates back to 1999, unfortunately with large gaps in between. Table 1 lists our current photometric data archive, not yet sufficient to present a meaningful O–C diagram due to the large gap between the observations in 1999 and 2004.

Follow-up spectroscopy

The 772 time resolved high-resolution Echelle spectra (20 s each) of HS 0702+6043 taken at the Hobby Eberly Telescope will provide rotational and in particular pulsational radial velocities. The pulsational amplitudes are expected to be larger for HS 0702+6043 than for HS 2201+2610 since the photometric amplitudes are larger. An analysis of the time-resolved spectroscopy of HS 2201+2610 can be found in Schuh et al. (2009).

Acknowledgments. The authors thank all observers who contributed observations to the HS 0702+6043 data archive: B. Beeck, Z. Bognar, E. M. Green and collaborators, M. Hundertmark, T. Nagel, R. Østensen, M. Paparo, P. Papics, T. Stahn. Partly based on observations collected in service mode by L. Montoya, M. Alises and U. Thiele for our program H08-2.2-009 at the Centro Astronómico Hispano Alemán (CAHA) at Calar Alto, operated jointly by the Max-Planck Institut für Astronomie and the Instituto de Astrofísica de Andalucía (CSIC). The authors thank the Astronomische Gesellschaft as well as the conference sponsors and in particular HELAS (European Helio- and Asteroseismology Network, an European initiative funded by the European Commission since April 1st, 2006, as a "Co-ordination Action" under its Sixth Framework Programme FP6) for financially supporting the poster presentation at JENAM 2008 Minisymposium N° 4 through travel grants to RL and SS.

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