

Discovery of four β Cephei stars in eclipsing binary systems

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Introduction

In the course of a search for β Cephei stars among bright stars observed within the ASAS-3 survey, we have discovered **102 new β Cephei stars** (Pigulski & Pojmański, in preparation). Of them, **four (Table 1) are primary components of the eclipsing binary systems**. This is a great advantage in view of the planned investigation of these stars by means of asteroseismology. The technique allows probing of stellar interiors, but requires good knowledge of masses and radii needed in modeling. These parameters can be easily derived for eclipsing binaries from spectroscopic and multicolour photometric observations which we are going to carry out as a follow-up.

The discovery brings the total number of the known β Cephei stars in eclipsing systems to **seven**. The three already known stars are: **16 (EN) Lac** (Jerzykiewicz et al. 1978, Pigulski & Jerzykiewicz 1988), **V381 Car** in NGC 3293 (Engelbrecht & Balona 1986, Freyhammer et al. 2005) and **A Sco** (Shobbrook & Lomb 1972, Uytterhoeven et al. 2004, Bruntt & Buzasi 2006).

The data

The data consist of the ASAS-3 V-filter photometry (Pojmański 1997, 2001; Pojmański et al. 2005). The data span the interval of over five years starting from 2000 till February 2006.

Table 1: Four new β Cephei stars in eclipsing binary systems

HD	ASAS name	Other name(s)	V [mag]	Orbital period [d]	Pulsation period(s) [d]	Notes
101794	114225-6228.6	HIP 57106 V916 Cen ALS 2460	8.68	1.463269	0.22465, 0.54362	In the open cluster Stock 14, Be star
101838	114249-6233.9	ALS 2463	8.42	5.41178 or 10.82356	0.31973	In the open cluster Stock 14
167003	181442-3308.5	HIP 89404 V4386 Sgr ALS 4801	8.45	10.797956	0.14765, 0.13252, 0.14253, 0.18593	
168050	181839-1906.2		9.81	5.02343	0.1802 (variable), 0.19044	

HD 101794 = V916 Cen

- Indicated as **Be star** by Garrison et al. (1977) who reported the MK spectral type of HD 101794 as **B1 Vne**. The observed β index of 2.54 - 2.56 and spectroscopic observations (McSwain & Gies 2005) confirm emission in hydrogen lines.
- Discovered as variable with erratic changes by Hipparcos (Fig. 1). Named **V916 Cen** with V Cas type of variability (meaning long-term changes observed in Be stars).
- Eclipsing nature was revealed by Pojmański (2000) from the I-filter ASAS-2 data.
- It is a member of the loose open cluster Stock 14 (Fig. 4)

All data available for HD 101794 are shown in Fig. 1. The eclipsing light curve is shown in Fig. 2. One of the short periods can be attributed to the β Cephei-type variability, the other, either to the g-mode pulsation (in that case the star would be an **hybrid β Cephei/SPB star**) or **A Eri-type** variations observed in Be stars.

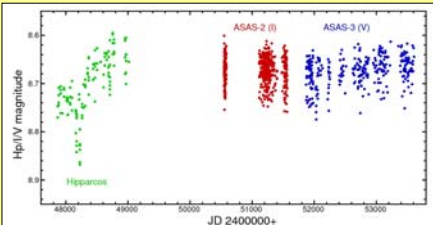


Fig. 1: Distribution of the available photometric data for HD 101794. Note the erratic long-term changes seen mainly in the Hipparcos data.

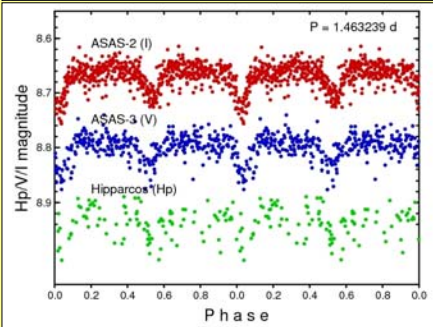


Fig. 2: The eclipsing light curve of V916 Cen folded with the period of 1.463239 d for the ASAS-2 (red), ASAS-3 (blue) and Hipparcos (green) data. The data were freed from the contribution of pulsations and erratic long-term changes prior folding.

HD 168050

- The only MK spectral type available, **B3/5 Ib** (Houk & Smith-Moore 1988) is slightly too late for a β Cephei star, but this might be due to the contribution of a relatively bright secondary to the composite spectrum.

