COMMISSIONS 27 AND 42 OF THE IAU
INFORMATION BULLETIN ON VARIABLE STARS
Number 4217

Konkoly Observatory
Budapest
6 July 1995

HU ISSN 0374 – 0676

SLOW APSIDAL MOTION IN V541 CYGNI

The detached eclipsing binary V541 Cyg (BD+30°3704 = GSC 2656.3703) is a less-known binary with high orbital eccentricity ($e = 0.47$) and a long period of 15.34 days. It is an important system for the study of the general-relativistic theory of the apsidal motion (Khaliullin, 1985). The theoretically expected rotational velocity of the line of apsides could be 0°.0097 yr^{-1}, caused by dominant relativistic contribution as well as by tidal distortion and rotational flattening of the component stars.

Our new CCD photometry of V541 Cyg was carried out on 20 June 1995 at the Ondřejov Observatory using a 65cm reflecting telescope with a CCD-camera (SBIG ST-6) at the primary focus. The measurements were done using the standard Johnson B filter with 60 s exposure time. The stars GSC 2656.1627 – listed also as star 3 by Karpowicz (1961) - on the same frame as V541 Cyg served as a comparison star. The CCD data were reduced using software developed at Ondřejov Observatory by P. Pravec and M. Velen. No correction was allowed for differential extinction, due to the proximity of the comparison star to the variable (2.8 arcmin) and the resulting small differences in the air mass. The secondary minimum and their error were determined using the Kwee-van Woerden (1956) method. The result for the moment of eclipse is:

$$\text{Sec. Min.} = \text{HJD } 24\ 49889.377 \pm 0.001$$

The apsidal motion of V541 Cyg was studied by means of an O−C diagram analysis. We took into consideration all photoelectric times collected in Table 1, the photographic measurements obtained by Karpowicz (1961), as well as the times of secondary minimum obtained by Kulikowski (1953). The original times of primary minimum were not used due to large scatter of the data. The epochs were calculated using the linear light elements given by Khaliullin (1985):

$$\text{Pri. Min.} = \text{HJD } 24\ 44882.2127 + 15.337873 \times \text{E}$$

Table 1. Photoelectric times of minimum of V541 Cyg.

JD Hel.− 2 400 000	Epoch	Reference
44882.2127	0.0	Khaliullin (1985)
44889.2192	0.5	Khaliullin (1985)
46998.8424	138.0	Lines et al. (1989)
48839.387	258.0	Diethelm (1992)
49168.4951	279.5	Agerer (1994) ⋆
49889.377	326.5	this paper

⋆ *mean value of V and B measurements*

Table 2. Apsidal motion parameters.

T_0	=	$2\,444\,881.7920 \pm 0.0006$
P_s	=	$15^{d}.3379020 \pm 0^{d}.0000005$
P_a	=	$15^{d}.3379111 \pm 0^{d}.0000005$
e	=	0.4735 ± 0.0021
ω	=	$(0^{\circ}.000\,223 \pm 0^{\circ}.000\,045)$ cycle^{-1} =
	=	$(0^{\circ}.0053 \pm 0^{\circ}.0011)$ yr^{-1}
ω_0	=	$262^{\circ}.7 \pm 0^{\circ}.1$
U	=	1.614×10^6 P_a = $68\,000 \pm 13\,000$ yr

