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DETECTION OF A RAPIDLY PULSATING COMPONENT IN THE ALGOL-TYPE ECLIPSING BINARY YY Boo

HAMBSCH, FRANZ-JOSEF[1,2]; LAMPENS, PATRICIA[3]; VAN CAUTEREN, PAUL[1,4]; KLEIDIS, STELIOS[5,6]; ROBERTSON, C.W.[7]; KRAJCI, TOM[8]; WILS, PATRICK[1]

[1] Vereniging Voor Sterrenkunde, Belgium

[2] Bundesdeutsche Arbeitsgemeinschaft für Veränderliche Sterne e.V. Germany

[3] Koninklijke Sterrenwacht, Ringlaan 3, B-1180 Brussels, Belgium

[4] Beersel Hills Observatory, Beersel, Belgium

[5] Zagori Observatory, Epirus, Greece

[6] Helliniki Astronomiki Enosi, Athens, Greece

[7] SETEC Observatory, Goddard, Kansas, USA

[8] Astrokolkhoz, New Mexico, USA

YY Boo is an Algol-type eclipsing binary which was discovered by Hoffmeister (1949). Götz and Wenzel (1969) determined the spectral type to be A4. Halbedel (1984) lists four radial velocity measurements (ranging from −59.5 km/s to +29.9 km/s) and a spectral type A7 (III), while also possibly detecting an F or G type companion. The spectral type F9IV given by Simbad refers to the earliest possible spectral type of the companion (Halbedel, 1984). Because of the spectral type of the primary component, it is a potential oscillating Algol-type eclipsing binary (oEA star, see Mkrtichian et al., 2004). However it is neither listed in the recent catalogue of pulsating components in binary systems (Zhou, 2010), nor as a candidate for pulsation in the catalogue of close eclipsing binary systems with at least one component located in the lower Cepheid instability strip (Soydugan et al., 2006), probably due to its Simbad classification as of spectral type F9IV.

YY Boo was observed unfiltered out-of-eclipse on February 5/6, 2010. Rapid variations were detected with an amplitude of ≈ 0.1 mag and a period of around 88 minutes. Following this detection, a follow-up campaign was initiated using B and V filters. The contributing observatories and the instruments used are listed in Table 1, as well as the number of nights and hours the target was observed. The rapid variability was confirmed during the following nights. Standard aperture photometry was applied to all the frames to obtain differential instrumental magnitudes with respect to the comparison stars GSC 3059-614 and GSC 3059-615. A light curve acquired in the B passband, after removal of a synthetic binary light curve (see below), is shown for illustration in Fig. 1. It is a typical light curve of a δ Scuti star with a fairly high amplitude.

After three months of intensive photometric observations, an almost complete eclipsing binary light curve has been obtained in both filters (see Fig. 2). Even during the descending and ascending branches of the primary eclipse, the pulsations could be clearly

