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Differential Photoelectric Photometry of the Eclipsing Binary GO Cygni

Differential photoelectric photometry of the eclipsing binary GO Cygni was performed in Baja (Hungary) in July 1996. The instrumental system consisted of a Ritchey-Chretien telescope (focal length 4m, diameter 50 cm) and a Starlight1 photometer equipped with a photo multiplier tube and UBVRI filters. The measurements were made with V and B filters. The light curves in V and in B band are shown in figures 3 and 4, respectively. The moments of minima have been calculated. The results are in accordance with the expected results – the period of GO Cyg is increasing.

Introduction

GO Cygni is an eclipsing binary star that has been classified as a β Lyrae system. β Lyrae systems are close binary stars. Both components have filled their Roche s lobes and are ellipsoidal in shape. This results in a distorted light curve – outside the eclipses the brightness of the system is not constant. Some of the β Lyrae systems have periods that are increasing. The primary star is usually a white dwarf, while the secondary star is bigger but cooler.

GOCygni s equatorial coordinates (for the 1996.5 epoch) are: $\alpha = 20^{h}\,37^{m}\,12^{s}$ (right ascension) and $\delta = 35°\,21'\,26''$ (declination). According to Jones et al. (1994) the period of this star is increasing at a constant rate (this will be discussed further in the following passages).

For the comparison star, SAO 70314 was used, primarily because of the spectral class close to that of GO Cygni primary star and the favorable position – the stars are only 15 arc minutes apart. Equatorial coordinates of this star (for the 1996.5 epoch) are: $\alpha = 20^{h}\,38^{m}\,04^{s}$ (right ascension) and $\delta = 35°\,37'\,24''$ (declination). The magnitudes are: $V = 8^{m}.27$ and $8^{m}.33$.

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Method

Differential photoelectric photometry is based on the comparison of the variable star s magnitude and the comparison star s magnitude. Usually, the brightness of a third star, called the check star, is measured, to be sure that the brightness of the comparison is constant. In this work, the check star was not used because of a short period of brightness variation of GO Cygni – approx. 0.718 days. A set of observations consisted of several identical sequences of measurements. One sequence consisted of brightness measurements of: the comparison star, the sky near the comparison star, the variable star and the sky near the variable star. All measurements were done in V and B filters. At the end of each set of measurements the brightness of the comparison and the sky around the comparison was measured.

Data reduction was done with the FOTOKORR (a program developed by Borkovits Tamás on the Astronomical Observatory of Bács-Kiskun County) using the standard method. The complete explanation of the data reduction process is given in Hall et al. (1988) and in Henden et al. (1982). In this research, there was no need to transform the raw difference in magnitudes to the extraterrestrial difference in magnitudes. The stars are not very far apart so the atmospheric conditions influenced the measurements of both stars equally – the raw difference equals the extraterrestrial. The raw difference in magnitudes was transformed to the standard difference in magnitudes, that is – the difference in magnitudes in the Johnson UBV system. This allows the determination of the depths of both minima in V and B band.

The momentss of minimum light have been determined by fitting a second degree polynomial through the data obtained on July 20/21,1996, when the primary minimum occurred. Several attempts with fitting polynomials of a higher degree have been made. Those results were not used because the errors of the terms were approx. 50% of terms values. Fitting of the second degree polynomial was done in the FOTOKORR and the ORIGIN; fitting of the higher degree polynomials was done in the ORIGIN.

Because some changes in the period of GO Cygni were detected, the observed moments of minimum light were compared with those calculated by using the constant period suggested by Purgathofer and Prochazka (1967):

$$\mathrm{JD(hel.)} = 2433930.40561 + 0^{d}.71776382\,e \qquad (1)$$

where e is the number of cycles that occurred since 2433930.406 JD. By using the data given in Jones et al. (1994) (see Appendix A) the difference between the observed and the calculated moments of minimum (designated $O - C_1$) may show the expected increase of the period. It seems that the period increase follows a linear trend. However, Jones (Jones et al. 1994) suggest that this change can be taken into account when calculating the moments of minimum if we use:

$$\mathrm{JD(hel.)} = 2433930.40561 + 0^{\mathrm{d}}.71776285\, e + 1^{\mathrm{d}}.531 \cdot 10^{-10}\, e^2 \qquad (2)$$

