COMMISSIONS 27 AND 42 OF THE IAU
INFORMATION BULLETIN ON VARIABLE STARS

Number 5501

Konkoly Observatory
Budapest
3 February 2004

HU ISSN 0374 – 0676

THE BEAT CEPHEIDS NSV 6728, GSC 8607-0608, EY Car AND BE Pup

WILS, PATRICK[1]; OTERO, SEBASTIÁN A.[2]

[1] Vereniging Voor Sterrenkunde, Belgium; e-mail: patrick.wils@cronos.be

[2] Grupo Wezen 1 88, Centro de Estudios Astronómicos (CEA), Liga Iberoamericana de Astronomía (LIADA); e-mail: varsao@fullzero.com.ar

The online edition of the General Catalogue of Variable Stars (GCVS, Kholopov et.al., 2003) lists sixteen Galactic double mode or beat Cepheids (GCVS type CEP(B) or DCEP(B)). In addition to these sixteen stars, DZ CMa (Berdnikov and Turner, 1998) and HD 304373 (Beltrame and Poretti, 2002), have been found only recently to be beat Cepheids. Two other stars, V371 Per (Schmidt et.al., 1995) and BE Pup (Hacke and Richert, 1989), are suspected of being double mode pulsators (Welch, 1998). Only CO Aur and HD 304373 are pulsating in the first and second radial overtones, all other stars pulsate in the fundamental (F) and first overtone (1O) modes.

From the publicly available ASAS3 survey data (Pojmanski, 2002), we found that also NSV 6728, GSC 8607-0608 and EY Car are double mode Cepheids, pulsating in F and 1O modes. In addition, we could confirm the double mode nature of BE Pup, so that the number of known Galactic beat Cepheids has now risen to 22. The source data for BE Pup, GSC 8607-0608, EY Car and NSV 6728 can be found at the ASAS3 home page. The electronic version of the IBVS contains direct links. Fundamental data about the four stars are listed in Table 1. It includes values for the invariant Fourier parameters and for the generalized phase difference $G_{1,1}$ of the cross coupling term $f_0 + f_1$ as defined by Poretti and Pardo (1997). Formal errors are given between parentheses in units of the last significant decimal.

Table 1: Characteristics of the four new double mode Cepheids

	NSV 6728	GSC 8607-0608	EY Car	BE Pup
V Range	9.75-10.35	10.70-11.40	9.90-10.45	13.0-13.9
HJD Maximum	2452082.85	2452655.94	2451891.71	2452981.78
Period F (d)	4.317(7)	4.089(3)	2.876(3)	2.870(3)
Period 1O (d)	3.037(3)	2.869(4)	2.036(2)	2.048(2)
Period ratio (1O/F)	0.7035(14)	0.7017(11)	0.7077(8)	0.7136(8)
R_{21}(F)	0.21(1)	0.18(2)	0.30(2)	0.39(12)
R_{21}(1O)	0.11(2)	0.07(2)	0.16(7)	0.46(25)
Φ_{21}(F)	4.40(3)	4.20(7)	4.01(5)	3.96(34)
Φ_{21}(1O)	4.97(7)	5.12(14)	4.60(44)	3.44(41)
Amplitude ratio (1O/F)	0.61(1)	0.72(2)	0.22(2)	0.49(13)
$G_{1,1}$	4.31(5)	4.35(6)	3.90(6)	3.38(35)

NSV 6728 (= BV 447 = GSC 8691-1294 = CPD−57 6710) was suspected of variability by Strohmeier et al. (1964). Phase plots for the fundamental period and for the first overtone, after prewhitening for the fundamental period and three harmonics, are presented in Figs. 1 and 2.

