Progress in the study of the long-term variability of CY Aqr

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Abstract. New observations were made for CY Aqr, leading to the determination of 5 new times of maximum light. Together with the times of maximum light listed in the literature, a new ephemeris formula is obtained. The O–C diagram is constructed and two models proposed by previous authors are applied to fit the data points. The results show that both interpretations are acceptable.

1. Introduction
CY Aqr is a SX Phoenicis star with short period (P=87.9 min) and large amplitude (∆V=0.71 mag). Since its light variation was discovered in 1934 [1], it has been observed extensively. The study on the long-term period variation of CY Aqr leads to two interpretations on the discrepancies between the observed and calculated times of maximum light: 1) straight-line segments [2]; 2) a linear period change combined with the light-time effect in a highly-eccentric binary orbit [3]. However, both models seem equally acceptable.

We keep observing CY Aqr and collecting new data published in the literature to study the period variation of this variable star. In present paper, we describe our observations made in 2005 and 2006, and the result of period variation study by using all available data up to date.

2. Observations and new times of maximum light
CY Aqr was observed in October 3 of 2005 with a 80-cm telescope plus a CCD camera at Xinglong station of National Astronomical Observatories of China. Johnson V filter was used during the observations. Figure 1 shows CY Aqr and the comparison star. The collected data were processed with a standard procedure of CCD photometry images. Then, the magnitude values were extracted with the software MOMF [4]. Figure 2 shows the derived light curves, where the time is helio-centric Julian date and V is the differential magnitudes of CY Aqr relative to the comparison in Johnson V.

CY Aqr was then observed on September 28, 2006 with a Meade 40-cm telescope plus a ST-7 CCD camera in the campus of Beijing Normal University. No filter was used. The software Maxim DL (http://www.cyanogen.com/products/maxim_main.html) was used to process the images and aperture photometry. The derived light curves are shown in Figure 3, where W is the differential magnitudes in white light.

Two times of maximum light were estimated by fitting the observed light curves around the peak times with a three-order polynomial, as T_{max}=HJD 2453647.0339 and 2454007.0997.
The project TAOS took CY Aqr as one target star and collected some data in 2003 [5]. Some data were obtained from AAVSO website (http://www.aavso.org/cgi-bin/newql.pl?name=CY%20Aqr&output=html). We made helio-centric corrections to these data and fit the data points around the peak times, leading to determination of three new times of maximum light: $T_{\text{max}} = \text{HJD } 2452899.2523$, $2454032.4915$, and $2454032.5521$.

3. $O - C$ diagram

The 5 new times of maximum light were combined with those in the literature [2], [3], [6] to calculate the up-to-date ephemeris formula,
\[ C = \text{HJD} \ 2426159.4966 + 0.061038372 \cdot E \]  

where the uncertainties of of \( T_0 \) and \( P \) are 0.0004 \( d \) and 0.000000002 \( d \), respectively. The \( O-C \) diagram was hence constructed and shown in Figure 4 as open circles for the times of maximum light in the literature and the symbols of “x” for those newly-determined.

Figure 4. \( O-C \) diagram of CY Aqr. The solid lines show the fit with 5 straight-line segments.

Figure 5. \( O-C \) diagram of CY Aqr. The solid curves show the fit with a quadratic plus a sine function.

5 straight-line segments are fit to the data points in the \( O-C \) diagram and shown as solid lines in Figure 4, which leads to the updated period value of CY Aqr of 0.061038371±0.000000006 \( d \) since the year 1999.

Following the second model of [3], a quadratic plus a sine function was fitted to the \( O-C \) points and shown in Figure 5. The fit leads to the parameters of \( \frac{dP}{Pdt} = (1.8±0.3) \times 10^{-10} \ d/yr \), semiamplitude=628±13 \ s, \( e=0.77±0.01 \), orbital period=52.5±0.3 \ yr, periastron time=HJD 2429096±103, the projection of semi-major axis of the binary orbit \( a_1 \sin i=1.26±0.03 \ AU \).

4. Conclusions

Five new times of maximum light are determined based on new observations for CY Aqr. Combined with the data in the literature, the updated period value of CY Aqr is derived as 0.061038371±0.000000006 \( d \).

The fit to the \( O-C \) points with the two models proposed in the literature seems equally acceptable. More data are needed in the future to verify the two interpretations, to reveal the reason of the long-term period variability of CY Aqr.
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