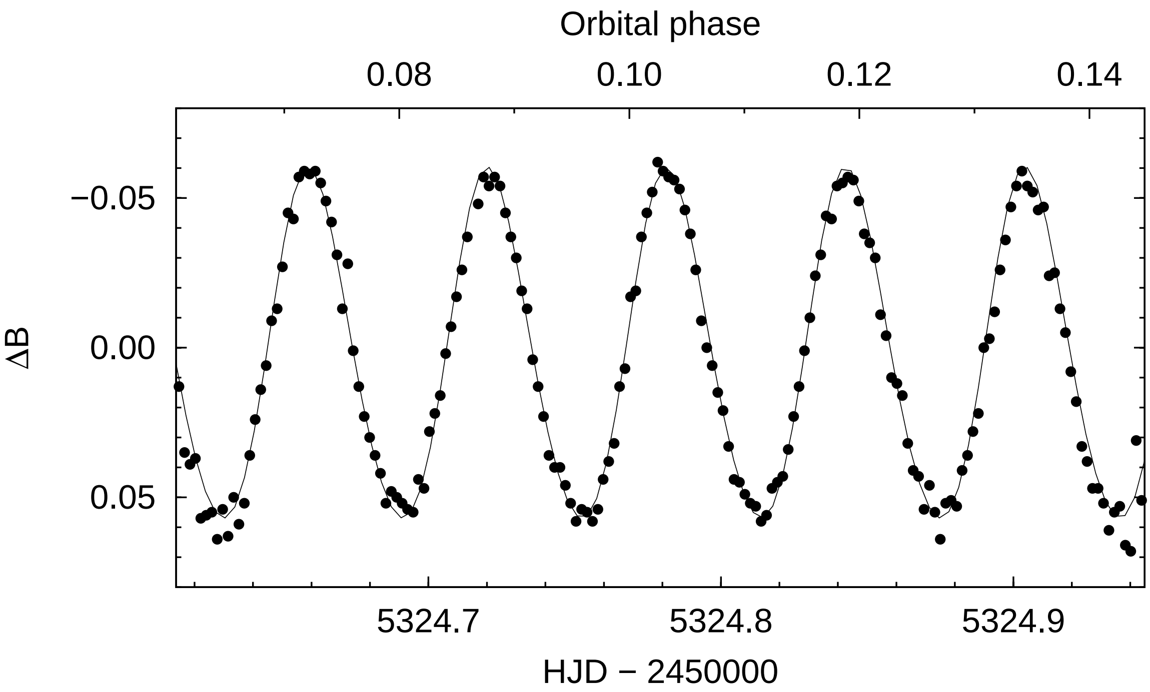

Figure 1. Light curve of YY Boo in B with a synthetic binary light curve subtracted. The full line shows the light curve based on the elements listed in Table 2.

detected (see Fig. 3). Without detailed radial velocity data it is difficult to determine an accurate value of the mass ratio, and it is therefore not the purpose of this paper to present a reliable binary solution. However the photometry is still useful to calculate a rough binary model, which can then be used to disentangle the pulsations and the variations due to the binary motion. To calculate these binary model parameters the following iterative method was used. In the first step, all data were used uncorrected in Phoebe (Prša & Zwitter, 2005), to find initial parameters. The second step was then to subtract the synthetic light curve thus obtained from the data and use the points outside of the primary and secondary eclipses to calculate the pulsation parameters with Period04 (Lenz & Breger, 2005). In step three, those pulsations were then subtracted from the original data. For observations during primary eclipse, a reduced amplitude was taken into account, as the primary is partly hidden by the companion. This reduced amplitude can be computed approximately by using the previously obtained synthetic light curve and the average radius of the primary (illustrated in Fig. 4; note that YY Boo is rather faint during primary minimum for the instruments used). This is strictly correct only if the light variations are caused solely by temperature changes and if the disc has a uniform temperature (disregarding limb darkening effects). In reality of course the star expands and contracts, and therefore the correction is only an approximation. In principle this would allow to measure the relative change in radius of the primary during the pulsation cycle and the phase of maximum radius (if the change in temperature is known). This is however beyond the scope of this paper, as more precise photometry is needed and detailed spectroscopic observations are required as well. The slightly enhanced amplitude during the secondary eclipse (because the main star dominates the total light even more, as part of the light of the companion is blocked) has been neglected as the change in brightness is at most 3 mmag in both B and V, less than the precision of the photome-

Table 1: List of the instruments used for the observations.

Observer Initials	Telescope type	Aperture (cm)	Observatory	CCD (SBIG)	Filter	Nights	Hours
HMB	Catadioptric	28	Mol, Belgium	ST-10XME	B	17	86.8
PL & PVC	Newtonian	40	R.O.B.-Humain	ST-10XME	V	6	35.3
PL & PVC	Refractor	18	R.O.B.-Humain	ST-10XME	V	2	7.4
PL & PVC	Newtonian	25	Beersel Hills	ST-10XME	V	5	14.0
SK	Catadioptric	30	Zagori	ST-7XMEI	B	8	38.0
SK	Catadioptric	30	Zagori	ST-7XMEI	V	11	57.9
CWR	Catadioptric	40	SETEC	ST-8XME	B	4	28.8
CWR	Catadioptric	30	SETEC	ST-8XMEI	V	3	20.6
TK	Catadioptric	30	Astrokolkhoz	ST-9XME	B	5	13.9
TK	Catadioptric	30	Astrokolkhoz	ST-9XME	V	5	14.0

try. With the light curve corrected for the pulsations, a new eclipsing binary model was then calculated. Step two and further above were then repeated until convergence was obtained.

