

UY Camelopardalis Possibly Has an Unseen Companion

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ABSTRACT

We used a 50 cm telescope plus a Princeton Instrument Vers Array 512B CCD at Xinglong station of the National Astronomical Observatory of China to observe UY Cam in February 2008 and totally 7 times of maximum light were obtained. We used omc01.exe software for (O-C) analysis and found that its pulsation period is steadily increasing with a rate of about 4.8×10^{-9} per year. This is reasonable from the stellar evolution theory point of view. We conclude that it has an unseen companion with an orbital period of about 49.5 years. Due to few observations of this variable star, we call for more people to observe and collect more data on this star.

Keywords: variable stars, Delta Scuti, HADS, period changes, light time effect. Stellar evolution

INTRODUCTION

UY Camelopardalis (=HIP 39009 = GSC 04369-01129, R.A. 2000 = 07:58:59.90, Dec. 2000 = +72:47:23.7, V=11.44 mag, A3–A6 III) was discovered as a variable star by Baker in 1937. He classified it as a Cepheid type variable with a period of 6.16 days and gave its spectral type as A3 which is an early type compared with a Cepheid type. In 1964, Wallerstein gave its spectral type varied from A3 III to A6 III. In the same year, Williams used 5 night observations of photoelectric UBV photometry to determine a new period of 0.267 day with an amplitude of 0.45 magnitude in V band. He found that its B-V = 0.20, which was matched with the spectral type A3 III. So he classified it as a RRc type variable. In 1966, Beyer used 10 years of visual observations to get 21 times of maximum light and gave a formula as follows:

$$\text{HJD } T_{\max} = 2435565.239 + 0.26704234 \times E$$

Bloglia and Conconi (1992) used 5 night observations of B and V photoelectric photometry to get 5 times of maximum light and gave a formula:

$$\text{HJD } T_{\max} = 2435565.2414(\pm 0.0012) + 0.267042254(\pm 0.000000128) \times E - 4.05(\pm 0.35) \times 10^{-13} \times E^2$$

Rodriguez et al. (2000) classified it as a high amplitude Delta Scuti variable. Zhou and Liu (2003) published their observations and included it in their program dedicated to the investigation of poorly studied Delta Scuti stars. From 1999 to 2003 they spent 19 nights using a CCD photometer and a 3 channel photoelectric photometer to observe UY Cam in the V band. They used their time series photometry to do frequency analysis and found that it was a mono-periodic radial pulsator. They found the light variation of the amplitude may have changed from 1985 to 2000, but it was constant from 2000 to 2003. They got 16 times of maximum light for the (O-C) analysis. By using parabolic fits on (O-C) of times of maximum light, they suggested that a period change rate dP/dt was $(-3.32 \pm 2.53) \times 10^{-11}$ day per day. Because of the gaps in the data in the two periods 1965-1984 and 1986-2000 and few data of the points in the (O-C) plot, the fitting to the (O-C) residuals suffered from great uncertainties. In our measurements we used omc01.exe software to do our analysis and found its period distribution as in Figure 1. It looked as if there was some long period variation. To check this phenomenon, we searched 6 times of maximum light from IBVS 5643 (2), 5657 (1), 5701 (1), 5731 (1) and 5761 (1). Then we did an (O-C) analysis again and found it still showed some periodical variation. So we decided to observe it again to get more times of maximum light to see if it really has periodical variation.

THE NEW OBSERVATIONS

In February 2008 we used a 50 cm telescope at Xinglong station of the National Astronomical Observatory of China to observe UY Cam for 5 nights. We got 7 times of maximum light. The focal length of the telescope is 2,400mm; the focal plan scale is 86 arc seconds per mm. The detector is a Princeton Instrument Vers Array 512B CCD with a pixel size of 24 microns square which covers 10.6 arc minutes square field of view. A typical CCD frame of UY Cam is taken from the 50 cm telescope as shown in Figure 2 in which V is UY Cam, a Reference star (Ref) = TYC 4369-719-1 = GSC 04369-00719, and a check star(Chk) = TYC 4380-1705-1 = GSC 04380-01705. We used MaxIm DL software to do data reduction. Figure 3 is the typical light curve of UY Cam; it looks quite good. The RMS of each measurement is ± 0.005 . We used 5 order curves to fit the peak part of the light curve to get the time of maximum light. The RMS of the times of maximum light is ± 0.0001 day. All the 7 new times of maximum light are listed in Table 1. In Table 1 we list cycle number (E), time of maximum light in HJD (HJD Tmax), weight (W), and the amplitude in v band (A_v).

