

On the apsidal motion of MY Cygni (Research Note)

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ABSTRACT

MY Cygni is a relatively bright eclipsing binary system with a slightly eccentric orbit. Tucker and collaborators found that it shows retrograde apsidal motion in contradiction with theory. Based on a new O–C diagram solution, we concluded that the apsidal motion is prograde in agreement with theory, and its period is about 1400 years. The determined internal structure constant is close to the theoretically expected value. The relativistic effect is significant, being about 18% of the total apsidal motion rate.

Key words. stars: binaries: eclipsing – stars: individual: MY Cyg – stars: fundamental parameters

1. Introduction

The eclipsing nature of the 8th magnitude star MY Cygni (HD 193637, BD+33°3862, HIP 100258, Sp. A7m) was discovered by Hoffmeister (1930) on plates of Sonneberg Observatory. The first photographic light curves were presented by Wachmann (1948) and Gaposchkin (1953) with the period of 2 days. The correct 4-day orbital period was confirmed later from spectroscopy by Popper (1969). The system has a slightly eccentric orbit ($e \approx 0.01$). With its period of almost precisely an integer number of days, MY Cyg is a difficult object to study with light curve photometry.

Tucker et al. (2009, hereafter T09) derived orbital solutions and precise absolute dimensions of the similar components (Table 3). They also established an apsidal motion period ($U \approx 1700$ yr) and found a retrograde/negative value of the apsidal motion rate ($\dot{\omega} = -0.21 \pm 0.07$ deg/year). If MY Cyg does have a retrograde apsidal motion, it would be a new candidate that contradicts theory and requires further study.

The historical O–C diagram for MY Cyg was presented in Kreiner et al. (2001). This system is also included in the current compilation of eclipsing binaries with eccentric orbits (Bulut & Demircan 2007) as well as in the Catalogue of close binaries in δ Scuti region (Soydugan et al. 2006).

2. Apsidal motion

MY Cyg has a small but significant orbital eccentricity. Both the classical theory of tides and General Relativity predict that such a close system should exhibit a periastron advance. We completed a new apsidal motion study of MY Cyg by performing an O–C diagram analysis and adopting a complete list of times of minimum light. The method described by Giménez & Bastero (1995), which is a weighted least-squares iterative procedure, including terms in the eccentricity up to the fifth order, was

routinely used. The periastron position ω at epoch E is defined by the linear equation

$$\omega = \omega_0 + \dot{\omega} E,$$

where $\dot{\omega}$ is the rate of periastron advance, and the position of periastron for the zero epoch T_0 is denoted as ω_0 . The relation between the sidereal and the anomalistic period, P_s and P_a , is given by

$$P_s = P_a (1 - \dot{\omega}/360^\circ),$$

and the period of apsidal motion by

$$U = 360^\circ P_a / \dot{\omega}.$$

Numerous eclipse timings for MY Cyg have been reported in the literature using a variety of techniques. Photoelectric or CCD measurements have greater precision and are the most useful for our analysis. The additional CCD photometry of MY Cyg was obtained by Ms. Kučáková on May 7, 2008. The observations were carried out with the 20-cm reflecting telescope of the Johann Palisa Observatory and Planetarium, which is located at Ostrava, Czech Republic. The SBIG ST-8 CCD camera and Johnson's *VRI* filters were used. The C-MUNIPACK¹ (Motl 2007), the user-friendly software package, was used for reduction of our CCD images. Using the *Hipparcos* photometry (ESA 1997), we were able to derive three additional secondary times of minimum light with lower accuracy. The light-curve profile fitting method was used. The epochs in Table 1 were computed according to the linear ephemeris of T09:

$$\begin{aligned} \text{Pri. Min.} &= \text{HJD } 2\,441\,585.62896 + 4.005187081 \cdot E, \\ \text{Sec. Min.} &= \text{HJD } 2\,441\,587.64061 + 4.005188234 \cdot E. \end{aligned}$$

¹ <http://c-munipack.sourceforge.net/>

Table 1. New times of minimum light.

JD Hel.-	Error	Epoch	Method	Observatory
2 400 000	[day]		Filter	Source
47 859.766	0.002	1566.5	pe, H	<i>Hipparcos</i>
48 104.081	0.002	1627.5	pe, H	<i>Hipparcos</i>
48 500.596	0.002	1726.5	pe, H	<i>Hipparcos</i>
54 594.47660*	0.0004	3248.0	CCD, R	Ostrava
54 594.47762*	0.0006	3248.0	CCD, V	Ostrava
54 594.47773*	0.0014	3248.0	CCD, I	Ostrava

Note: * presented also in Brát et al. (2008).

Table 2. Apsidal motion elements of MY Cyg.