The resulting pulsation parameters are presented in Table 2. An ephemeris for the pulsation maxima was derived from our data, supplemented with SuperWASP data from 2004 and 2007 (Norton et al., 2007), as follows:

$$HJD\ Max\ Pulsation = 2455244.5033(1) + 0\overset{\mathrm{d}}{.}06128095(2) \times E \qquad (1)$$

Because of the fairly large amplitude, the pulsation mode is most likely a radial one. For the calculation of the binary parameters, a semi-detached configuration was assumed, with the secondary filling its Roche lobe. The following ephemeris (derived from our data) was used:

$$HJD\ Min\ I = 2455265.3796(2) + 3\overset{\mathrm{d}}{.}933049(12) \times E \qquad (2)$$

The temperature T_1 of the main component was taken to be $8000K$ in accordance with its mid A spectral type. Calculations done using the Wilson-Devinney method as implemented in PHOEBE (Prša & Zwitter, 2005), resulted in the following model parameters (with formal uncertainties): $q = M_2/M_1 = 0.29 \pm 0.01$, $i = 81.7 \pm 0.1°$, $T_2 = 4650 \pm 10K$, $\Omega_1 = 7.03 \pm 0.01$. The uncertainty on T_1 is on the order of a few $100K$ and this will make the real uncertainties larger than the given values. The eclipses are partial, with 92% of the pulsator's disc eclipsed by the companion at minimum light. The limited radial velocity data from Halbedel (1984), only four points, were not used for the modeling. After subtracting the synthetic binary model and the fit to the pulsations the residual standard deviations (RMS) in both B and V are 7 millimag.

YY Boo is a new member of the group of mass-accreting pulsating components in Algol-type eclipsing binary systems (Mkrtichian et al., 2004). As such, it has the second largest pulsation amplitude among the known oEA stars after BO Her (Sumter & Beaky, 2007). It is therefore an ideal target to study the physical pulsation characteristics, taking advantage of the changing geometric aspects. A further campaign for spectroscopic follow-up has been started at the National Astrophysical Observatory (NAO) in Rozhen, in cooperation with Dr. Z. Kraicheva et al. of the Institute of Astronomy (Sofia, Bulgaria).