Thus, it is expected that the difference between the observed and the calculated (by using eq. (2)) moments of minimum (designated $O - C_2$) is zero. Still, the $O - C_2$ is changing (see fig. 4). Jones et al. (1994) suggest that these changes are sinusoidal but, as can be seen from fig. 4, some other functions can be fitted through the data, not just a sine function. Moreover, Jones et al. (1994), give a sinusoidal correction that should represent the changes of $O - C_2$:

$$f(e) = 2.503 \cdot 10^{-3} \sin (3.18 \cdot 10^{-4}\, e + 2.376 \cdot 10^{-1} \qquad (3)$$

If $O - C_2$ changes are sinusoidal it would mean that there is a third body in the system that causes changes of the period.

On the basis of the measurements the present value of the period can be determined. By using equation (2) for and $e + 1$:

$$\mathrm{JD(hel.)}_1 = 2433930.40535 + 0^{\mathrm{d}}.71776285\, e + 1^{\mathrm{d}}.531 \cdot 10^{-10}\, e^2$$

$$\mathrm{JD(hel.)}_2 = 2433930.40535 + 0^{\mathrm{d}}.71776285\, (e + 1) + 1^{\mathrm{d}}.531 \cdot 10^{-10}\, (e + 1)^2$$

and then subtracting them:

$$T = \mathrm{JD(hel.)}_2 - \mathrm{JD(hel.)}_2 = 0^{\mathrm{d}}.7177628501531 + 2 \cdot 10^{-10}\, e \qquad (4)$$

one can obtain the present value of the period.

On the basis of the present value of the period and the observed moments of minimum all measurements were reduced to phase.

The present value of the period of GO Cygni was determined by using equation (4) (in this work):

$$T = 0.717698.$$

Results and discussion

Approximately 350 measurements were made with each filter. Variations of the extraterrestrial difference in magnitudes are shown in fig. 1 and 2, for the V and B band respectively. Variations of the standard difference in magnitudes are shown in fig. 3 and 4, for the V and B band respectively.

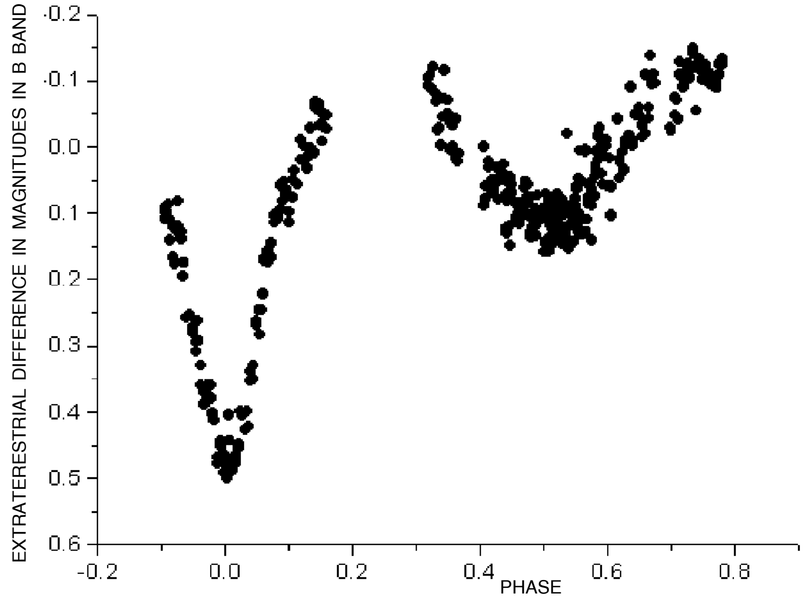

Fig. 1.
Variation of the extraterrestrial difference in magnitudes during one period (V band).

Slika 1.
Promena izvanatmosferske razlike u magnitudama tokom jednog perioda promene sjaja (V filter).