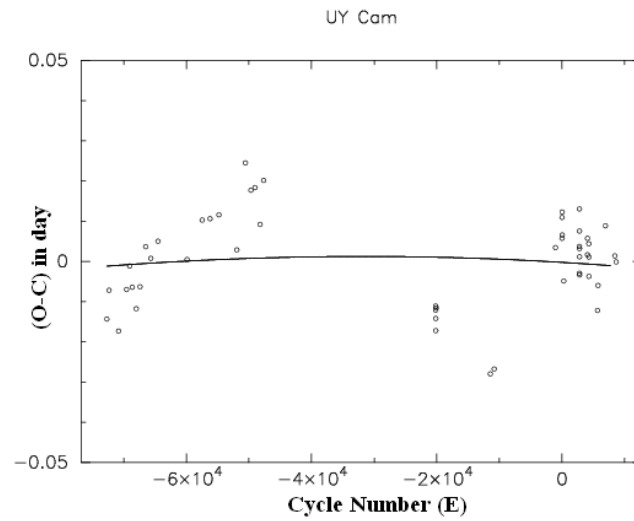


Figure 1 The (O-C) distribution of UY Cam from 1937 to 2003

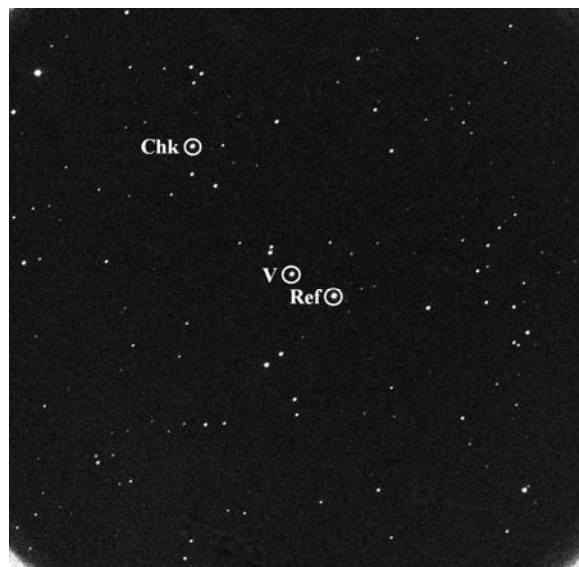


Figure 2 The typical frame of UY Cam was taken by a 50 cm telescope at Xinglong station of the National astronomical Observatory of China.

Table 1 The new times of maximum light and its amplitude

| E | HJD Tmax | Weight | Amplitude in V band |
|---------|--------------|--------|---------------------|
| 11102.0 | 2454521.9664 | 1.0 | 0.36 |
| 11103.0 | 2454522.2334 | 1.0 | 0.36 |
| 11106.0 | 2454523.0257 | 1.0 | 0.36 |
| 11107.0 | 2454523.2930 | 1.0 | 0.36 |
| 11110.0 | 2454524.0920 | 1.0 | 0.36 |
| 11111.0 | 2454524.3612 | 1.0 | 0.36 |
| 11114.0 | 2454525.1635 | 1.0 | 0.36 |

THE (O-C) DISTRIBUTION AND PERIOD VARIATIONS

Totally, we collected 57 times of maximum light and left 2 times of maximum light from IBVS 5643 in 2005 are excluded due to its large error. We used (O-C) analysis to do data reduction and got the following linear and quadratic solutions:

$$C_L = T1 + P1 \times E$$

$$T1 = \text{HJD } 2451557.2634 + 0.267041198 \times E$$

$$C_{LQ} = T2 + P2 \times E + 0.5 \times \text{Beta} \times E^2$$

$$T2 = \text{HJD } 24\ 51557.2632 + 0.26704128 \times E + 1.43 \times 10^{-12} E^2$$

$$\text{Beta} = (dP / dt) / P = 9.35 \times 10^{-13} \text{ Day / cycle} = 4.8 \times 10^{-9} \text{ year}^{-1}$$

C_L = Linear calculation of times of maximum light

$T1$ = The first time of maximum light for linear calculation

$P1$ = Pulsating period of linear calculation

C_{LQ} = Quadratic calculation of times of maximum light

$T2$ = The first time of maximum light for quadratic calculation

$P2$ = Pulsating period of quadratic calculation

E = Cycle number

Beta = Period variation rate

The RMS of the linear calculation and quadratic calculation are 0.010863 mag and 0.010853 mag, respectively.