GSC 8607-0608 (= CPD−56 2913 = TDS 7069) is noted as either a fundamental or first overtone Cepheid by Pojmanski (2004). It is a double star (TDSC 28377, Fabricius et.al., 2002) with a separation of $0\farcs9$ and a primary star with $V_T = 11.44$ and $B_T - V_T = 1.26$, and a secondary with $V_T = 11.86$ and $B_T - V_T = 1.17$. Because ASAS3 cannot resolve this pair, it is impossible to determine which of the components is variable. Because of the period ratio of 0.7017 ± 0.0011, it is however highly unlikely that both components are normal single-mode Cepheids, rather than one being a beat Cepheid. The proper motions of the components given by TDSC are identical, so that it could be a physical pair. Y Car, a spectroscopic binary (Böhm-Vitense et al., 1997), has been the only known beat Cepheid in a multiple system (Szabados, 2003). The phase plots from ASAS3 data for GSC 8607-0608 are given in Figs. 3 and 4.

EY Car (= GSC 8957-1924 = HIP 52380) had been suspected of being a beat Cepheid before, based on (sparse) data from Mitchell et al. (1964). It was therefore observed by Pike and Andrews (1979), and later also by Mantegazza and Poretti (1992), but they failed to detect the first overtone pulsation. Since these authors observed the star for only three and two weeks respectively, and the first overtone period of EY Car turns out to be close to two days, the phase coverage was poor. Combined with the small amplitude of the first overtone variation, this explains why these authors did not find it. The star is also near the limiting magnitude of Hipparcos (ESA, 1997), so that it is not surprising this instrument did not reveal a secondary frequency. The phase plots from ASAS3 data are given in Figs. 5 and 6.

BE Pup is not catalogued in the GSC version 1, its GSC 2.2 position is $\alpha_{2000} = 07^{\rm h}33^{\rm m}35\fs486$, $\delta_{2000} = -25^\circ50'37\farcs18$. It is near the faint limit for accurate observations of ASAS3. The errors in Table 1 and the scatter in the phase plots in Figs. 7 and 8 are therefore larger than for the other three stars. BE Pup was classified as a possible population II object (GCVS type CWB:) by Fernie and Hube (1968), based on a deduced distance of 400 *pc* from the Galactic plane. However, no spectroscopic observations are available to confirm this. Fernie and Hube (arbitrarily) chose 400 pc as the lower limit for population II objects. BD Pup, close to BE Pup, but at a distance of 390 pc from the Galactic plane, was classified as a population I Cepheid.

The fundamental periods of BE Pup and EY Car are almost the same, but their period ratios are significantly different. This indicates that there is no simple relation between the fundamental period and the period ratio, but an other parameter such as metallicity is involved as well (Morgan and Welch, 1997). A plot of the period ratio against period for all known Galactic double mode (1O/F) Cepheids is given in Fig. 9. For previously known beat Cepheids, data from Welch (1998) have been used (points). The stars discussed in this paper are denoted by crosses. Fig. 10 plots the values of the generalized phase difference $G_{1,1}$ for the cross coupling term $f_0 + f_1$. Values are taken from Poretti and Pardo (1997), supplemented with values derived from the ASAS3 data for some additional stars. The lowest value (with the largest error bar) is for BE Pup.

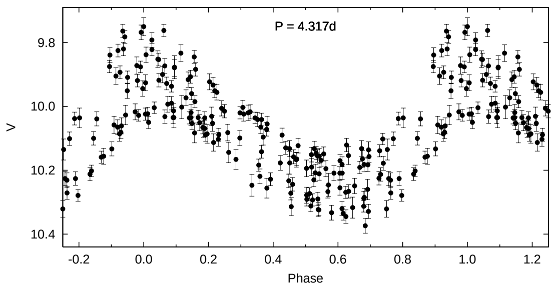

Figure 1. ASAS3 phased light curve for the fundamental period of NSV 6728.

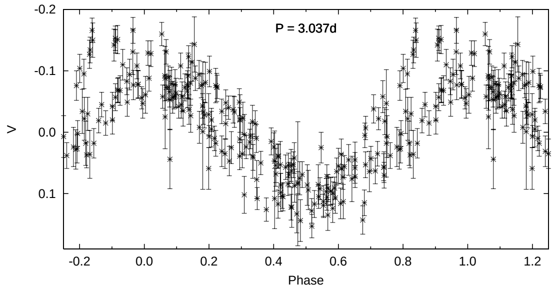

Figure 2. ASAS3 phased light curve for the first overtone period of NSV 6728 after prewhitening with the fundamental period and harmonics.