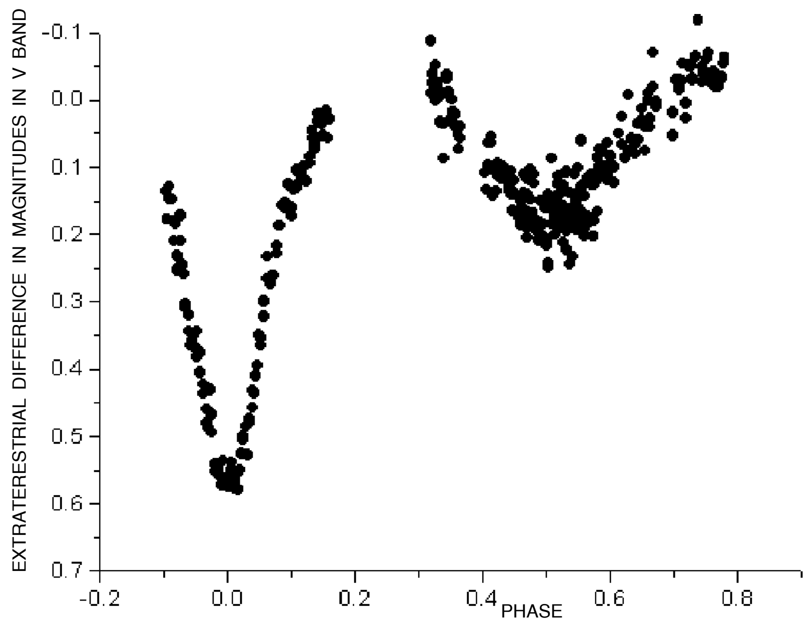

Fig. 2.
Variation of the extraterrestrial difference in magnitudes during one period (B band).

Slika 2.
Promena izvanatmosferske razlike u magnitudama tokom jednog perioda promene sjaja (B filter).

There seems to be a small asymmetry in the primary minimum (from phase 0.1 to phase 0.2). This asymmetry might be a consequence of some physical properties of the system. However, the measurements in question were made near dawn and it is more probable that this affected the counts of the photometer and not some physical properties of the system.

All measurements were reduced to the UBV system. The transformational coefficients of the system are:

$e = -0.06903$ (for the V band)
$\mu = 1.26807$ (for the B band).

If the instrumental system was good μ should be around zero and should be around one. These results show that the instrumental system used is good for measuring in the V band, but not in the B band. The cause of this may be the poor state of the B filter or some differences in response of the photo multiplier tube to the different wavelengths. The variations of the standard difference in magnitudes are shown in fig. 3 (V band) and fig. 4 (B band).

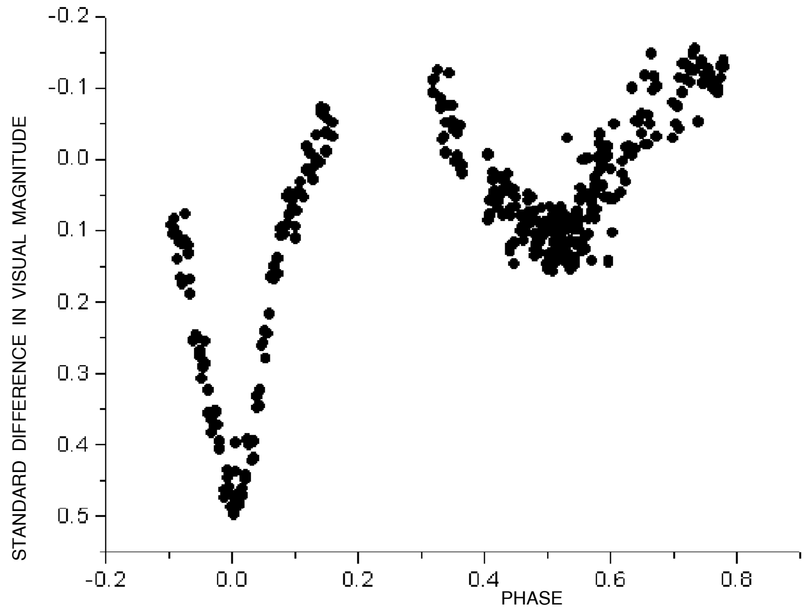

Fig. 3.
Variation of the standard difference in magnitudes during one period (V band).