Parameter	Unit	T09	This paper
T_0	HJD	–	2 441 585.6334 (3)
P_s	days	4.005186427	4.00518779 (12)
P_a	days	–	4.00521882 (12)
e	–	0.010 (1)	0.0094 (2)
$\dot{\omega}$	deg cycle ⁻¹	–	0.0028 (3)
$\dot{\omega}$	deg yr ⁻¹	–0.21 (7)	0.25 (3)
ω_0	deg	69.6 (2.4)	291.7 (0.4)
U	years	1700	1420 (160)

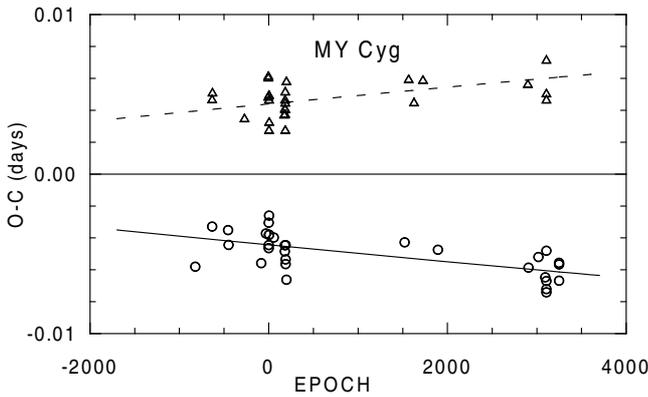


Fig. 1. The O–C diagram for the times of minimum of MY Cyg. The continuous and dashed lines represent predictions for the primary and secondary eclipses, respectively. The individual primary and secondary minima are denoted by circles and triangles, respectively.

Besides those minima given in Table 1, we added the photoelectric times of minimum obtained by Pohl & Kizilirmak (1964, 1966, 1975), Williamon (1975, his Table V), Tremko et al. (1979, their Table 2), Blättler (1993), Caton & Smith (2005), Hübscher et al. (2006), and T09 (their Table 8). A total of 57 reliable photoelectric times of minimum light were used in our dataset, 26 secondary eclipses being among them. The orbital inclination was assumed to be $i = 88^{\circ}58'$, based on the current photometric analysis (T09). The computed apsidal motion parameters and the internal errors of the least-squares fit are given in Table 2, and the O–C diagram is shown in Fig. 1.

3. Internal structure constant

Observations of eccentric binary systems with apsidal motion allow us to determine the internal structure constant, k_2 , which is an important parameter in stellar evolution models. The observed average value of $\bar{k}_{2,\text{obs}}$ is given by

$$\bar{k}_{2,\text{obs}} = \frac{1}{c_{21} + c_{22}} \frac{P_a}{U} = \frac{1}{c_{21} + c_{22}} \frac{\dot{\omega}}{360}, \quad (1)$$

Table 3. Astrophysical parameters of MY Cyg.

Parameter	Unit	Value
M_1	M_{\odot}	1.82 (3)
M_2	M_{\odot}	1.80 (3)
r_1	–	0.1359 (6)
r_2	–	0.1400 (6)
i	deg	88.58 (2)
$\dot{\omega}_{\text{rel}}$	deg cycle ⁻¹	0.000 51
$\dot{\omega}_{\text{rel}}/\dot{\omega}$	%	18.3
$\log k_{2,\text{obs}}$	–	–2.43 (3)
$\log k_{2,\text{theo}}$	–	–2.45

where c_{21} and c_{22} are well-known functions of the orbital eccentricity, fractional radii, the masses of the components, and the ratio of the rotational velocity of the stars to the Keplerian velocity (Kopal 1978). The rotation of the stars was assumed to be synchronized with the maximum angular orbital velocity achieved at periastron (pseudo-synchronous rotation). Taking the value of the eccentricity and the masses of the components into account, one has to subtract a relativistic correction $\dot{\omega}_{\text{rel}}$ (Giménez 1985)

$$\dot{\omega}_{\text{rel}} = 5.45 \times 10^{-4} \frac{1}{1 - e^2} \left(\frac{M_1 + M_2}{P} \right)^{2/3}, \quad (2)$$

where M_i denotes the individual masses of the components in solar units and P is the orbital period in days. The values of $\dot{\omega}_{\text{rel}}$ and the resulting mean internal structure constant $\bar{k}_{2,\text{obs}}$ are given in Table 3. Its error was evaluated according to the relation presented in Wolf & Zejda (2005), and the uncertainty in the eccentricity was neglected due to the presence of its higher terms. The theoretical value $k_{2,\text{theo}}$ was taken as a mean value from the tables of the Granada stellar models according to the adopted masses and chemical composition (Claret 2004). The chemical composition of $(X, Z) = (0.70, 0.02)$ and $(0.70, 0.03)$ was supposed to agree with previous studies.

4. Summary

MY Cygni is an eccentric eclipsing binary exhibits slow apsidal motion. Our new O–C diagram analysis has proved that the apsidal motion is prograde and has a period of about 1400 years. The prograde motion means that MY Cyg is not a problematic case, and is in agreement with theory. We concluded that the negative apsidal motion rate determined by T09 was due to their relatively short observational time interval and the method used for its determination.

Nevertheless, the radial velocity amplitudes K_1 and K_2 presented in T09 have quite large uncertainties compared to those given by Popper (1971). Moreover, they are not in agreement with the given absolute dimensions, cf. their Tables 4 and 5. It is also clearly evident that our resulting $\omega_0 = 291^{\circ}7'$ is close to the value $2\pi - \omega_0$ given in T09.

We also calculated the internal structure constant of MY Cyg and found that it is close to its theoretical value. The slight difference should be removed in the future with the compilation of a more comprehensive O–C diagram. Therefore, minima observations of MY Cygni are needed in the future.

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