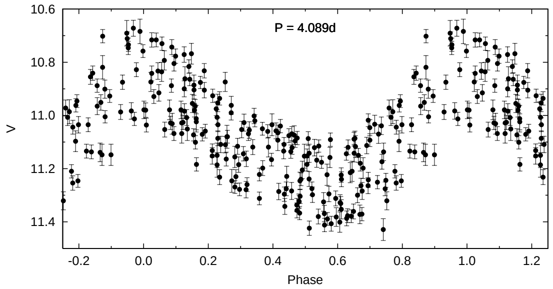

Figure 3. ASAS3 phased light curve for the fundamental period of GSC 8607-0608.

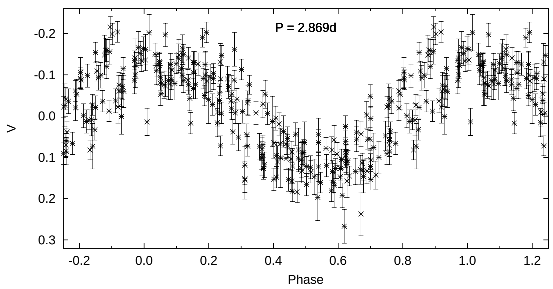

Figure 4. ASAS3 phased light curve for the first overtone period of GSC 8607-0608 after prewhitening with the fundamental period.

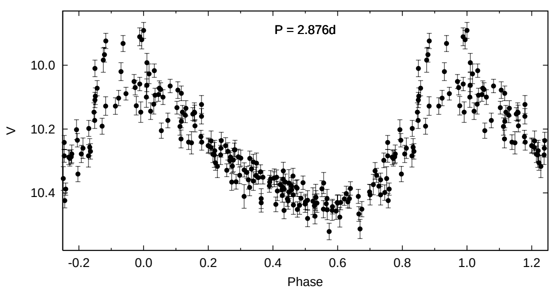

Figure 5. ASAS3 phased light curve for the fundamental period of EY Car.

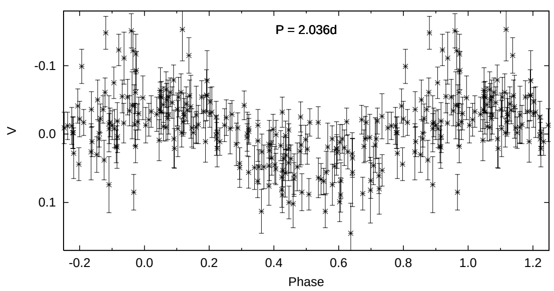

Figure 6. ASAS3 phased light curve for the first overtone period of EY Car after prewhitening with the fundamental period and harmonics.

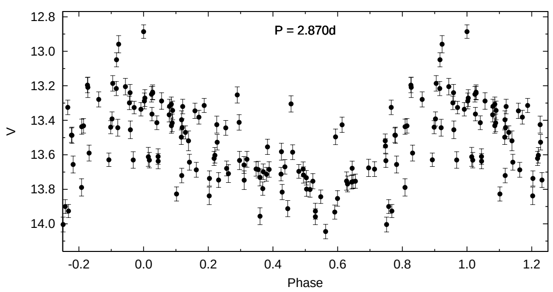

Figure 7. ASAS3 phased light curve for the fundamental period of BE Pup.

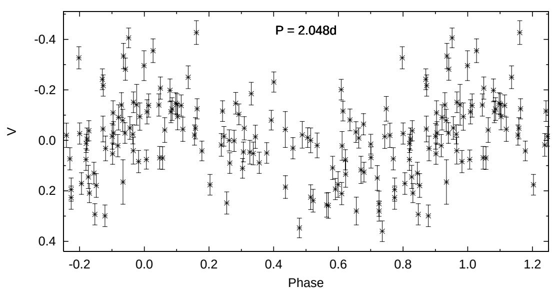

Figure 8. ASAS3 phased light curve for the first overtone period of BE Pup after prewhitening with the fundamental period and harmonics.