Slika 3.
Promena standardne razlike u magnitudama tokom jednog perioda promene sjaja (V filter).

The depths of both minima in both bands were estimated:

0.59 ± 0.01 (the primary minimum in V band),
0.56 ± 0.01 (the primary minimum in B band),
0.27 ± 0.07 (the secondary minimum in V band) and
0.24 ± 0.07 (the secondary minimum in B band).

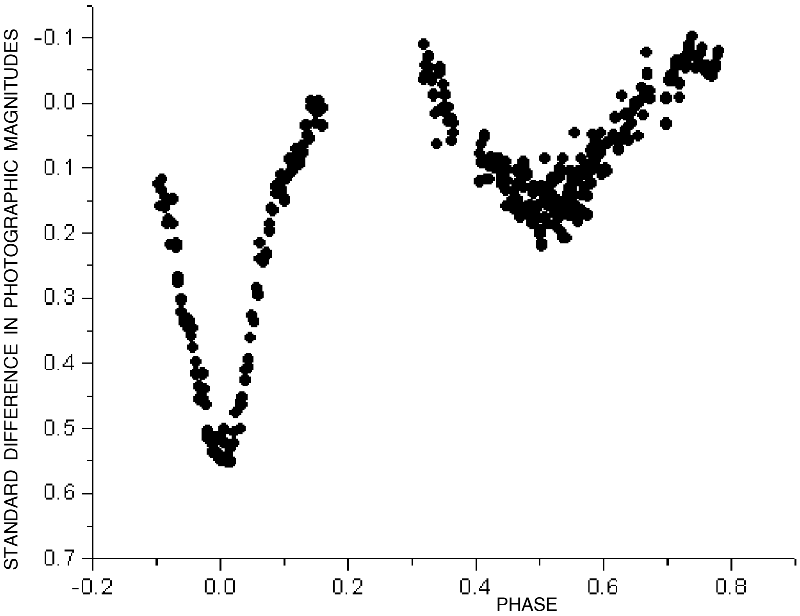

Fig. 4.
Variation of the standard difference in magnitudes during one period (B band).

Slika 4.
Promena standardne razlike u magnitudama tokom jednog perioda promene sjaja (B filter).

The results are unsatisfactory. Secondary minima in both V and B bands were obtained using the measurements of several different nights – – the different weather conditions (sky transparency, temperature, etc.) affected the counts of the photometer. Thus the depths of the secondary minima were estimated by averaging the maximum and the minimum amplitudes obtained from the figures 3 and 4.

A rough estimate shows that the primary minimum lasts 0.28711 days and the secondary 0.35888 days. However, the whole light curve should be covered to obtain precise information about how long the minima last. Even then, it may be difficult to distinguish where, on the light curve, one minimum ends, because of the stars peculiar shapes (see Introduction).

The observed moments of minima (determined on the basis of July 20/21.1996. data) are:

$$t_{oV} = 2450285.427 \pm 0.002$$

$$t_{oB} = 2450285.428 \pm 0.002$$

for the V and B band respectively. The differences between the observed and the calculated (using eq. (1)) times of minimum ($O - C_1$) are:

$$(O - C_1)_V = 0.055 \pm 0.002$$

$$(O - C_1)_B = 0.056 \pm 0.002$$

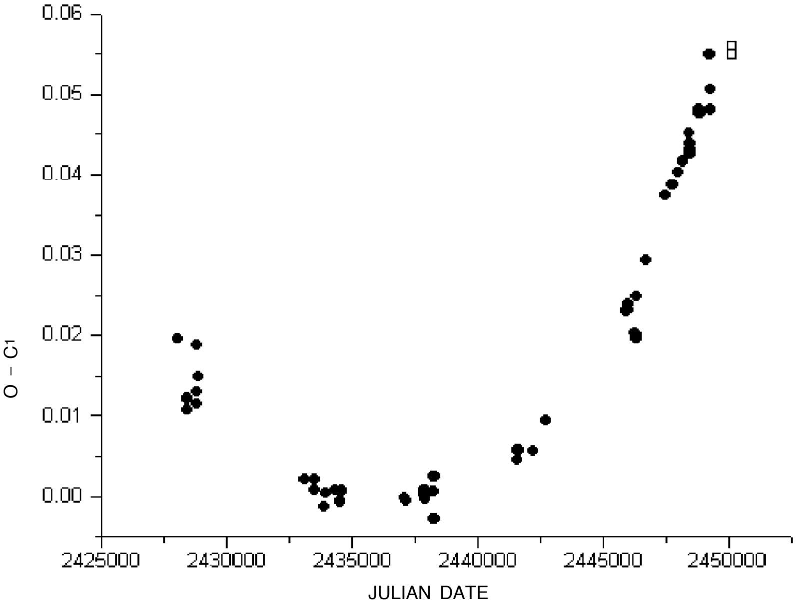

Fig. 5.
Variation of the $O - C_1$ depending on the Julian date; open squares are new data, solid circles are data given in Jones et al. (1994).

Slika 5.
Promena $O - C_1$ u zavisnosti od Julijanskog dana; kvadrati predstavljaju podatke iz ovog rada, a kružići podatke iz Jones et al. (1994).

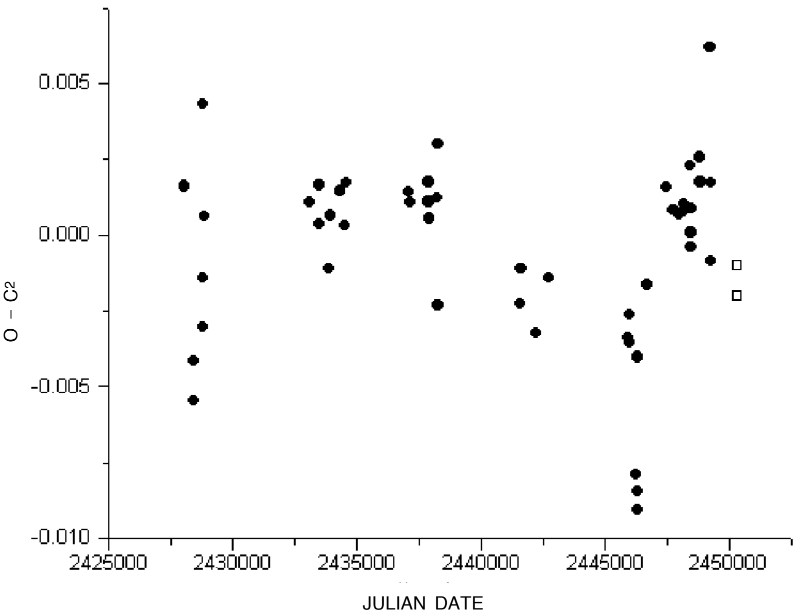

Fig. 6.
Variation of the $O - C_2$ depending on the Julian date; open squares are new data, solid circles are the data given in Jones et al. (1994).

Slika 6.
Promena $O - C_2$ u zavisnosti od Julijanskog dana; kvadrati predstavljaju podatke iz ovog rada, a kružići podatke iz Jones et al. (1994).

for the V and the B band respectively (in this work $e = 22786$). These two values, along with other data shown in Table 1, Appendix A) are shown on fig. 5.

The data shown on fig. 5 cover the period from 1935 to 1996. As can be seen, the value of $O - C_1$ from this paper fits the previous data and follows the trend of parabolic increase. The differences between the observed and the calculated (using eq. (2)) moments of minima ($O - C_2$) are:

$$(O–C_2)_V = -0.002 \pm 0.002$$
$$(O - C_2)_B = -0.001 \pm 0.002$$

for the V and B band respectively. The accuracy of this data is not satisfying. Nevertheless, according to equation (3), for $e = 22786$ the value of $O - C_2$ should be positive if the model of sinusoidal changes of $O - C_2$ is adequate. But, it is obvious that the data shown on fig. 6 cannot be used to determine minute variations in the period of GO Cygni because of their low accuracy. However, further study of this system should give a clue to the nature of $O - C_2$ changes.