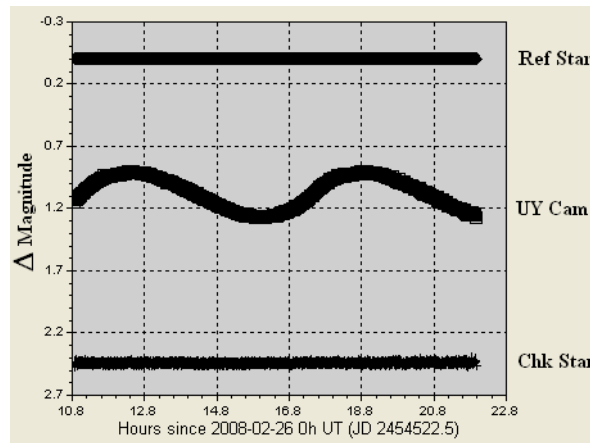


Figure 3 Light Curve of UY Cam, Reference star and Check star observed on February 26, 2008

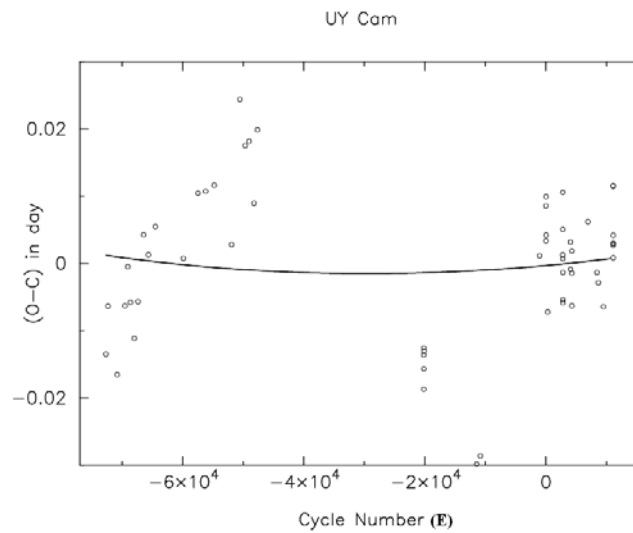


Figure 4 The (O-C) distribution of UY Cam from 1937 to 2008

DISCUSSION AND CONCLUSION

As we can see from Table 1, the amplitude is about 0.36 in V band; it is quite similar with what was observed by Zhou and Liu 2003. The RMS of linear calculation and quadratic calculation are as large as 0.010863 and 0.010853, respectively. The reason is that UY Cam seems to have a long period of light time variation of an unseen companion as shown in Figure 4. There have been too few observations between 1937 to 2008; there were not any observations during 20 years from HJD 2438831.168 to HJD 2446170.4948, 6 years from HJD 2446184 to HJD 2448500, and 7 years

from HJD 2446184 to HJD 2451274. So we can not find a reliable periodical solution. In this paper we only give a frequency analysis to get a frequency of $(0.0000553 \pm 0.0000014)$ / day, the related period orbital (P_{orb}) = (18083 ± 446) days or (49.5 ± 1.2) years and the semi-amplitude = 1200 light seconds = 2.4 au. The orbital fitting formula is:

$$T_{max} = T_3 + P_3 \times E + 0.5 \{Beta\} \times E^2 + [A \sin (P_{orb}\varphi) + B \cos (P_{orb} \varphi)].$$

The last two terms correspond to possible light-time effect caused by the orbital motion. The mass function of this system is:

$$(M_2 \sin i)^3 / (M_1 + M_2)^2 = (2.4)^3 / 49.5^2 = 0.0056 M_{\odot}$$

M_1 is the mass of UY Cam which is about 2 times of solar mass, M_2 is the mass of an unseen companion, and i is the inclination angle of the orbit. The frequency solution fitting curve of the (O-C) quadratic of UY Cam is shown in Figure 5.

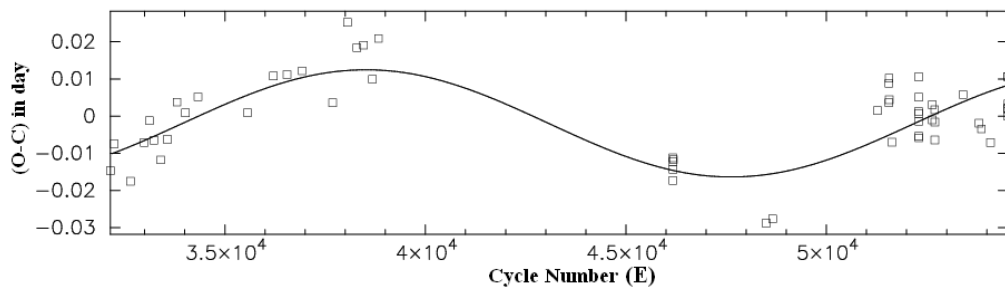


Figure 5 The frequency solution fitting curve of (O-C) quadratic of UY Cam. The P_{orb} = 49.5 years, semi-amplitude = 2.4 au.

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