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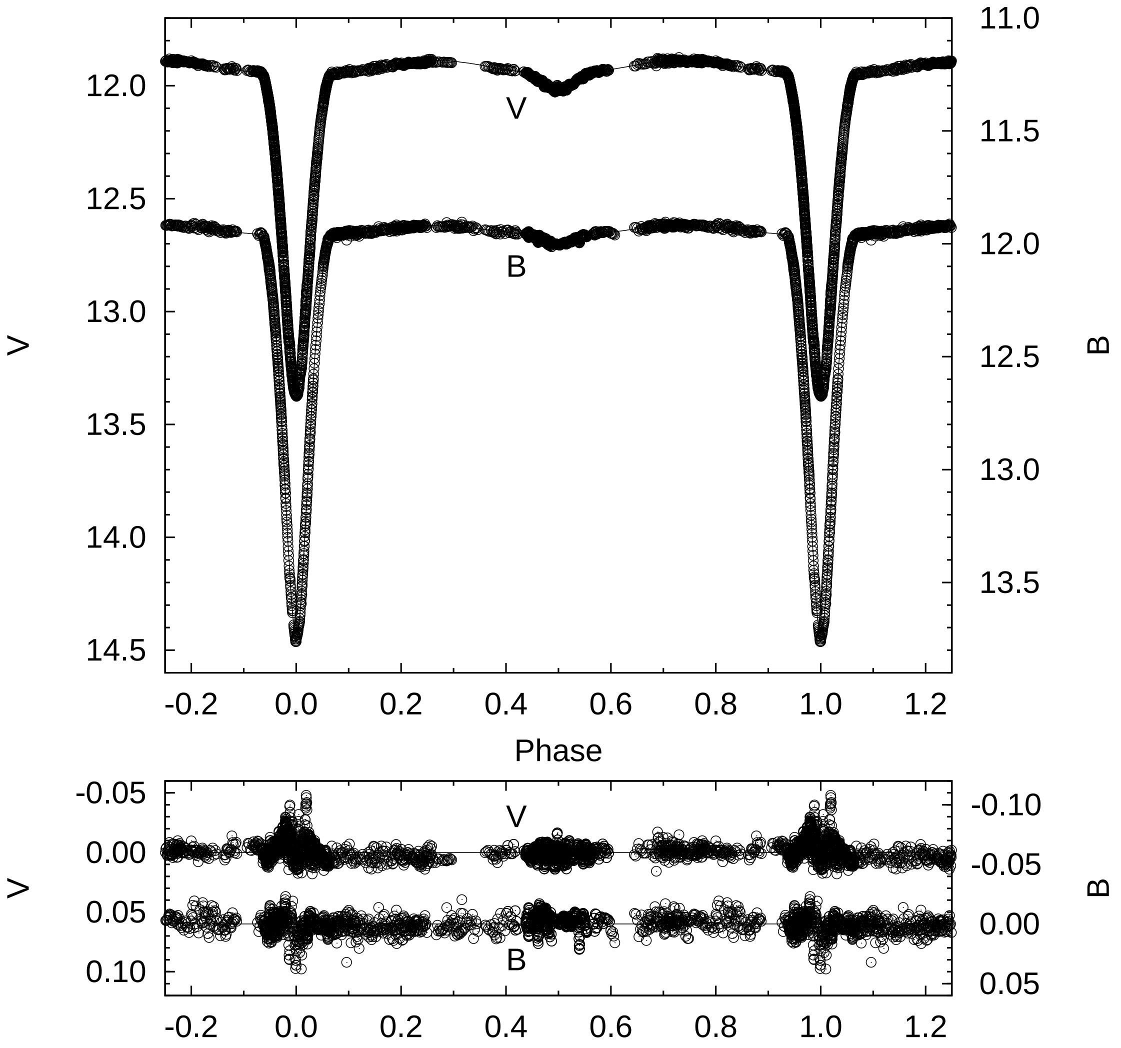

Figure 2. Phased light curve (upper panel) of YY Boo in B (lower curve) and V (upper curve) with the pulsations as described by Table 2 subtracted. The full line shows the model binary light curve. The bottom panel shows the residuals with both the pulsations and the binary model subtracted.

Table 2: Pulsation frequencies and associated parameters (details following the convention of PERIOD04 (Lenz & Breger, 2005). Uncertainties between brackets (in units of the last displayed decimal) are derived from Monte-Carlo simulations in PERIOD04.

Identification	Frequency (c/d)	Filter	Semi-amplitude (mmag)	Phase ($HJD_0 = 0$)
f	16.31828(2)	B	58.4(2)	0.7830(6)
		V	39.6(2)	0.7829(10)
$2f$	32.63656	B	4.2(3)	0.923(8)
		V	3.1(2)	0.924(13)