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References

[1] Tsesevich, V.P. 1971. *Zatmennye i peremennye zvezdy*. Moskva: Nauka.

[2] Hall, S.D. and Genet, M.R. 1988. *Photoelectric Photometry of Variable Stars*. I.A.P.P.P. Communications.

[3] Henden, A.A. and Kaitchuck, R.H. 1982. *Astronomical Photometry*. New York: van Nostrand Reinhold Company.

[4] Jones et al. 1994. Sinusoidal Variation in the Period of the Eclipsing Binary GO Cygni. *I.A.P.P.P. Communications*, 54: 34–40.

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Diferencijalna fotoelektrična fotometrija eklipsne promenljive GO Cygni

Fotoelektrična fotometrija eklipsno promenljive GO Cygni vršena je pomoću Ritchey-Chretien teleskopa (prečnik otvora 50 cm, žižna daljina 4m) i Starlight1 fotometra (uz korišćenje V i B filtera). Krive sjaja prikazane su na slikama 3 (V filter) i 4 (B filter). Izračunat je trenutak minimuma sjaja i potvđeno je da se period GO Cygni povećava.

Appendix

Observed moments of minimum, cycle number, and are given (ref. 1 – according to Jones et al. (1994), ref. 2 – according to this paper)

Julian date	Cycle number	$O - C_1$	$O - C_2$	References
2428035.431	–8213	0.019646	0.0016098	1
2428398.120	–7707	0.012150	–0.004158	1
2428418.708	–7679	0.010765	–0.005455	1
2428797.688	–7151	0.011467	–0.003036	1
2428807.744	–7137	0.018772	0.0043144	1
2428823.529	–7115	0.012970	–0.001422	1
2428838.604	–7094	0.149307	0.0006027	1
2433111.439	–1141	0.002110	0.0010643	1
2433483.957	–622	0.000786	0.0003815	1
2433496.878	–604	0.002037	0.0016558	1
2433861.499	–96	–0.00128	–0.001113	1
2433930.406	0	0.000389	0.0006485	1
2434309.386	528	0.000725	0.0014534	1
2434516.818	817	–0.00065	0.0003014	1
2434606.540	942	0.000694	0.0017281	1
2437106.510	4425	–0.00011	0.0014381	1
2437147.423	4482	–0.00047	0.0010643	1
2437882.414	5506	0.000801	0.0017586	1
2437887.438	5513	0.000149	0.0011024	1
2437910.406	5545	–0.00039	0.0005417	1
2438242.731	6008	0.000660	0.0012207	1
2438260.677	6033	0.002464	0.0030022	1
2438268.567	6044	–0.00284	–0.002308	1
2441595.410	10679	0.004558	–0.002285	1
2441608.331	10697	0.005760	–0.001121	1
2441895.465	11097	0.033920	0.0260925	1
2442210.535	11536	0.005691	–0.003231	1

Julian date	Cycle number	$O - C_1$	$O - C_2$	References
2442714.409	12238	0.009392	–0.001407	1
2445954.408	16752	0.023079	–0.003380	1
2445972.353	16777	0.023933	–0.002625	1
2445982.401	16791	0.023090	–0.003525	1
2446264.479	17184	0.020409	–0.007874	1
2446325.489	17269	0.020184	–0.008465	1
2446328.360	17273	0.019627	–0.009037	1
2446351.333	17305	0.024788	–0.004017	1
2446712.373	17808	0.029385	0.001636	1
2447470.340	18864	0.037491	0.0015678	1
2447762.471	19271	0.038715	0.0008125	1
2448016.561	19625	0.040325	0.0006561	1
2448177.341	19849	0.041828	0.0010223	1
2448194.568	19873	0.041695	0.0007706	1
2448459.426	20242	0.045147	0.0023079	1
2448474.498	20263	0.043804	0.0008583	1
2448479.521	20270	0.043068	0.0000839	1
2448484.545	20277	0.042614	–0.000404	1
2448839.844	20772	0.048222	0.0025711	1
2448862.812	20804	0.047577	0.0017548	1
2450285.427	22786	0.055	–0.002	2
2450285.428	22786	0.056	–0.001	2