We revealed two pulsating modes (Table 1) superimposed on the eclipsing light curve (Fig. 5). Surprisingly, the dominating mode exhibits **large period changes** which is rather rare in β Cephei stars. Since the other mode does not change period, the observed period change is not due to the light-time effect in a wider system, but have to be intrinsic. The eclipsing light curve is shown in Fig. 5.

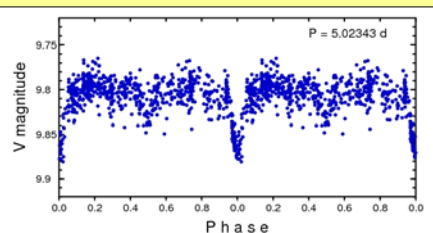


Fig. 5: The eclipsing light curve for HD 168050 freed from the contribution of two pulsating modes and folded with the orbital period of 5.02343 d.

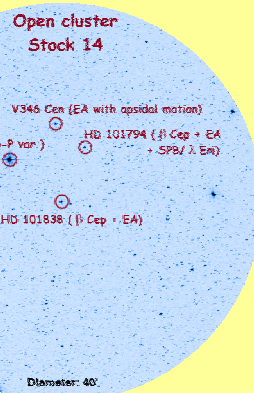


Fig. 4: The field of the loose young open cluster Stock 14. The two new β Cephei stars, HD 101794 and 101838, and two other variables, V810 Cen and V346 Cen, are labeled. All four variables are members of the cluster. North is up, east to the left.

HD 101838

- MK spectral types available: **B0 III** (FitZgerald & Miller 1983), **B1 III** (Feast et al. 1961, Walker 1963).
- The pulsation period is quite long; it amounts to 0.31973 d.
- Like HD 101794, it is a member of the open cluster Stock 14 (Fig. 4).

The two sources of variability (pulsation and eclipses) were separated and are plotted in Fig. 3.

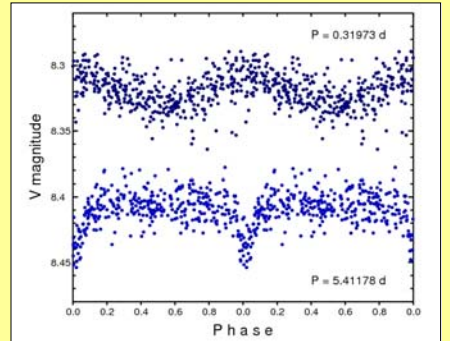


Fig. 3: The light curves of HD 101838. The upper light curve shows the contribution from pulsation, the lower, the eclipses. The two types of variability were separated before folding. The corresponding periods are shown in the figure. The pulsations and the eclipsing light curve are shown in scale, but the former was shifted in magnitude for clarity. There is a possibility that the true orbital period is twice as long, i.e., amounts to about 10.82 days.

HD 167003 = V4386 Sgr

- Detected as variable by Hipparcos with a note that it is possibly an eclipsing binary (see Fig. 6). Named as **V4386 Sgr**.
- Several spectral types are available, e.g. **B0.5 III** (Hill et al. 1974) or **B1 II** (Garrison et al. 1977).

Four periodic terms attributed to β Cephei-type pulsations were found (Table 1). The eclipsing light curve shows narrow primary minimum (Fig. 7) and a small reflection effect.

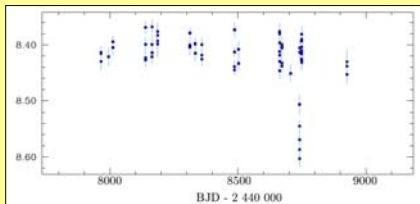


Fig. 6: Hipparcos light curve of V4386 Sgr. Five deviating points were made within an interval of 0.5 d, i.e., in the same primary eclipse.

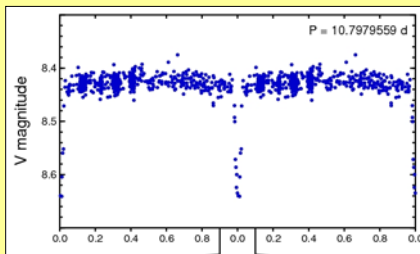


Fig. 7: The ASAS-3 eclipsing light curve of V4386 Sgr folded with the orbital period of 10.7979559 d. The upper figure shows the whole light curve, the lower, the magnification of the phases around the primary minimum. The yellow points denote Hipparcos data which fit the ASAS-3 light curve quite well. Only the ASAS-3 data were freed from the contribution of pulsations prior folding.

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