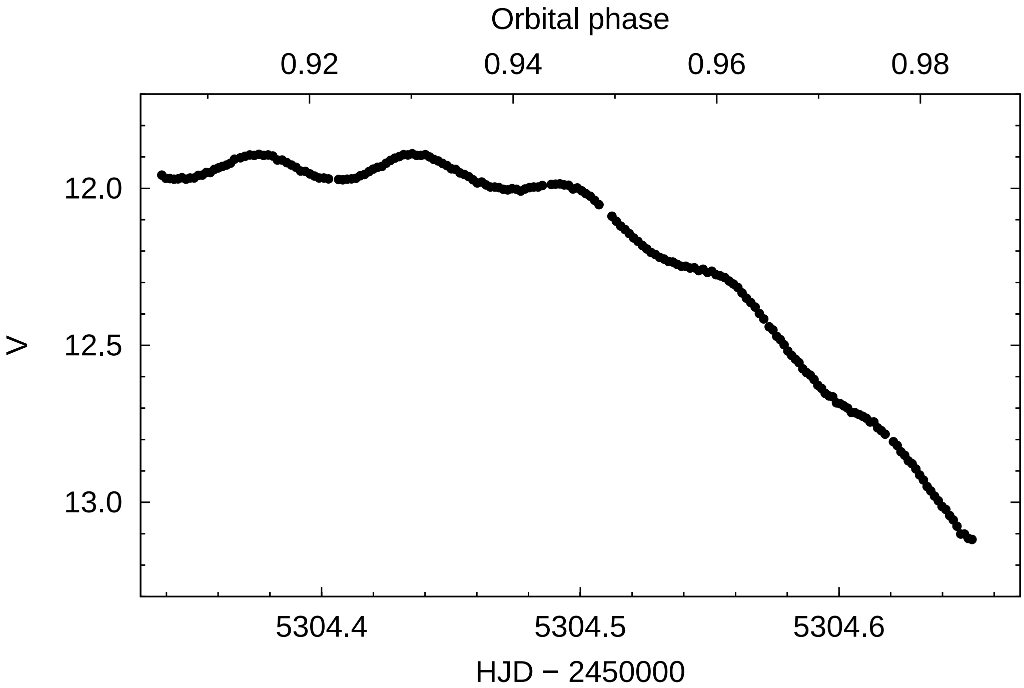

Figure 3. Light curve of YY Boo in V during the descending branch of an eclipse. The pulsations are still clearly seen during the fading.

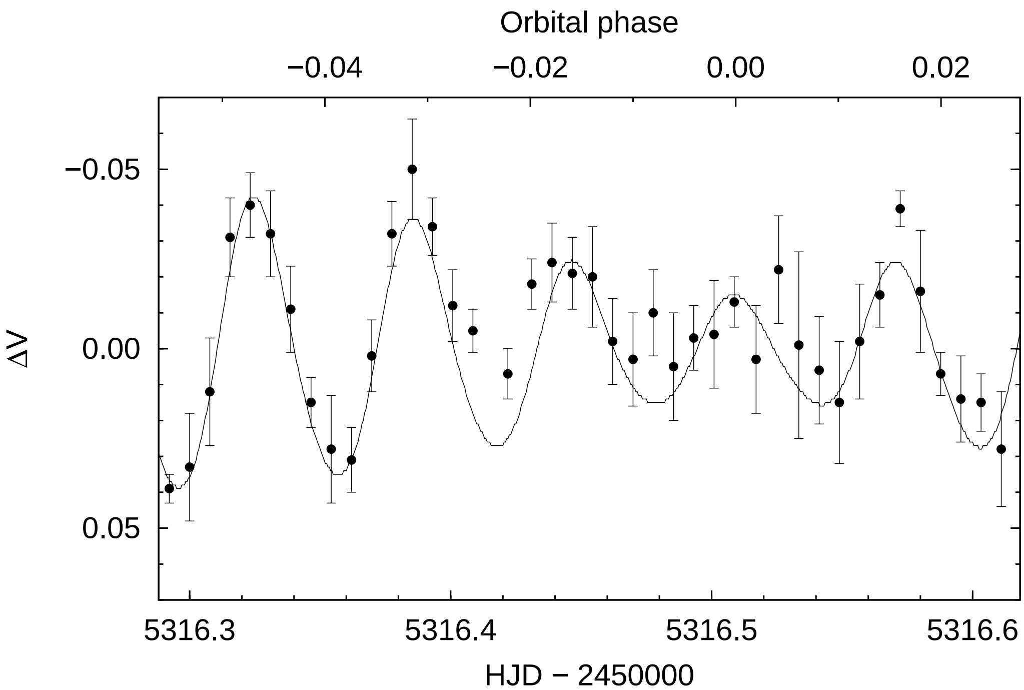

Figure 4. Light curve of YY Boo in V during primary eclipse with a synthetic binary light curve subtracted, based on 5-point averages (the uncertainties shown are the standard deviation on these averages). The full line shows the theoretical pulsation light curve taking into account that the primary is partly hidden by the companion (see text for details). Note the larger error bars at the phase of primary minimum.

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This work has further made use of the SIMBAD and VizieR databases operated at CDS, Strasbourg, France.

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