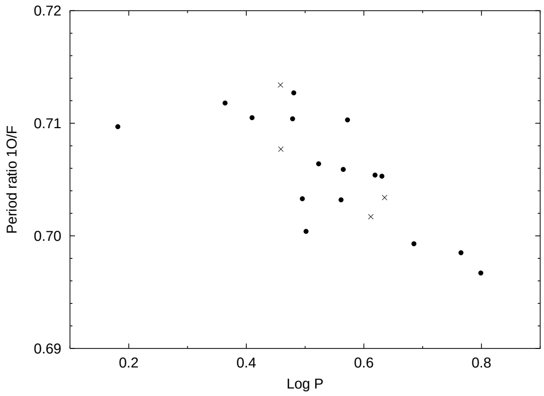

Figure 9. Plot of the 1O/F period ratio versus fundamental period for Galactic beat Cepheids.

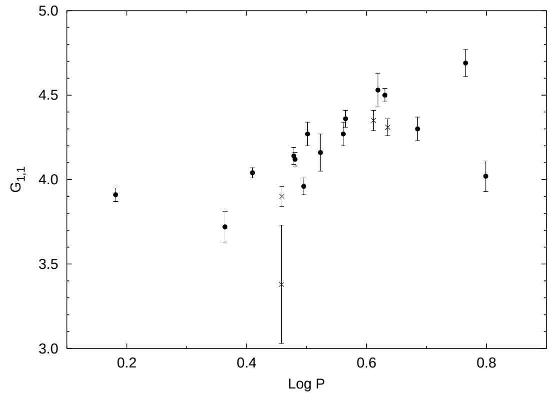

Figure 10. Plot of the phase difference $G_{1,1}$ versus fundamental period for 1O/F pulsators.

Acknowledgements: This research has utilised the ASAS3 public photometry catalogue and the SIMBAD and VizieR databases operated at the *Centre de Données Astronomiques (Strasbourg)* in France. The authors are grateful to John Greaves for helpful discussions and to Paul Van Cauteren for providing access to the Mitchell et al. paper.

References:

Beltrame, M., Poretti, E., 2002, *A&A*, **386**, L9

Berdnikov, N., Turner, D.G., 1998, *IBVS*, No. 4567

Böhm-Vitense, E., Evans, N.R., Carpenter, K., Morgan, S., Beck-Winchatz, B., Robinson, R., 1997, *AJ*, **114**, 1176

ESA, 1997, The Hipparcos and Tycho Catalogues, ESA SP-1200

Fabricius, C., Hog, E., Makarov, V.V., Mason, B.D., Wycoff, G.L., Urban, S.E., 2002, *A&A*, **384**, 180

Fernie, J.D., Hube, J.O., 1968, *AJ*, **73**, 492

Hacke G., Richert M., 1989, *Astron. Tsirk.*, **1539**, 14

Kholopov, P.N., et al., 2003, General Catalogue of Variable Stars version 1.4 Vol. IV, `http://www.sai.msu.su/groups/cluster/gcvs/gcvs/`

Mantegazza, L., Poretti, E., 1992, *A&A*, **261**, 137

Mitchell, R.I., Iriarte, B., Steinmetz, D., Johnson, H.L., 1964, *Bol.Obs.Ton.Tac.*, **3**, 153

Morgan, S.M., Welch, D.L., 1997, *AJ*, **114**, 1183

Pike, C.D., Andrews, P.J., 1979, *MNRAS*, **187**, 261

Pojmanski, G., 2002, *Acta Astronomica*, **52**, 397

Pojmanski, G., 2004, *Preprint*, astro-ph/0401125,

Poretti, E., Pardo, I., 1997, *A&A*, **324**, 133

Schmidt, E.G., Chab, J.R., Reiswig, D.E., 1995, *AJ*, **109**, 1239

Strohmeier, W., Knigge, R., Ott, H., 1964, *IBVS*, No. 62

Szabados, L., 2003, *IBVS*, No. 5394 (`http://www.konkoly.hu/CEP/intro.html`)

Welch, D., 1998, `http://dogwood.physics.mcmaster.ca/Cepheid/BeatCepheid.html`