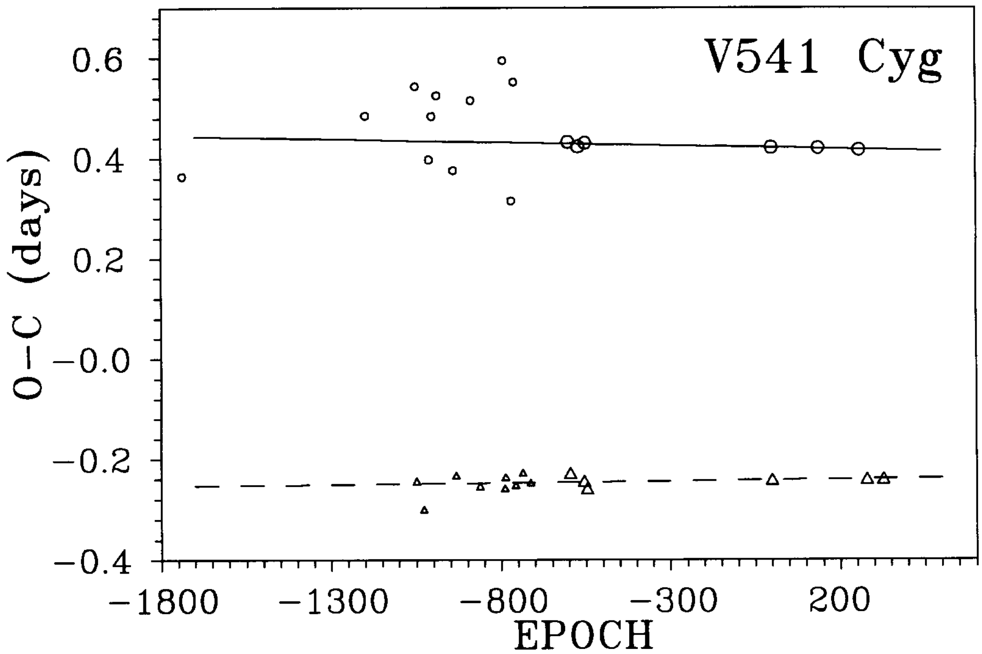

Figure 1. Residuals for the times of minimum of V541 Cyg with respect to the linear light elements. The continuous and dashed curves represent predictions for primary and secondary eclipses, respectively. The individual primary and secondary minima are denoted by circles and triangles, respectively. Larger symbols correspond to the photographic and photoelectric measurements with higher weight.

All photoelectric times of minimum were used in our computation, with a weight of 10, the photographic times obtained by Karpowicz (1961) were weighted with a weight of 5, the older photographic measurements with a weight of 1. A total 21 times of minimum light were incorporated in our analysis, with 6 primary eclipses among them.

For the apsidal motion analysis we used the method by Giménez & García-Pelayo (1983). This weighted least squares iterative procedure includes terms in the eccentricity up to the fifth order. Due to the high value of eccentricity of V541 Cyg, we used all terms in our calculation.

Adopting the orbital inclination, derived from the light curve solution, of i = $89\overset{\circ}{.}86$ (Khaliullin, 1985), the mean apsidal motion elements given in Table 2 can be determined. In this table P_s denotes the sidereal period, P_a anomalistic period, e represents the eccentricity, $\dot{\omega}$ the rate of apsidal motion. The zero epoch is given by T_0 and the corresponding position of the periastron is ω_0. Finally, U is the period of apsidal line rotation.

The O−C residuals for all times of minimum with respect to the linear part of the apsidal motion equation are shown in Figure 1. The original primary and secondary times of minimum obtained by Kulikowski (1953) are also plotted. The non-linear predictions, corresponding to the fitted parameters, are plotted as continuous and dashed curves for primary and secondary eclipses, respectively.

We derived the apsidal motion elements using the current data set. Our results indicate that the observed apsidal motion rate is less than expected from theory, in contradiction with previous good agreement announced by Khaliullin (1985) and Lines et al. (1989). This system could be the next member of a small group of binaries, which exhibit the discrepancy between observed and predicted rate of the apsidal motion. These anomalous cases, like DI Her (Guinan & Maloney, 1985) or AS Cam (Maloney et al., 1991) were not yet explained satisfactorily. More high-accuracy timings of this eclipsing system are necessary in the future to enlarge the time span for better analysis of the apsidal motion. Also the spectroscopic orbit of this system should be determined.

Acknowledgement. This work has been supported in part by the Grant Agency of the Czech Republic, grant No. 205-95-1498 and by the ESO C&EE Programme, grant No. A-02-069. I am grateful to Ms. Lenka Šarounová, who took part in our observations.

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References:

Agerer F., 1994, *BAV Mitteilungen*, No. 68, 5
Diethelm R., 1992, *BBSAG Bulletin*, No. 102, 4
Giménez A., García-Pelayo, 1983, *Astrophys. Space Sci.*, **92**, 203
Guinan E.F., Maloney F.P., 1985, *Astron. J.*, **90**, 1519
Karpowicz M., 1961, *Acta Astronomica*, **11**, 51
Khaliullin Kh.F., 1985, *Astrophys. J.*, **299**, 668
Kulikowski, P.G., 1953, *Perem. Zvezdy*, **9**, 169
Kwee K.K., Van Woerden H., 1956, *Bull. Astron. Inst. Neth.*, **12**, 327
Lines R.D., Lines H., Guinan E.F., Carroll S., 1989, *Inf. Bull. Var. Stars*, No. 3286
Maloney F.P., Guinan E.F., Mukherjee J., 1991, *Astron. J.*, **102**, 256